Appendix 1D

Comments from Interest Groups and Responses

This section contains copies of comment letters from interest groups on the Draft Environmental Impact Statement (EIS) for the Coordinated Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP). Each comment in the comment letters was assigned a number, in sequential order. The numbers were combined with the name of the interest group (example: AA 1). The comments with the associated responses are arranged alphabetically by interest group name, and appear in the chapter in that order.

Copies of the comments are provided in Section 1D.1. Responses to each of the comments follow the comment letters, and are numbered in accordance with the numbers assigned in the letters.

Large attachments included with letters from AquAlliance; California Water Impact Network and California Sportfishing Protection Alliance; Natural Resources Defense Council and The Bay Institute; and North Coast Rivers Alliance are provided in Section 1D.2.

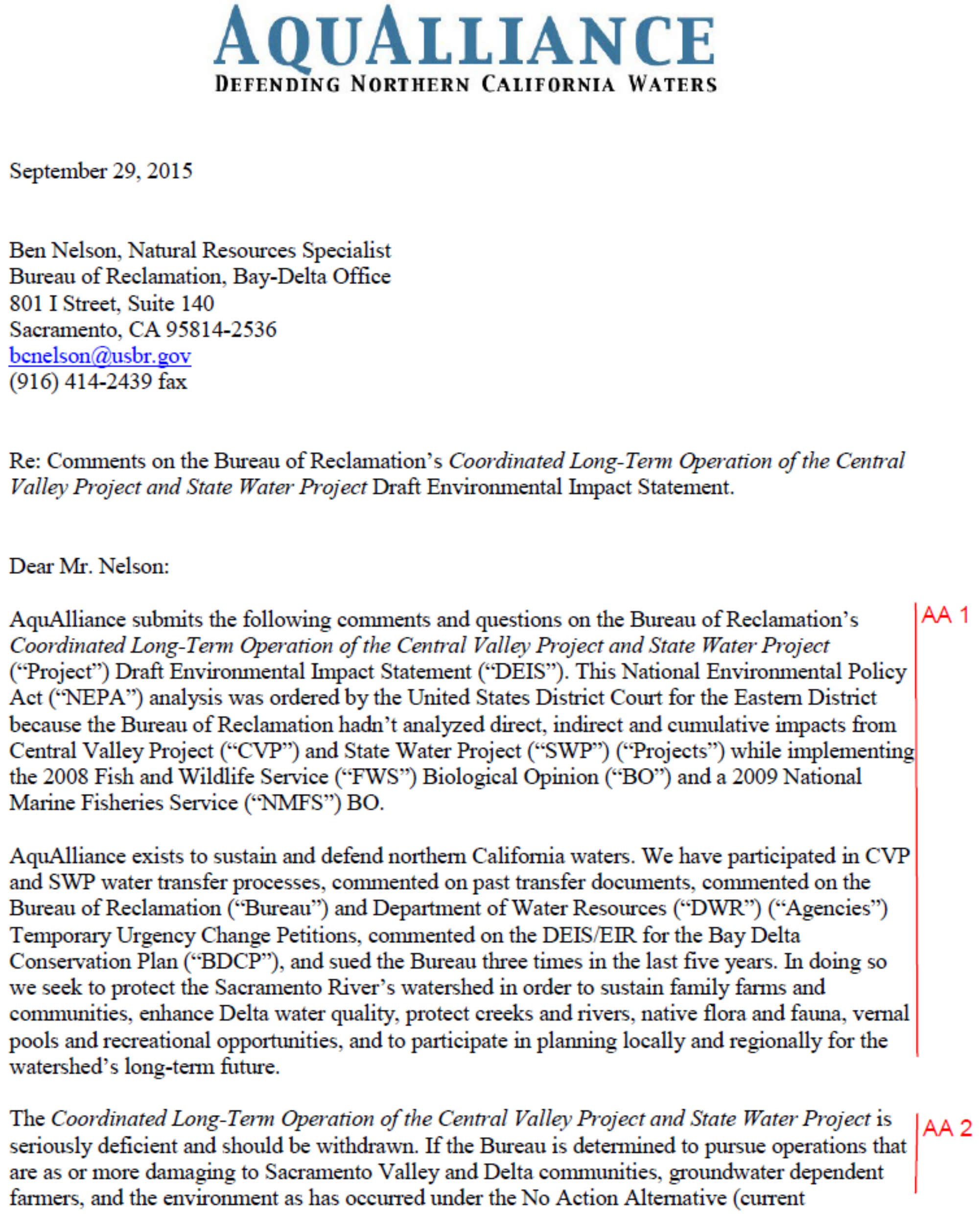
1D.1 Comments and Responses

The interest groups listed in Table 1D.1 provided comments on the Draft EIS.

Table 1D.1 Interest Groups Providing Comments on the Draft Environmental Impact Statement

Acronym	Commenter
AA	AquAlliance
CFBF	California Farm Bureau Federation
CSD	Coalition for a Sustainable Delta
CWIN	California Water Impact Network
CWIN - CSPA	California Water Impact Network and California Sportfishing Protection Alliance
CESAR	The Center for Environmental Science Accuracy and Reliability
EWC 1	Environmental Water Caucus
EWC 2	Environmental Water Caucus
FOTR	Friends of the River
GGSA-PC	Golden Gate Salmon Association and Pacific Coast Federation of Fishermen's Association
NRDC-TBI	Natural Resources Defense Council and The Bay Institute
NCRA	North Coast Rivers Alliance
Restore the Delta	Restore the Delta
SVWA	South Valley Water Association
SWC	State Water Contractors

1D.1.1 AquAlliance



AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

September 29, 2015

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Re: Comments on the Bureau of Reclamation's *Coordinated Long-Term Operation of the Central Valley Project and State Water Project* Draft Environmental Impact Statement.

Dear Mr. Nelson:

AA 1

AquAlliance submits the following comments and questions on the Bureau of Reclamation's *Coordinated Long-Term Operation of the Central Valley Project and State Water Project* ("Project") Draft Environmental Impact Statement ("DEIS"). This National Environmental Policy Act ("NEPA") analysis was ordered by the United States District Court for the Eastern District because the Bureau of Reclamation hadn't analyzed direct, indirect and cumulative impacts from Central Valley Project ("CVP") and State Water Project ("SWP") ("Projects") while implementing the 2008 Fish and Wildlife Service ("FWS") Biological Opinion ("BO") and a 2009 National Marine Fisheries Service ("NMFS") BO.

AquAlliance exists to sustain and defend northern California waters. We have participated in CVP and SWP water transfer processes, commented on past transfer documents, commented on the Bureau of Reclamation ("Bureau") and Department of Water Resources ("DWR") ("Agencies") Temporary Urgency Change Petitions, commented on the DEIS/EIR for the Bay Delta Conservation Plan ("BDCP"), and sued the Bureau three times in the last five years. In doing so we seek to protect the Sacramento River's watershed in order to sustain family farms and communities, enhance Delta water quality, protect creeks and rivers, native flora and fauna, vernal pools and recreational opportunities, and to participate in planning locally and regionally for the watershed's long-term future.

AA 2

The *Coordinated Long-Term Operation of the Central Valley Project and State Water Project* is seriously deficient and should be withdrawn. If the Bureau is determined to pursue operations that are as or more damaging to Sacramento Valley and Delta communities, groundwater dependent farmers, and the environment as has occurred under the No Action Alternative (current

AA 2 continued

operations), the Bureau must prepare a DEIS that truly discloses the damage the Projects have inflicted on California.

AA 3

This letter relies significantly on, references, and incorporates by reference as though fully stated herein, for which we expressly request that a response to each comment contained therein be provided, the following comments submitted here by AquAlliance:

- Custis, Kit H., 2014. Comments and recommendations on U.S. Bureau of Reclamation and San Luis & Delta-Mendota Water Authority Draft Long-Term Water Transfer DRAFT EIS/EIR, Prepared for AquAlliance.
- ECONorthwest, 2014. Critique of Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report Public Draft, Prepared for AquAlliance.
- Mish, Kyran D., 2014. Comments for AquAlliance on Long-Term Water Transfers Draft EIR/EIS.
- Cannon, Tom, Comments on Long Term Transfers EIR/EIS, Review of Effects on Special Status Fish. Prepared for California Sportfishing Protection Association.

AA 4

In addition, we renew the following comments previously submitted, attached hereto, as fully bearing upon the presently proposed project and request:

- *2009 Drought Water Bank* ("DWB").
- *2010-2011 Water Transfer Program.*
- *2013 Water Transfer Program.*
- *2014 Water Transfer Program.*
- C-WIN, CSPA, AquAlliance Comments and Attachments for the Bay Delta Conservation Plan's EIS/EIR.
- AquAlliance's comments on the Bay Delta Conservation Plan's EIS/EIR.
- CSPA's comments on the Bay Delta Conservation Plan's EIS/EIR.
- CSPA's comments on this DEIS for the *Coordinated Long-Term Operation of the Central Valley Project and State Water Project*

AA 5

I. The DEIS Contains an Inadequate Project Description.

AA 6

NEPA requires an accurate and consistent project description in order to fulfill its purpose of allowing informed decision-making. 43 u.s.c. s 4332(2)(c). Without a complete and accurate description of the project and all of its components, an accurate environmental analysis is not possible. *See, e.g., Blue Mountains Biodiversity Project v. United States Forest Service*, 161 F.3d 1208, 1215 (9th Cir. 2008).

The Project Description Contains an Inadequate Statement of Objectives, Purpose, and Need.

The lack of a stable project description and proposed alternative obfuscates the need for and impacts from the Project. The importance of this section in a NEPA document can't be overstated. "It establishes why the agency is proposing to spend large amounts of taxpayers' money while at the same time causing significant environmental impacts… As importantly, the project purpose

AA 6 continued

and need drives the process for alternatives consideration, in-depth analysis, and ultimate selection. The Council on Environmental Quality (CEQ) regulations requires that the EIS address the "no-action" alternative and "rigorously explore and objectively evaluate all reasonable alternatives." Furthermore, a well-justified purpose and need is vital to meeting the requirements of Section 4(f) (49 U.S.C. 303) and the Executive Orders on Wetlands (E.O. 11990) and Floodplains (E.O. 11988) and the Section 404(b)(1) Guidelines. Without a well-defined, well-established and well justified purpose and need, it will be difficult to determine which alternatives are reasonable, prudent and practicable, and it may be impossible to dismiss the no-build alternative" [1]

AA 7

The DEIS fails to fully inform the public due to the omissions in the DEIS of recently past and current operations that would explain the No Action Alternative. For example, the joint operations in the last two years have operated outside state and federal laws as presented in the Temporary Urgency Change Petitions sought by the Agencies. Fish were slaughtered in 2014 while the Agencies operated outside water quality and flow requirements with the approval of the State Water Resources Control Board ("SWRCB").[2]

<u>The Project Description Lacks Detail Necessary for Full Environmental Analysis.</u>

AA 8

The operation of the CVP and SWP were intended to be contingent on lawful acts, but the Projects have so seriously stepped outside the boundaries of contract and environmental laws that the ability to have a stable Project description in the DEIS is impossible. Of the many possible examples, two of the most current instances that severely alter the Project and are not disclosed in the DEIS are the Firebaugh Canal Water District v. the United States of America settlement and the 2014 and 2015 Temporary Urgency Change petitions and orders. Without full disclosure of 1) the ramifications of a settlement that provides a secure water delivery to a junior CVP claimant south of the Delta with an unknown ability, commitment, and timeframe to manage its polluted drainage and 2) the inability of the Projects to plan for and manage dry years in California without AA 9 Temporary Urgency Change petitions and orders that have and are currently destroying public trust resources, the DEIS is meaningless. The DEIS must not only describe what is on paper for CVP and SWP operations, but what is actually happening on the ground, as it were, that follows and deviates, sometimes significantly, from plans, programs, and the law.

<u>The Project Description does Not Include all Project Components.</u>

i. The Bureau Fails to Disclose Significant Past, Present, and Future Streamflow Depletion

AA 10

Streamflow depletion is only mentioned once in the DEIS. This deficiency strikes at the core of our critique, which views the CVP and the SWP as once operating within the law, albeit with more water on paper than could ever be available, until the limits of hydrology caused the Agencies and some of their contractors to look for tools to game the law – and the hydrology - of California. The CVP and SWP have extended water far from the areas of origin for agricultural, urban, and

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[1] Federal Transportation and Highway Administration, 1990. *NEPA and Transportation Decisionmaking: The Importance of Purpose and Need in Environmental Documents.* http://www.environment.fhwa.dot.gov/projdev/tdmneed.asp

[2] California Sportfishing Protection Alliance et al., 2015.Protest –(Petitions) Objection Petition for Reconsideration Petition for a Hearing, (p. 3).

AA 10 continued

industrial uses. In so doing, particularly with paper water, the state and federal governments have facilitated a destructively unrealistic demand for water. Ever willing to destroy natural systems to meet demand for profit, the San Joaquin River dried up and subsidence caused by groundwater depletion in the San Joaquin Valley is even cracking water conveyance facilities.[3] Enter conjunctive use where the Agencies facilitate and their contractors implement river water sales and pump groundwater to continue crop production. The continual, long-term groundwater overdraft in the San Joaquin Valley, the expansion of new permanent crops in both the San Joaquin and Sacramento valleys, and groundwater substitution transfers by CVP and SWP contractors *all* cause streamflow depletion (also see Groundwater Section below). Failing to disclose how the CVP and SWP cause streamflow depletion is a major omission that must be corrected and included in a recirculated DEIS.

ii. Historic Flow Data are Not Disclosed

AA 11

In providing an "[o]verview of hydrologic conditions in the Trinity River and Central Valley watersheds," the DEIS fails to provide actual, historic flow data. (p.5-14) There are broad descriptions of infrastructure, capacities, and mean daily flows in Chapter 5, but no mention of historic ranges of flow above or below dams. Additionally, the maps provided in the section *Surface Water Resources and Water Supply Figures* fail to identify towns that are used for geographic identification such as Douglas City.

iii. Water Conservation History and Potential is Absent

AA 12

The DEIS mentions that, "Water conservation is an integral part of water management in the study area," but fails to provide even a modicum of detail and analysis for the reader. (p. 5-58) The discussion ends in one paragraph without any reference to additional material in the DEIS. This is a serious omission that must be remedied in a recirculated draft EIS.

iv. Historic Water Transfer Background is Minimally Disclosed

AA 13

"Water transfers also are an integral part of water management," is the introduction to water transfers on page 5-58, yet the discussion focuses on 2012 and 2013 with minimal detail and then lists a few long-term transfer approvals from 2008 forward. What this divulges is that they are an "integral part of water management," *now*. That water transfers have become so essential in the past decade forces an examination of the Projects' foundational assumptions, operations, and management, or, as some would say, mismanagement. (see Water Claims below).

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[3] Sneed, et al., 2012. Abstract: *Renewed Rapid Subsidence in the San Joaquin Valley, California.* "The location and magnitude of land subsidence during 2006–10 in parts of the SJV were determined by using an integration of Interferometric Synthetic Aperture Radar (InSAR), Global Positioning System (GPS), and borehole extensometer techniques. Results of the InSAR measurements indicate that a 3,200-km^2 area was affected by at least 20 mm of subsidence during 2008–10, with a localized maximum subsidence of at least 540 mm. Furthermore, InSAR results indicate subsidence rates doubled during 2008. Results of a comparison of GPS, extensometer, and groundwater-level data suggest that most of the compaction occurred in the deep aquifer system, that the critical head in some parts of the deep system was exceeded in 2008, and that the subsidence measured during 2008–10 was largely permanent." Conference presentation at *Water for Seven Generations: Will California Prepare For It?*, Chico, CA.

AA 13
continued

The DEIS acknowledges that water transfers from the Sacramento Valley to south of the Delta began in earnest in 2001 and that up to 298,806 af were transferred between 2001 and 2012 – we assume the Bureau means this as an annual figure. (p. 5-58) However, only south-of-Delta transfers by Program are disclosed and for only two years: 2012 and 2013. Essential information is noticeably absent from the DEIS, such as:

- The Bureau, DWR, and individual water districts have claimed much of the transfer water market was "one-year," "short-term," or an "emergency." The serial and escalating nature of water transfers from the Sacramento Valley to south-of-Delta fit none of those descriptions. Examples of the kind of material that should be provided in the DEIS include:
    a. Environmental Assessment and Findings of No Significant Impact ("FONSI") for the *2008 Option and Forbearance Agreement Between Glenn-Colusa Irrigation District, San Luis & Delta-Mendota Water Authority and the United States Bureau of Reclamation, and Related Forbearance Program*. The proposed project planned to transfer Sacramento River water, up to 85,000 acre-feet (AF), in accordance with a forbearance program undertaken by Glenn Colusa Irrigation Project ("GCID") through voluntary crop idling or crop shifting (82,500AF), and to provide up to 2,500 acre-feet with groundwater substitution produced from two GCID-owned groundwater wells located near the western edge of Butte County. Final figures for this water sale and all other planned and actual sales in 2008 should be disclosed by contractor.
    b. Environmental Assessment and FONSI, *2009 Drought Water Bank*. The Bureau and 20 of its contractors planned to sell 199,885 af through a combination of crop idling, crop substitution, groundwater substitution, and reservoir reoperation. (Final FONSI pp. 2-3) "The cumulative total amount potentially transferred under the DWB from all sources would be up to 370,935 af." (*Id.* p. 10) However, DWR and the Bureau allowed up to a maximum 600,000 af .[4] Final figures for all planned and actual water sales in 2008 should be disclosed by contractor.
    c. Environmental Assessment and FONSI for the *2010-2011 Water Transfer Program*. 395,910 AF of CVP and non-CVP water. This should be disclosed and whatever amount of water was actually transferred. That AquAlliance sued over the inadequate Environmental Assessment should be noted.
    d. In 2012 and 2013 the DEIS discloses the amount of water that was actually transferred, but fails to reveal that significantly more water was planned for south-of-Delta transfers. This is a crucial point when considering a growing dependence on transfers as demand escalates and in analyzing cumulative impacts.
        i. Initiating Section 7 Consultation letter 2012. "For 2012 water transfers, Reclamation anticipates a maximum of approximately 76,000 acre-feet of water could be transferred. The 76,000 acre-feet of transfer water would be made available through groundwater substitution." (p. 2) The DEIS reveals that 47,420 af were actually transferred, but the uppermost potential for the 76,000 af transfer all from groundwater substitution combined with all other transfers is not disclosed and should be.

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[4] DWR 2009. *Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report.* http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=107

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AA 13 continued

ii. The DEIS discloses that in 2013 63,790 af were transferred. The amount of water planned for transfer from all sources should also be disclosed.

e. The Bureau and the San Luis Delta Mendota Water Authority's ("SLDMWA") 2014 Environmental Assessment/Initial Study. Not disclosed in the DEIS is that, "The Proposed Action is for sellers to potentially make available up to 175,226 AF of water based on a 75 percent CVP water supply forecast for Settlement Contractors. Sellers could make water available for transfer through groundwater substitution, cropland idling, or crop shifting. Other transfers not involving the SLDMWA and its participating members could occur during the same time period. The Tehama Colusa Canal Authority (TCCA) released a separate EA/IS to analyze transfers from a very similar list of sellers to the TCCA Member Units." AquAlliance sued the Bureau over the inadequate EA/IS. This complete background information should be corrected in a revised and recirculated DEIS.

f. The Bureau and SLDMWA's *Environmental Impact Statement* and *Environmental Impact Report* for the 2015-2024 *Long Term North-to-South Water Transfer Program*. The DEIS mentions the 10-year water transfer program, but failed to disclose the uppermost amount of water that may be transferred: 600,000 af each year. Also lacking is that AquAlliance and partners sued over the inadequate EIS/EIR, which is moving forward.

- The Bureau should disclose how it and DWR began a Programmatic EIS to facilitate water transfers from the Sacramento Valley and the interconnected actions that are integrally related to it, but never completed that EIS and for years impermissibly broke out the annual transfers from the overall Program for piecemeal review as AquAlliance presents above. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "include[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" *Id.* At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on *Short-term Sacramento Valley Water Management Program EIS/EIR*).

AA 14

Lastly, noticeably missing from the DEIS is also the Agencies involvement in funding infrastructure to expand water transfers. One example is the *U.S. Bureau of Reclamation September 2006 Grant Assistance Agreement with Glenn Colusa Irrigation District.* "GCID shall define three hypothetical water delivery systems from the State Water Project (Oroville), the Central Valley Project (Shasta) and the Orland Project reservoirs sufficient to provide full and reliable surface water delivery to parties now pumping from the Lower Tuscan Formation. The purpose of this activity is to describe and compare the performance of three alternative ways of furnishing a substitute surface water supply to the current Lower Tuscan Formation groundwater users to eliminate the risks to them of more aggressive pumping from the Formation and to optimize conjunctive management of the Sacramento Valley water resources." Disclosure of this and all other funding actions that are part of CVP and SWP operations must be presented in a revised and recirculated DEIS.

The Over Allocation of Water Claims is not Disclosed

AA 15

The DEIS must describe existing water right claims of sellers, buyers, the Bureau, and DWR. Without this foundational background, the reviewer is unable to understand the Project. In response to inquiries from the Governor's Delta Vision Task Force, the SWRCB acknowledged that while average runoff in the Delta watershed between 1921 and 2003 was 29 million acre-feet annually, the 6,300 active water right permits issued by the SWRCB is approximately 245 million acre-feet [5] (pp. 2-3). In other words, **water rights on paper are 8.4 times greater than the real water in California's Central Valley rivers and streams diverted to supply those rights on an average annual basis.** And the SWRCB acknowledges that this 'water bubble' does not even take account of the higher priority rights to divert held by pre-1914 appropriators and riparian water right holders (*Id.* p. 1). More current research reveals that the average annual unimpaired flow in the Sacramento River basin is 21.6 MAF, but the consumptive use claims are an extraordinary 120.6 MAF – 5.6 times more claims than there is available water. [6] Informing the public about water rights claims would necessarily show that buyers and the Agencies clearly possess junior water rights as compared with those of many willing sellers. Full disclosure of these disparate water rights claims and their priority is needed to help explain the Project. Without it, the public and decision makers have insufficient information on which to support and make informed choices.

To establish a proper legal context for these water rights, the DEIS should also describe more extensively the applicable California Water Code sections about the treatment of water rights involved in water transfers.

Like federal financial regulators failing to regulate the shadow financial sector, subprime mortgages, Ponzi schemes, and toxic assets of our recent economic history, the Bureau and the State of California have been derelict in its management of scarce water resources. As we mentioned above we are supplementing these comments on this matter of wasteful use and diversion of water by incorporating by reference and attaching the 2011 complaint to the State Water Resources Control Board of the California Water Impact Network the California Sportfishing Protection Alliance, and AquAlliance on public trust, waste and unreasonable use and method of diversion as additional evidence of a systemic failure of governance by the State Water Resources Control Board, the Department of Water Resources and the U.S. Bureau of Reclamation, filed with the SWRCB on April 21, 2011.[7]

II. Alternatives

AA 16

The No Action Alternative is supposed to describe the current operations of the CVP and SWP ("Projects") in the last seven years that were to follow the Reasonable and Prudent Alternatives ("RPAs") from the Biological Opinions ("BOs"). (DEIR p. 3-3) Yet the species that were meant to

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[5] SWRCB, 2008. Water Rights Within the Bay Delta Watershed

[6] California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance 2012. *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay-Delta Estuary.*

[7] C-WIN et al. 2011. Complaint, California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance v. SWRCB, DWR and Respondent Bureau of Reclamation.

AA 16 continued

be protected by the BOs are tipping into extinction due to the mismanagement of the Projects and the consistent waiver of requirements that have been sought by the Bureau and DWR and approved by the State Water Resources Control Board ("SWRCB") in temporary urgency change orders.[8] [9]

AA 17

- Alternative 1 would eliminate RPA actions that would not otherwise occur without the RPA's, and revert to operations and flow requirements that existed prior to issuance of the BOs. However, it would retain non-operational RPA requirements that have already been implemented or are in the process of being implemented. Alternative 1 also predicts, "Long-term average annual exports would be 1,051 TAF (22 percent) more …" (DEIS p. 3-60)

- Alternative 2 would eliminate a series of physical measures included in the RPA's, including fish passage at CVP dams, temperature improvements at CVP dams on the American River, actions to reduce entrainment at CVP and SWP export facilities, and others. (DEIS p. 3-32)

- Alternative 3 would eliminate RPA actions that would not otherwise occur without the RPA's. It would weaken Old and Middle River (OMR) export restrictions from the present restrictions in the BOs, implement a suite of actions on the Stanislaus River that substantially reduce flow requirements and establish a "predator control program," trap and haul salmonid out-migrants in the San Joaquin River from March through June, and reduce ocean harvest of salmon.

- Alternative 4 would eliminate RPA actions that would not otherwise occur without the RPA's. It would limit development in floodplains, replace levee riprap with vegetation, establish a "predator control program," trap and haul salmonid out-migrants in the San Joaquin River from March through June, and reduce ocean harvest of salmon.

- Alternative 5 would implement the RPA's and additionally require positive OMR flows in April and May. It would also require April and May pulse flows from the Stanislaus River, whose volume would be determined by water year type and the location of X2. (DEIS p. 3-42)

AA 18

As we explain throughout our comments, none of the alternatives, including the No Action Alternative are sufficient to avoid jeopardy to listed species or to protect other public trust resources consistent with applicable law. The Bureau must reject the Alternatives in the DEIS including the No Action Alternative and craft Project Alternatives that is fully compliant with the Endangered Species Act and fully protective of all public trust resources.

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[8] C-WIN et al. 2011. Complaint, California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance v. SWRCB, DWR and Respondent Bureau of Reclamation.

[9] The Bay Institute, 2015. Appendix to Temporary Urgency Change Protest, February 2015.

III. Modeling

AA 19

The Central Valley Hydrologic Model (CVHM) spans a 42-year simulation period starting in water year 1962. The model ends in 2003, which fails to account for current conditions, accelerating climate change conditions, and future conditions. On this basis alone the model is completely inadequate and any conclusions from the model are as well. (p. 7-110) It is impossible for the public to have any confidence in modeling results that are using such antiquated input data. Moreover, that "[C]alSIM outputs are included in the CVHM input files," exacerbates AquAlliance's concerns regarding the modeling as CalSIM's adequacy has repeatedly been called into question.[10] Just one of the many issues with CalSIM is the shocking assumption that, "Groundwater resources are assumed infinite, i.e., there is no upper limit to groundwater pumping." (*Id.* p. 8)

AA 20

We also question the heavy reliance on modeling when the Agencies have had decades of opportunity to gather and use actual stream and groundwater data. The DEIS relies only on modeling to consider impacts from the Project when it needs to compile and present results from actual monitoring and reporting prior to recirculating a revised DEIS.

Climate Change

AA 21

The DEIS discloses that, "A growing body of evidence indicates that Earth's atmosphere is warming. Records show that surface temperatures have risen about 0.7°C since the early twentieth century and that 0.5°C of this increase has occurred since 1978 (NAS 2006)." (p. 5A A-25). It acknowledges that, "Observed climate and hydrologic records indicate that more substantial warming has occurred since the 1970s and that this is likely a response to the increases in greenhouse gas (GHG) increases during this time." (*Id.*) Moreover, the DEIS reveals that, "The GCM [global climate models] simulations of historical climate capture the historical range of variability reasonably well (Cayan et al. 2009), but historical trends are not well captured in these models. Projections of future precipitation are much more uncertain than those for temperature." (*Id.*) AA 22 One would think that the modeling weaknesses with historical trends and projections of future precipitation would cause alarm at the Bureau. What has prevented the Agencies from locating models with better predictability? Barring location of more proficient models, and in light of the devastating environmental impacts from current operation of the Projects,[11] [12] the Agencies must err on the side of caution and reject the Alternatives in the DEIS including the No Action Alternative and craft a Project Alternative that is fully compliant with the Endangered Species Act and fully protective of all public trust resources.

AA 23

The DEIS relates that, "Projected change in stream flow is calculated using the VIC macroscale hydrologic model. The use of the VIC model is primarily intended to generate changes in inflow magnitude and timing for use in subsequent CalSim II modeling. While the model contains several sub-grid mechanisms, the coarse grid scale should be noted when considering results and analysis of local-scale phenomena. The VIC model is currently best applied for the regional-scale

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[10] Close, A., et al, 2003. A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California

[11] C-WIN et al. 2011. Complaint, California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance v. SWRCB, DWR and Respondent Bureau of Reclamation.

[12] The Bay Institute, 2015. Appendix to Temporary Urgency Change Protest, February 2015.

AA 23
continued

hydrologic analyses. There are several limitations to long-term gridded meteorology related to spatial-temporal interpolation due to limited availability of meteorological stations that provide data for interpolation. In addition, the inputs to the model do not include any transient trends in the vegetation or water management that may affect stream flows; they should only be analyzed from a "naturalized" flow change standpoint. Finally, the VIC model includes three soil zones to capture the vertical movement of soil moisture, but does not explicitly include groundwater. The exclusion of deeper groundwater is not likely a limiting factor in the upper watersheds of the Sacramento and San Joaquin river watersheds that contribute approximately 80 to 90 percent of the runoff to the Delta. However, in the valley floor, interrelation of groundwater and surface water management is considerable. Water management models such as CalSim II should be used to characterize the heavily "managed" portions of the system." (5A.A-38 to 5A A-39) This paragraph raises numerous concerns: 1) We appreciate that the DEIS disclosed some of the major limitations of the VIC model, but wonder what the Agencies intend to do to overcome the "the coarse grid scale" and "long-term gridded meteorology related to spatial-temporal interpolation" problems. This should be disclosed. 2) The DEIS dismisses that the VIC model "does not explicitly include groundwater" and asserts that it is not a limiting factor in the upper watersheds although "upper watershed" is not defined or illustrated in a map. The Bureau must elaborate further by describing where the upper watershed begins and ends and how ignoring all groundwater there is inconsequential. 3) The DEIS states that "CalSim II should be used to characterize the heavily "managed" portions of the system," without answering why this hasn't already happened. This should have preceded the DEIS. And again, we encourage the Bureau to seek a model other than CalSIM for all of the reasons presented above.

Lastly, what prevented the Bureau from using science from reputable sources such as Souymaya Belmecheri and colleagues who find that, "The exceptional character of the 2012-2015 drought has been revealed in millennium-length paleoclimate records…" and "The spring snowpack on mountains crucial to California's water supply reached its lowest level this year in half a millennium, according to a study published on 14 September in Nature Climate Change."[13] Not only does this demonstrate the importance of using more recent data than what the Bureau models used (e.g. CVHM ending in 2003), but the results should have significant bearing on the creation and analysis of alternatives.

Groundwater Storage Modeling

AA 24

A U.C. Davis Master's Thesis finds that the CVHM model used for the DEIS varies drastically from DWR's model, C2VSIM.[14] "As seen in the change in storage region totals at the bottom of Table 3.5, the differences are large in the Sacramento region, with CVHM showing overall gain to the groundwater storage and C2VSIM showing 12.4 MAF of overdraft." (*Id.* p. 34) Table 3.5 reveals that the CVHM model calculates an increase in storage for the Sacramento Valley of approximately 8.4 million acre-feet ("maf"), which when combined with the C2VSIM results becomes a difference of approximately 20.8 maf. (*Id.*) This is hardly a trivial matter when the Bureau is relying on a model that produces wildly different conclusions from its' SWP partner to

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[13] Belmecheri, Soumaya et al., 2015. *Mid-Century evaluation of Sierra Nevada snowpack*. Correspondence. http://www.nature.com/news/california-snowpack-lowest-in-past-500-years-1.18345

[14] Chou, Heidi, 2010. *Groundwater Overdraft in California's Central Valley: Updated CALVIN Modeling Using Recent CVHM and C2VSIM Representations*. Table 3.5, p. 35.

AA 24 continued

determine impacts to about half of the entire state (most of the CVP facilities and service areas and all of the SWP facilities and service areas, DEIS p. 1-10)

IV. Groundwater

AA 25

The Bureau Fails to Disclose Existing Groundwater Conditions in the Sacramento Valley

The DEIS provides limited groundwater elevation data of the Sacramento Valley groundwater basin in the Groundwater Resources and Groundwater Quality chapter. (pp. 7-1 to 7-184) The DEIS erroneously concludes that, "Overall, the Sacramento Groundwater Basin is approximately balanced with respect to annual recharge and pumping demand." (p. 7-14) Without defining "approximately balanced," the DEIS continues by stating, "However, there are several locations showing early signs of persistent drawdown, suggesting limitations due to increased groundwater use in dry years. Locations of persistent drawdown include: Glenn County, areas near Chico in Butte County, northern Sacramento County, and portions of Yolo County." (*Id.*) Unfortunately, the DEIS fails to elaborate through maps or text leaving the public without specific details.

AquAlliance's tables below cover 11 years and illustrate what could have been shared with the public in the DEIS. They show maximum and average groundwater elevation decreases for Butte, Colusa, Glenn, and Tehama counties, all the counties believed to overlie the Tuscan Aquifer, at three aquifer levels in the Sacramento Valley between the fall of 2004 and 2014.[15] These data contradiction numbers provided in Section 7.3, the Affected Environment, that provides windows of decline that are shorter, albeit mostly incorrect without the ending caveat, "[a]nd in some areas more than 10 feet." (p. 7-17) If the Bureau wanted to truly share significant shorter term data, they should disclose that maximum fall decreases for deep wells between 2013 and 2014 were 3.1 feet for Butte, 42.2 feet for Colusa, 26.9 feet for Glenn ,and 15.1 feet for Tehama – three counties significantly over 10 feet! (*Id.*)

County Fall '04 - '14	**Deep Wells (Max decrease gwe)**	**Deep Wells (Avg. decrease gwe)**
Butte	-12.7 (-11.4)*	-10.5 (-8.8)*
Colusa	-59.5 (-31.2)*	-59.5 (-20.4)*
Glenn	-79.7 (-60.7)*	-44.3 (-37.7)*
Tehama	-34.6 (-19.5)*	-10.9 (-6.6)*

County Fall '04 - '14	**Intermediate Wells (Max decrease gwe)**	**Intermediate Wells (Avg. decrease gwe)**
Butte	-23.0 (-21.8)*	-9.4 (-6.5)*
Colusa	-40.6 (-39.1)*	-22.6 (-16.0)*
Glenn	-57.2 (-40.2)*	-25.0 (-14.5)*
Tehama	-30.2 (-20.1)*	-12.4 (-7.9)*

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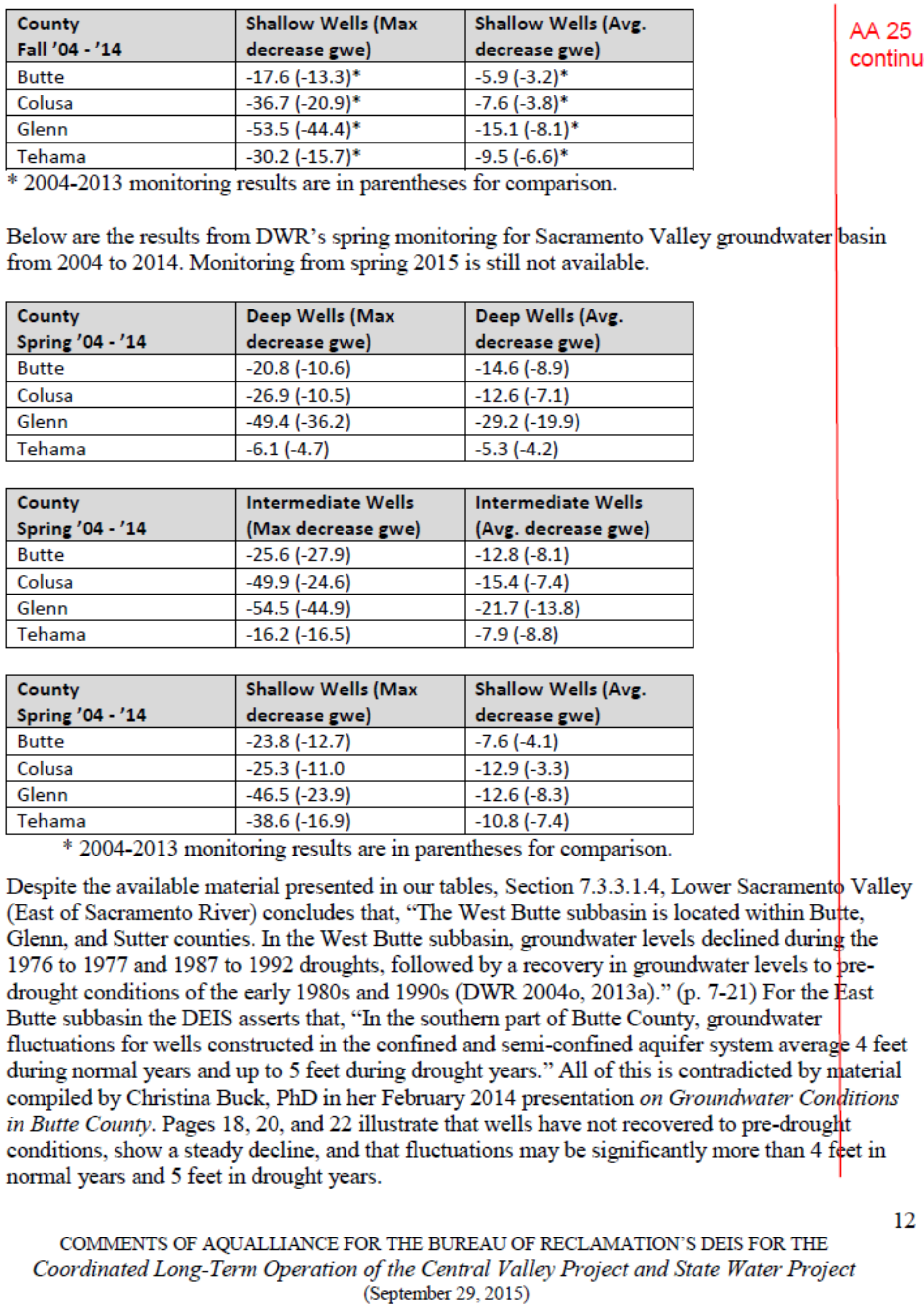
[15] *Id.*



County Fall '04 - '14	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-17.6 (-13.3)*	-5.9 (-3.2)*
Colusa	-36.7 (-20.9)*	-7.6 (-3.8)*
Glenn	-53.5 (-44.4)*	-15.1 (-8.1)*
Tehama	-30.2 (-15.7)*	-9.5 (-6.6)*

* 2004-2013 monitoring results are in parentheses for comparison.

Below are the results from DWR's spring monitoring for Sacramento Valley groundwater basin from 2004 to 2014. Monitoring from spring 2015 is still not available.

County Spring '04 - '14	Deep Wells (Max decrease gwe)	Deep Wells (Avg. decrease gwe)
Butte	-20.8 (-10.6)	-14.6 (-8.9)
Colusa	-26.9 (-10.5)	-12.6 (-7.1)
Glenn	-49.4 (-36.2)	-29.2 (-19.9)
Tehama	-6.1 (-4.7)	-5.3 (-4.2)

County Spring '04 - '14	Intermediate Wells (Max decrease gwe)	Intermediate Wells (Avg. decrease gwe)
Butte	-25.6 (-27.9)	-12.8 (-8.1)
Colusa	-49.9 (-24.6)	-15.4 (-7.4)
Glenn	-54.5 (-44.9)	-21.7 (-13.8)
Tehama	-16.2 (-16.5)	-7.9 (-8.8)

County Spring '04 - '14	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-23.8 (-12.7)	-7.6 (-4.1)
Colusa	-25.3 (-11.0	-12.9 (-3.3)
Glenn	-46.5 (-23.9)	-12.6 (-8.3)
Tehama	-38.6 (-16.9)	-10.8 (-7.4)

* 2004-2013 monitoring results are in parentheses for comparison.

Despite the available material presented in our tables, Section 7.3.3.1.4, Lower Sacramento Valley (East of Sacramento River) concludes that, "The West Butte subbasin is located within Butte, Glenn, and Sutter counties. In the West Butte subbasin, groundwater levels declined during the 1976 to 1977 and 1987 to 1992 droughts, followed by a recovery in groundwater levels to pre-drought conditions of the early 1980s and 1990s (DWR 2004o, 2013a)." (p. 7-21) For the East Butte subbasin the DEIS asserts that, "In the southern part of Butte County, groundwater fluctuations for wells constructed in the confined and semi-confined aquifer system average 4 feet during normal years and up to 5 feet during drought years." All of this is contradicted by material compiled by Christina Buck, PhD in her February 2014 presentation *on Groundwater Conditions in Butte County*. Pages 18, 20, and 22 illustrate that wells have not recovered to pre-drought conditions, show a steady decline, and that fluctuations may be significantly more than 4 feet in normal years and 5 feet in drought years.

AA 25 continued

AA 26

The Bureau acknowledges that its partner in coordination of the Projects, DWR, hasn't provided a comprehensive assessment of groundwater overdraft in California for 35 years! (DEIS p. 7-12) Undaunted by such a dearth of information, the DEIS suggest that *assumptions* made by DWR in 2003 are a sufficient substitute for factual data today: "[o]verdraft is estimated at between 1 to 2 million acre-feet annually." (*Id.)* AquAlliance strenuously objects to the adequacy of this material that feigns as fact in the DEIS and raises the following conclusions and questions. 1) An *estimate* of a serious overdraft condition fails to provide the reviewer with accurate information. 2) If groundwater conditions are as serious or more so than the estimated 1 to 2 maf annually, this represents a devastating environmental impact that hasn't been analyzed as an impact in the DEIS. 3) No matter what the actual groundwater overdraft is in California, how do significant and continuing groundwater withdrawals by the Projects' contractors deplete current and future stream flow thereby escalating a cycle of hydrologic deficit (see section "The Bureau Fails to Analyze Significant Past, Present, and Future Streamflow Depletion" below)? Strikingly, nothing remotely touching on this critical hydrologic reality is presented or analyzed in the DEIS thereby making the document wholly deficient.

AA 27

Lastly, the DEIS continues a Bureau pattern by ignoring the importance of the Cascade Range to the hydrology of the Sacramento River and Valley, Cascade streams in this particular statement: "The hydrology of this area is dominated by numerous smaller drainages that originate in the Sierra Nevada and Coast Ranges and drain to the Sacramento River (DWR 2003a)." (p. 7-16) Please correct this.

The Bureau Has Failed to Consider the Cumulative Impact of Other Groundwater Development and Surface Water Diversions Affecting the Sacramento Valley

AA 28

See Cumulative Impact section below.

Past CVP transfers allowed groundwater substitution and appear to violate CVPIA's mandate that any transfer have no significant impact on the seller's groundwater.

AA 29

CVPIA Section 3405 (a)(l)(J) states that no transfer shall be approved unless it is determined that "such transfer will have no significant long-term adverse impacts on groundwater conditions in the transferor's service area." However, The DEIS fails to include an analysis of impacts to groundwater in the areas of origin participating in CVP and SWP water transfers. Therefore the DEIS makes no findings on impacts and proposes no mitigation to evaluate the actual effects on groundwater levels and subsequent measures to insure the long-term protection of the underlying basins. To comply with the provision of CVPIA, the Bureau will have to arrive at some level of certainty that groundwater substitution will not adversely affect the transferor's basin under current operations or the preferred alternative. Again, this must be developed and presented in a revised and recirculated DEIS.

Subsidence

AA 30

This is the only mention of subsidence in Chapter 7. "Land subsidence due to groundwater withdrawals historically occurred in the Yolo subbasin of the Sacramento Valley Groundwater Basin and Delta-Mendota and Westside subbasins of the San Joaquin Valley Groundwater Basin in the Central Valley Region; Santa Clara Valley Groundwater Basin in the San Francisco Bay

AA 30 continued

Area Region; and the Antelope Valley and Lucerne Valley groundwater basins in the Southern California Region. Under the No Action Alternative, it is anticipated that increased groundwater withdrawals due to reductions in CVP and SWP water supplies and reduced groundwater recharge due to climate change could result in increased irreversible land subsidence in these areas." (p. 7-117)

Even Appendix 7A just touches on subsidence that was modeled by CVHM, the model that spans a 42-year simulation period starting in water year 1962 and ends in 2003. As noted above, this eliminates the last 12 years and fails to account for current conditions and future conditions. The DEIS acknowledges another vulnerability: "The subsidence package, as implemented in the version of CVHM used for the impacts analysis, does not consider the potential reduction in the rate of subsidence that would occur as the magnitude of compaction approaches the physical thickness of the affected fine-grained interbeds. Thus, subsidence forecasts from the predictive versions of CVHM were judged to be overly conservative. Therefore, a qualitative approach was used for estimating the potential for increased land subsidence in areas of the Central Valley that have historically experienced inelastic subsidence because of the compaction of fine-grained interbeds." (pp. 7-112 and 7A-17). However, the Impact section of Chapter 7, Groundwater Resources and Groundwater Quality, provides nothing in the way of analysis. The conclusions are:

- "As described above and summarized in Table 7.3, implementation of Alternatives 1 through 5 as compared to the No Action Alternative would result in either similar or less groundwater pumping and potential for land subsidence; and similar groundwater quality conditions. Therefore, there would be no adverse impacts to groundwater; and no mitigation measures are needed." (p. 7-141)
- "However, implementation of No Action Alternative and Alternative 5 (in the Central Valley, San Francisco Bay Area, Central Coast, and Southern California regions) and Alternative 3 (in the San Francisco Bay Area, Central Coast, and Southern California regions) as compared to the Second Basis of Comparison would result in increased groundwater pumping and associated potential for land subsidence and poorer groundwater quality; and could contribute to cumulative impacts related to groundwater conditions as compared to the Second Basis of Comparison conditions." (pp. 7-142 and 7-143)

How were the conclusions reached, specifically? There is subsidence occurring right now and has for decades in some areas served by the Projects. To state that the No Action Alternative, "[w]ould result in either similar or less groundwater pumping and potential for land subsidence; and similar groundwater quality conditions," circumvents requirements of NEPA. Because impacts may be "similar" does not stop past, present or future direct and indirect impacts that require disclosure, avoidance, and/or mitigation. Even when the DEIS finds impacts (pp. 7-142 and 7-143), still there is no mitigation offered. This is another seriously deficient attempt at meeting NEPA requirements.

AA 31

The DEIS also fails to mention that DWR has a continuous global positioning system (GPS) network for periodic monitoring of changes in ground elevation. A baseline GPS survey was performed in 2004 and DWR and the Bureau conducted a second survey jointly in 2008.[16] Since these surveys aren't even mentioned in the DEIS, specific information on the results of the GPS

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[16] Department of Water Resources and United State Bureau of Reclamation, 2008, Project Report, *2008 DWR/USBR Sacramento Valley GPS Subsidence Report, September 30, 2008*, 7 pp., Appendices A to F.

AA 31 continued

subsidence monitoring is also lacking. The Bureau's SWP partner, DWR, presented the results of the 2004 and 2008 GPS subsidence monitoring to the Glenn County Water Advisory Committee in February 2015, which identified an area of subsidence east of the GCID wells at an average of -0.38 feet.[17] Also absent from the DEIS is the potential impact from land subsidence due to the Glenn Colusa Irrigation District's past, current, and planned groundwater extraction in an already stressed groundwater basin[18] and that there are five extensometers near GCID's existing and planned wells in Glenn County. This is demonstrated in comments submitted by AquAlliance on GCID's 10-Wells EIR.[19] It is the lack of disclosure like this that requires the Bureau to revise and recirculate another Draft Environmental Impact Statement.

The Bureau Failed to Analyze Impacts to Groundwater Quality

AA 32

The DEIS extrapolates that many impacts could occur. For example, "Changes in groundwater quality could occur in several ways under implementation of the alternatives as compared to the No Action Alternative and Second Basis of Comparison. Reductions in groundwater levels could change groundwater flow directions, potentially causing poorer quality groundwater to migrate into areas with higher quality groundwater, or cause intrusion of poor water quality (e.g. from aquitards) as water levels decline." (p. 7-112)

While the DEIS suggests that analysis was conducted, there are no conclusions reached beyond those that are very general in nature as with the quoted section above. "Within the Central Valley, changes in groundwater use and groundwater flow direction are analyzed using the CVHM. The model does not directly simulate changes in groundwater quality. However, in regions with existing poorer quality groundwater, changes in groundwater levels or flow directions can be used to evaluate potential impacts to groundwater quality. For example, declines in groundwater levels that result in seawater intrusion, or the migration of good quality groundwater into areas with poor quality can result in groundwater quality degradation. Further, reduction in groundwater quality could also occur due to migration or upwelling of poorer quality groundwater into areas with good quality groundwater." (p. 7-113) With such ambiguous conclusions, the Bureau quite obviously finds that none of the Alternatives including the No Action Alternative would cause a significant impact, so no mitigation is offered.

How this is remotely possible fails to pass the blush test. The CVP alone has caused massive pollution in San Joaquin Valley groundwater. You don't need a model to know that. Is it the Bureau's belief that the groundwater is already so bad that any additional groundwater degradation would be minimal? Before a call of less than significance may be made the DEIS must first provide maps and data that disclose where known groundwater contamination exists, what are the MCLs for pollutants in those locations, and what activities that are part of CVP and SWP operations could exacerbate them. This should be done for all of the Project Area.

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[17] Ehorn, B., 2015, Letter to Glenn County Board of Supervisors, and Glenn County Water Advisory Committee, on results of 2004 to 2008 land subsidence GPS surveys performed in Glenn County, dated February 3, 2015, presented at February 10, 2015 Water Advisory Committee meeting, Willows, CA, 3 pp., 1 Figure.

[18] http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Well%20Depth%20Summary%20Maps

[19] AquAlliance, 2015. *Comments on the Draft Environmental Impact Report for the Glenn Colusa Irrigation District 10-Wells Project (Groundwater Supplemental Supply Project SCH# 2014092076).* Custis Exhibit 16.

AA 32 continued

Regarding the Sacramento Valley, all of the alternatives have the potential to degrade water quality due to the escalating involvement of groundwater substitution transfers. As we suggested above, the Bureau must provide maps and data that disclose where known groundwater contamination exists, what are the MCLs for pollutants in those areas, and what activities that are part of CVP and SWP operations could exacerbate them.

AA 33

The Bureau Fails to Analyze Significant Past, Present, and Future Streamflow Depletion

All water discharged by wells is balanced by a loss of water somewhere.[20] The DEIS unfortunately fails to present existing conditions for the Sacramento Valley. The increasing use of groundwater has caused the loss of 1.5 maf per year from Sacramento Valley rivers and streams as suggested by C.F. Brush and colleagues and the Northern California Water Association ("NCWA").[21] Kit Custis created a graphic depiction of this historic groundwater extraction and stream interaction (1920s – 2009) that illustrates groundwater pumping, groundwater change in storage, and stream accretion.[22] He found that stream accretion flattened in the mid to late 1990s which suggests that , "First, after depleting 1.5 MAFY from the Sacramento Valley streams, the surface waters may not be able to provide much more, at least no increase to match the pumping. Second, this may also be a consequence of the model design because the number of streams simulated was limited. Third, the model's grid may not extend out far enough to encompass all of the streams that contribute to groundwater recharge." (*Id.* p. 35) This cries out for additional analysis that the Projects should fund or tackle.

Custis goes on to state, that "Accounting for the transfer of groundwater between regions is critical for understanding the impacts of pumping in one region or area on the adjacent regions. The sources of water backfilling a groundwater depression don't all have to come from surface waters, ie., stream depletion, precipitation, deep percolation, and artificial recharge. Some of that "recharge" can come from adjacent aquifers by horizontal and vertical flow." (*Id.* p. 33) The DEIS fails to account for any of the information provided here or by Brush, Custis, or NCWA. Without this context, the DEIS improperly defeats its own purpose under NEPA to fully disclose the setting as a baseline for evaluating water supply and groundwater impacts of the alternatives and recommending mitigation measures.

i. The Bureau Fails to Adequately Assess Economic Costs

AA 34

The solitary mention of streamflow depletion is presented in Appendix 19A that discusses the *California Water Economics Spreadsheet Tool (CWEST) Documentation* and states that, "Additional costs associated with groundwater use include lower groundwater tables, subsidence, streamflow depletion, depreciation, and well replacement that should be included," as well as costs to treat groundwater that may become contaminated. (p. 19A-20) However, the need for these additional costs are only estimated since the Bureau claims that, "No consistent source of

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[20] Theis, C.V. 1940. The source of water derived from wells—Essential factors controlling the response of an aquifer to development. Civil Engineering 10: 277–280.

[21] Custis, Kit 2014. Comments and Recommendations prepared for AquAlliance on U.S. Bureau of Reclamation and San Luis & Delta Mendota Water Authority Long-Term Water Transfer Draft EIS/EIR. pp. 33-34.

[22] Custis, Kit 2014. Exhibit 10.7 prepared for AquAlliance on U.S. Bureau of Reclamation and San Luis & Delta Mendota Water Authority Long-Term Water Transfer Draft EIS/EIR.

information is available to assess these other costs…" (*Id.*) This conclusion is indefensible without disclosure why such information isn't found in the public domain.

AA 34 continued

The information necessary to analyze impact/cost most likely exists in academic literature, government reports, and reports by industry and interest groups. In the event that economic analysis isn't able to exactly quantify dollar costs per quantity of groundwater use, it would provide a likely range of impacts, and be able to talk about the degree of uncertainty in the resulting estimate. Unfortunately, the Bureau's response was to arbitrarily increase costs by 10 percent in the DEIS, which lacks foundation. How was 10 percent selected, what factors were considered, and what information did they review? If a "consistent source" isn't available, all relevant information should have been considered and reviewed to reach an impact/cost from available information.

Municipal and Industrial Groundwater Impacts

AA 35

The DEIS presents that, "It is recognized that municipal and industrial pumping in urban areas in the Central Valley could cause localized impacts to groundwater levels from increased drawdown. The increased withdrawals could also impact groundwater quality due to the migration of existing plumes, as described in the Affected Environment section." (p. 7-11) Despite this acknowledgement, the DEIS again takes the position that there are no significant impacts and offers no mitigation measures.

In summary for Chapter 7, *Groundwater and Groundwater Quality*, the DEIS failed to find any impacts of significance and therefore produced no mitigation measures. Sadly, the Bureau improperly defeats its own purpose under NEPA to fully disclose the setting as a baseline for evaluating all the alternative's water supply and groundwater impacts and recommending mitigation measures.

V. The EIS/EIR Fails to Adequately Analyze Numerous Cumulative Impacts.

The Ninth Circuit Court makes clear that NEPA mandates "a useful analysis of the cumulative impacts of past, present and future projects." *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). "Detail is required in describing the cumulative effects of a proposed action with other proposed actions." *Id.*

AA 36

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an

AA 36 continued

environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3) (emphasis added).

As discussed, below, and in the 2014 expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance for the 10-Year Water Transfer Program (aka Long-Term Transfer Program), the DEIS fails to comport with these standards for cumulative impacts upon surface and groundwater supplies, vegetation, and biological resources; and, the baseline and modeling data relied upon by the DEIS that does not account for related projects in the last 12 years.

Recent Past Transfers.

Because the groundwater modeling effort didn't include the most recent 11 years record (1970-2003), it appears to have missed simulating the most recent periods of groundwater substitution transfer pumping and other groundwater impacting events, such as recent changes in groundwater elevations and groundwater storage (DWR, 2014b), and the reduced recharge due to the recent periods of drought. Without taking the hydrologic conditions during the recent 11 years into account, the results of the CVHM model simulation may not accurately depict the current conditions or predict the effects from the proposed groundwater substitution transfer pumping during the next 10 years.

- In 2009, the Bureau approved a 1 year water transfer program under which a number of transfers were made. Regarding NEPA, the Bureau issued a FONSI based on an EA.
- In 2010, the Bureau approved a 2 year water transfer program (for 2010 and 2011). No actual transfers were made under this approval. Regarding NEPA, the Bureau again issued a FONSI based on an EA.
- The Bureau planned 2012 water transfers of 76,000 AF of CVP water all through groundwater substitution.[23]
- In 2013, the Bureau approved a 1 year water transfer program, again issuing a FONSI based on an EA. The EA incorporated by reference the environmental analysis in the 2010-2011 EA.
- The Bureau and SLDMWA's 2014 Water Transfer Program proposed transferring up to 91,313 AF under current hydrologic conditions and up to 195,126 under improved conditions. This was straight forward, however, when attempting to determine how much water may come from fallowing or groundwater substitution during two different time periods, April-June and July-September, the reader was left to guess.[24]

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[23] USBR 2012. Memo to the Deputy Assistant Supervisor, Endangered Species Division, Fish and Wildlife Office, Sacramento, California regarding Section 7 Consultation.

[24] The 2014 Water Transfer Program's EA/MND was deficient in presenting accurate transfer numbers and types of transfers. The numbers in the "totals" row of Table 2-2 presumably should add up to 91,313. Instead, they add up to 110, 789. The numbers in the "totals" row of Table 2-3 presumably should add up to 195,126. Instead, they add up to 249,997. Both Tables 2-2 and 2-3 have a footnote stating: "These totals cannot be added together. Agencies could make water available through groundwater substitution, cropland idling, or a combination of the two; however, they

These closely related projects impact the same resources, are not accounted for in the environmental baseline, and must be considered as cumulative impacts.

AA 36 continued

Yuba Accord

AA 37

The relationship between the Projects and the Lower Yuba River Accord is not found in the DEIS, but is illuminated in a 2013 Environmental Assessment. "The Lower Yuba River Accord (Yuba Accord) provides supplemental dry year water supplies to state and Federal water contractors under a Water Purchase Agreement between the Yuba County Water Agency and the California Department of Water Resources (DWR). Subsequent to the execution of the Yuba Accord Water Purchase Agreement, DWR and The San Luis & Delta- Mendota Water Authority (Authority) entered into an agreement for the supply and conveyance of Yuba Accord water, to benefit nine of the Authority's member districts (Member Districts) that are SOD [south of Delta] CVP water service contractors." [25]

In a Fact Sheet produced by the Bureau, it provides some numerical context and more of DWR's involvement by stating, "Under the Lower Yuba River Accord, up to 70,000 acre-feet can be purchased by SLDMWA members annually from DWR. This water must be conveyed through the federal and/or state pumping plants in coordination with Reclamation and DWR. Because of conveyance losses, the amount of Yuba Accord water delivered to SLDMWA members is reduced by approximately 25 percent to approximately 52,500 acre-feet. Although Reclamation is not a signatory to the Yuba Accord, water conveyed to CVP contractors is treated as if it were Project water." [26] However, the Yuba County Water Agency ("YCWA") may transfer up to 200,000 under Corrected Order WR 2008-0014 for Long-Term Transfer and, "In any year, up to 120,000 af of the potential 200,000 af transfer total may consist of groundwater substitution. (YCWA-1, Appendix B, p. B-97.)." [27]

Potential cumulative impacts from the Project and the YCWA Long-Term Transfer Program from 2008 - 2025 are not disclosed or analyzed in the DEIS. Moreover, the *2015-2024 Water Transfer Program* could transfer up to 600,000 AF per year through the same period that the YCWA Long-Term Transfers are potentially sending 200,000 AF into and south of the Delta. How these two projects operate simultaneously could have a very significant impact on the environment and economy of the Feather River and Yuba River's watersheds and counties as well as the Delta. The involvement of Browns Valley Irrigation District and Cordua Irrigation District in both long-term programs must also be considered. This must be analyzed and presented to the public in a revised DEIS.

Also not available in the DEIS is disclosure of any issues associated with the YCWA transfers that have usually been touted as a model of success. The YCWA transfers have encountered troubling

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will not make the full quantity available through both methods. Table 2-1 reflects the total upper limit for each agency."

[25] Bureau of Reclamation, 2013. *Storage, Conveyance, or Exchange of Yuba Accord Water in Federal Facilities for South of Delta Central Valley Project Contractors*.

[26] Bureau of Reclamation, 2013. *Central Valley Project (CVP) Water Transfer Program Fact Sheet*.

[27] State Water Resources Control Board, 2008. ORDER WR 2008 - 0025

AA 37 continued

trends for over a decade that, according to the draft Environmental Water Account ("EWA") EIS/EIR, are mitigated by deepening domestic wells (2003 p. 6-81). While digging deeper wells is at least a response to an impact, it hardly serves as a proactive measure to avoid impacts. Additional information finds that it may take 3-4 years to recover from groundwater substitution in the south sub-basin[28] although YCWA's own analysis fails to determine how much river water is sacrificed to achieve the multi-year recharge rate. None of this is found in the EIS/EIR. What is found in the EIS/EIR is that even the inadequate SACFEM2013 modeling reveals that it could take more than six years in the Cordua ID area to recover from multi-year transfer events, although recovery is not defined (pp, 3.3-69 to 3.3-70). This is a very significant impact that isn't addressed individually or cumulatively.

BDCP

AA 38

The DEIS acknowledges the Bay Delta Conservation Plan ("BDCP") in its Cumulative Impacts list. However we believe that DEIS fails to consider the potential cumulative impacts if the Twin Tunnels are built as planned with the capacity to take 15,000 cubic feet per second ("cfs") from the Sacramento River. They will have the capacity to drain almost two-thirds of the Sacramento River's average annual flow of 23,490 cfs at Freeport[29] (north of the planned Twin Tunnels). As proposed, the Twin Tunnels will also increase water transfers when the infrastructure for the Project has capacity. This will occur during dry years when SWP contractor allocations drop to 50 percent of Table A amounts or below or when CVP agricultural allocations are 40 percent or below, or when both projects' allocations are at or below these levels (BDCP DEIS/EIR Chapter 5, 2013). With BDCP, North to South water transfers would be in demand and feasible.

Communication regarding assurances for BDCP indicates that the purchase of approximately 1.3 million acre-feet of water is being planned as a mechanism to move water into the Delta to make up for flows that would be removed from the Sacramento River by the BDCP tunnels. [30] There is only one place that this water can come from: the Sacramento Valley's watersheds. It is well know that the San Joaquin River is so depleted that it will not have any capacity to contribute meaningfully to Delta flows. Additionally, the San Joaquin River doesn't flow past the proposed north Delta diversions and neither does the Mokelumne River.

The DEIS also fails to reveal many more programs, plans and projects to develop water transfers in the Sacramento Valley, to develop a "conjunctive" system for the region, and to place water districts in a position to integrate the groundwater into the state water supply. BDCP is one of those plans that the federal agencies, together with DWR, SLDMWA, water districts, and others have been pursuing and developing for many years.

i. Biggs-West Gridley

AA 39

The *Biggs-West Gridley Water District Gray Lodge Wildlife Area Water Supply* Project, a Bureau project, is not mentioned anywhere in the Vegetation and Wildlife or Cumulative Impacts

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[28] 2012. *The Yuba Accord, GW Substitutions and the Yuba Basin*. Presentation to the Accord Technical Committee. (pp. 21, 22).

[29] USGS 2009. http://wdr.water.usgs.gov/wy2009/pdfs/11447650.2009.pdf Exhibit KK)

[30] Belin, Lety, 2013. E-mail regarding Summary of Assurances. February 25 (Department of Interior). (Exhibit LL)

AA 39 continued

sections.[31] This water supply project is located in southern Butte County where Western Canal WD, Richvale ID, Biggs-West Gridley WD, and Butte Water District actively sell water on a regular basis, yet impacts to GGS from this project are not disclosed. This is a serious omission that must be remedied in a recirculated draft DEIS.

ii. Other Projects

AA 40

a) Court settlement discussions between the Bureau and Westlands Water District over provisions of drainage service. Case # CV-F-88-634-LJO/DLB will further strain the already over allocated Central Valley Project with the following conditions:

- A permanent CVP contract for 890,000 acre-feet of water a year exempt from acreage limitations.
- Minimal land retirement consisting of 100,000 acres; the amount of land Westlands claims it has already retired (115,000 acres) will be credited to this final figure. Worse, the Obama administration has stated it will be satisfied with 100,000 acres of "permanent" land retirement.
- Forgiveness of nearly $400 million owed by Westlands to the federal government for capital repayment of Central Valley Project debt.

b) Five-Year Warren Act Contracts for Conveyance of Groundwater in the Tehama-Colusa and Corning Canals – Contract Years 2013 through 2017 (March 1, 2013, through February 28, 2018).

Additional projects with cumulative impacts upon groundwater and surface water resources affected by the Project:

- The DWR Dry Year Purchase Agreement for Yuba County Water Agency water transfers from 2015-2025 to SLDMWA.[32]
- GCID's *Stony Creek Fan Aquifer Performance Testing Plan* to install seven production wells in 2009 to extract 26,530 AF of groundwater as an experiment that was subject to litigation due to GCID's use of CEQAs exemption for research.
- Installation of numerous production wells by the Sellers in this Project many with the use of public funds such as Butte Water District,[33] GCID, Anderson Cottonwood Irrigation District,[34] and Yuba County Water Authority [35] among others.

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[31] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=15381

[32] SLDMWA Resolution # 2014 386 http://www.sldmwa.org/OHTDocs/pdf_documents/Meetings/Board/Prepacket/2014_1106_Board_PrePacket.pdf

[33] Prop 13. Ground water storage program: 2003-2004 Develop two production wells and a monitoring program to track changes in ground.

[34] "The ACID Groundwater Production Element Project includes the installation of two groundwater wells to supplement existing district surface water and groundwater supplies." http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=8081

[35] Prop 13. Ground water storage program 2000-2001: Install eight wells in the Yuba-South Basin to improve water supply reliability for in-basin needs and provide greater flexibility in the operation of the surface water management facilities. $1,500,00;

AA 40 continued

- GCID's 10 Wells Project proposes to install five new production wells and continue operating five additional production wells during dry and critically dry years for 8.5 months from approximately February 15-Marh 15 and April 1-November 15. The annual, maximum, cumulative total pumping is 28,500 af and is more water than the annual use of the Chico district of California Water Service Company that serves over 100,000 people.[36]

VI. Procedural Issues

AA 41

- Will there be a California Environmental Quality Act ("CEQA") equivalent document for the Project that is produced and circulated for public comment?

AA 42

- When will mitigation measures be circulated for public review and comment? "Consideration for Mitigation Measures" are not mitigation measures.

AA 43

- The public is prevented from knowing what the preferred alternative is because, "This Draft EIS does not recommend a preferred alternative. A preferred alternative will be included in the Final EIS." (p. ES-5) Letting the public know in a final document is not sufficient for a project of this magnitude.

AA 44

- The public is unnecessarily confused by the creation of a Second Basis of Comparison that, "[i]s not a true alternative, in accordance with NEPA guidelines, Reclamation could not select Second Basis of Comparison as a preferred alternative. Therefore, Alternative 1 was defined as being identical to the Second Basis of Comparison, as defined in Section 3.3.2." (p. 3-31)

AA 45

As demonstrated in our comments, the DEIS is seriously deficient and should be withdrawn. AquAlliance hopes that the Bureau and DWR may better understand the serious harm the Projects have wrought on Sacramento Valley, San Joaquin Valley, and Delta communities, groundwater dependent farmers, and the environment over many decades. AquAlliance requests that the Bureau regroup and prepare an adequate DEIS with a new suite of alternatives that are less damaging and potentially restorative.

Sincerely,

B. Vlamis

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[36] California Water Service Company *2010 Urban Water Management Plan Chico-Hamilton City District*, p. 32.

1D.1.1.1 Attachments to Comments from AquAlliance

Attachments to the AquAlliance letter are included in Attachment 1D.1 located at the end of Appendix 1D.

1D.1.1.2 Responses to Comments from AquAlliance

AA 1: Comment noted.

AA 2: Comment noted. The EIS analysis adequately addresses the effects of the coordinated long-term operation of the CVP and SWP.

AA 3: The letters listed in this comment were submitted to Reclamation as comments on another project, the Long-Term Transfers EIR/EIS. Responses to those comments can be found in the Final Long-term Transfers EIR/EIS posted on the Reclamation website at www.usbr.gov/mp/nepa/index.cfm.

AA 4: The letters listed in this comment were submitted to Reclamation as comments on other projects, not the EIS for the coordinated long-term operation of the CVP and SWP. Responses to those comments on projects that have completed the NEPA process are included in the final version of the NEPA documents posted on the Reclamation website at http://www.usbr.gov/mp/nepa/index.cfm.

Responses to comments on projects that are still undergoing evaluation will be posted on the Reclamation website at www.usbr.gov/mp/nepa/index.cfm in the final NEPA documents.

AA 5: Please see responses to Comments AA 6 through AA 40.

AA 6: The purpose of the action is presented in Chapter 2, Purpose and Need, of the EIS, and considers the purposes for which the CVP was authorized, as amended by CVPIA, as well as the regulatory limitations on CVP operations, including applicable state and federal laws and water rights.

The need for the action also is presented in Chapter 2, and in accordance with the District Court order is to evaluate potential modifications to the continued long-term operation of the CVP, in coordination with the operation of the SWP, related to Reclamation's acceptance and implementation of the Reasonable and Prudent Alternatives (RPAs) included in the Biological Opinions (BOs) issued in 2008 and 2009 by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), respectively, pursuant to the Federal Endangered Species Act of 1973 (ESA) as amended (United States Code [U.S.C.] 1531 et. seq.).

AA 7: The CVP and SWP operate within the federal and state regulatory requirements, as described in Appendix 3A, No Action Alternative: Central Valley Project and State Water Project Operations. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources.

AA 8: The *Westlands v. United States* Settlement in the *Firebaugh Canal Co v. United States* was signed on September 15, 2015. This settlement agreement requires congressional authorization prior to implementation. Therefore, this project has been included in the cumulative effects analysis in the Final EIS.

AA 9: The CVP and SWP operations prioritize meeting federal and state regulatory requirements and deliveries to senior water rights holders. The modeling analyses presented in the EIS include these prioritizations for long-term operation of the CVP and SWP using an 82-year hydrology analyzed with the CalSim II model. This analytical approach results in low water storage elevations in CVP and SWP reservoirs and low deliveries to CVP agricultural water service contractors located to the south of the Delta in critical dry periods. The modeled operations do not include changes in SWRCB requirements intended to reduce the effects of extreme flood or drought events, such as the recent changes in CVP and SWP drought operations.

Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions, as described in the response to Comment AA 7.

AA 10: The interaction of streamflow and groundwater is included in the groundwater analytical tool, CVHM, as described in Appendix 7A, Groundwater Model Documentation.

AA 11: The historic reservoir storages and stream flows presented in Figures 5.7 through 5.45 in the EIS were generally presented for the period of time from 2001 through 2012. This time frame represents conditions under the operations of the CVP and SWP since full implementation of operations in accordance with State Water Resources Control Board (SWRCB) Decision 1641 (D-1641) and biological opinions adopted by the USFWS and NMFS in the early 2000s. Historic stream flow data and locations of the gauges, such as Douglas City, can be found on the CDEC website at www.cdec.water.ca.gov.

AA 12: The EIS does include references to the efforts being implemented to meet the statewide goals for reduction of municipal per capita water use by 20 percent by 2020 and optimization of agricultural water use efficiency. The EIS analysis is conducted at the Year 2030, and it is assumed that the legislative requirements of water conservation by municipal and agricultural water users have been achieved in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

AA 13: Many of the projects referenced in this comment are related to short-term water transfer programs. It is acknowledged in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 that these annual water transfer programs are anticipated to continue in the Year 2030. The Long-Term North-to-South Water Transfer Program is acknowledged in this EIS to provide for water transfers from 2015 through 2024. As with the short-term water transfer programs, it is anticipated that similar programs would continue in the Year 2030 in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

The maximum amount of water transfers across the Delta referenced in this comment were defined by Reclamation in the *Biological Assessment on the Continued Long-Term Operations of the Central Valley Project and the State Water Project* August 2008 document. These limitations were included in the 2008 USFWS BO and 2009 NMFS BO as the Proposed Action from the Biological Assessment. The effect of moving total amounts of water (including transferred water) across the Delta through CVP and SWP facilities is conducted in accordance with the federal and state requirements, as in included in the CalSim II model.

AA 14: The project referenced in this comment was not completed by Glenn-Colusa Irrigation District; and therefore, it was not included in the No Action Alternative, the Second Basis of Comparison, or Alternatives 1 through 5.

AA 15: The coordinated long-term operation of the CVP and SWP assumes continued use of water rights by Reclamation, DWR, and all other water users. The EIS analysis is conducted with projected conditions at Year 2030 with climate change and sea level rise assumptions. The climate change assumptions include a reduction in snow pack, warmer air temperatures, and larger rainfall events than in recent history. As described in Chapter 5, Surface Water Resources and Water Supplies, and Chapter 7, Groundwater Resources and Groundwater Quality, this could lead to less carryover storage in all reservoirs in September and less natural groundwater recharge. This could affect the amount of water available for all water rights holders.

The water rights system in California was developed with consideration of a highly variable hydrology. The water rights system is based upon a priority of diversion rates (e.g., maximum daily rates or instantaneous diversion rates), limited to beneficial uses and not wasteful uses, instead of a priority of volumes. The maximum daily or instantaneous diversion rates are frequently expressed as maximum monthly or annual volumes. However, the volume of water that can be diverted is determined through the prioritization of water rights and minimum downstream flows required for other water users and environmental considerations as regulated by federal and state agencies. Many of the water rights are for non-consumptive use (such as for power generation). Many consumptive use water rights holders also return a portion of their diversions to the river as agricultural return flows and wastewater effluent. These return flows are also available for downstream uses. The CalSim II model used in this EIS simulates this complex system. The model prioritizes deliveries and associated return flows to water rights holders and federal and state stream flow and water quality requirements prior to determining the available water supplies for CVP and SWP water contractors. Listings of water rights in California can be found on the SWRCB website at www.swrcb.ca.gov/waterrights.

AA 16: The EIS describes that under the No Action Alternative, benefits from implementation of the 2008 USFWS BO and 2009 NMFS BO RPA actions are anticipated to improve aquatic resources conditions. However, it must be recognized that some of the RPA actions are either under construction, or recently completed construction (e.g., Battle Creek restoration and Red Bluff Pumping Plant, respectively). Other RPA actions are still under development (e.g., fish passage around CVP reservoirs). Therefore, conditions described in the Affected Environment section of Chapter 9 do not represent the anticipated conditions that would occur under the No Action Alternative by the Year 2030 with full implementation of the RPA actions.

AA 17: The comment is consistent with the information presented in the EIS related to Alternatives 1 through 5.

AA 18: The analysis in the EIS compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for a broad range of physical, environmental, and human resources. The NEPA analysis does not determine if the alternatives would change the findings of the biological opinions in the determination of the likelihood of the alternatives to cause jeopardy to the continued existence of the species, or destroy or adversely affect their critical habitat.

AA 19: CVHM was used to support the EIS groundwater analysis as is it was deemed to have the greatest resolution (vertically and spatially) and more robust calibration than any of the other currently available Central-Valley wide models. While it is true that the CVHM model simulation period ends at the end of 2003, none of the Central-Valley wide models that simulate groundwater conditions for more recent periods post-2003 were available or deemed adequate for the analysis at the time of preparation of the EIS. The 1961 through 2003 time period simulated by CVHM includes varying hydrologic conditions that range from extreme dry periods (such as 1987-92) and extreme wet periods (such as 1983). The model includes assumptions for climate and typical hydrologic conditions at 2030 that alternate between dry and wet conditions to capture the range of possible impacts.

The CalSim II model output used in the CVHM model includes river flows and CVP and SWP water deliveries. It is recognized that the CalSim II model does include assumptions for groundwater use in the Sacramento Valley.

AA 20: Models are used in the EIS analysis to evaluate the differences of long-term operations under the various alternatives as compared to the No Action Alternative and Second Basis of Comparison. Historical conditions cannot be used to evaluate expected results under varying operational alternatives since operational constraints have changed continuously since the project was first developed. Furthermore, the EIS analysis is conducted to analyze conditions in 2030 which will include changes from recent conditions in land use, hydrology, and water quality due to future development, climate change, and sea level rise.

Sole use of historic observations would not be appropriate for evaluating operations under these future conditions. However, the historic observations were used in development of the analytical tools that are used in this EIS.

AA 21: Additional details have been included in Appendix 5A, Section A, CalSim II and DSM2 Modeling, to provide more clarity about the climate change assumptions used in CalSim II, CVHM, and all related models. As described in Appendix 5A, Section A, the climate change models used in this EIS indicate that the future conditions are anticipated to result in less snow pack, warmer air temperatures, and more intense rainfall events. These conditions would result in a reduction of water available for CVP and SWP contractors as compared to historical conditions, as discussed in Section 5.4.2 of Chapter 5, Surface Water Resources and Water Supplies. These conditions are included in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

AA 22: Please response to Comment AA 18.

AA 23: As discussed in this comment, the analytical tools do have limitations and uncertainties, as discussed in the appendices of the EIS. The acknowledgement of these limitations and uncertainties is why all model results in all EIS chapters must be used in a comparative manner to determine the incremental differences between Alternatives 1 through 5 as compared to the No Action Alternative, and between the No Action Alternative and Alternatives 1 through 5 as compared to the Second Basis of Comparison. The model results are not used to project specific physical, biological, or human resource values. By using the models in a comparative manner, the results of the analysis are less affected by the limitations and uncertainties. The quantitative model results are used in conjunction with the qualitative analyses presented in this EIS to consider the comparative results of the entire analyses.

AA 24: Central Valley groundwater models are complex due to the extremely differing hydrogeology in the watershed that provides groundwater recharge and the wide range of depletions that occur through wells, streamflow depletion, and losses to deep aquifers. As stated in the 2010 Masters Thesis (referred to in the comment), “Actual groundwater storage capacity in California is unknown and is not accurately measureable at this time.”

The two Central Valley wide groundwater flow models, CVHM and C2VSim, differ in their structure, simulation period, and input assumptions. CVHM was used for the EIS groundwater impact analysis because it provides higher resolution (both in horizontal grid spacing and vertical layering – 10 layers versus 3 layers) and has undergone a more robust calibration.

A peer review of these models was led by CWEMF (California Water Environment Modeling Forum) and developed by renowned groundwater scientists in 2013. The findings indicate that both C2VSim and CVHM are valid models for the evaluation of water resources planning and impact studies in the Central Valley. Therefore, while differences in model forecast exist, CVHM is a more robust tool to support the EIS impact analysis.

AA 25: The EIS cites different groundwater drawdown magnitudes than mentioned in the comment, as it used the data presented in the 2014 DWR Drought Update report (as cited in Chapter 9, Groundwater Resources and Groundwater Quality in the EIS).

The differences between the reported groundwater level trends the EIS and the Butte County groundwater levels included in the comment are due to the differences in groundwater data references cited. It is recognized that local and regional data are collected and reported for many locations throughout the state. However, because the EIS study area included a large portion of the state, federal and state data references were used in the EIS to provide a uniform dataset for the entire analysis.

AA 26: The actual magnitude of overdraft in the Central Valley groundwater basin is known at specific locations with groundwater elevations; however, regional overdraft values are only estimates based upon groundwater models and regional observations. DWR is the state agency tasked with collecting state-wide groundwater elevation data and therefore is a reasonable source for estimates of the type mentioned in the comment. The EIS impact analysis is based upon a comparative methodology to inform Reclamation and others about the differences between Alternatives 1 through 5 as compared to the No Action Alternative, and between the No Action Alternative and Alternatives 1 through 5 as compared to the Second Basis of Comparison. The EIS provides information related to the effects of the alternatives as compared to the No Action Alternative and the Second Basis of Comparison on groundwater in the Central Valley.

AA 27: The EIS referenced the Sierra Nevada as a surrogate for all eastside streams. The text on page 7-16 of the Draft EIS should have stated the "Sierra Nevada and Cascade Ranges", and will be modified in the Final EIS.

AA 28: Please see responses to Comment AA 36 through AA 40.

AA 29: The requirements for water transfers, including transfers with provisions for groundwater substitution, that involve either CVP and SWP water contract water supplies or facilities are described in Section 5.4.2.1.3 of Chapter 5, Surface Water Resources and Water Supplies. It is assumed that water transfers occurring under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 would meet the requirements listed in CVPIA and any other requirements. Specific water transfers for the Year 2030 have not been identified at this time except for continued water transfers under the Lower Yuba River Accord. Therefore, quantitative analyses presented in the EIS only included water transfers under the Lower Yuba River Accord, as described in Appendix 3A, No Action Alternative: Central Valley Project and State Water Project Operations. Qualitative analyses for conditions that could occur for other water transfers by 2030 are presented in the EIS.

AA 30: Please see responses to Comments AA19 and AA24 for the discussion on the adequacy of using CVHM for the groundwater impacts analysis.

The first bullet in this comment states that Alternatives 1 through 5 as compared to the No Action Alternative would result in similar or less groundwater pumping. This is based on modeling results. If implementation of these alternatives results in similar or less pumping than under No Action Alternative, there is no potential for additional drawdown-induced subsidence to occur, and further analysis is not required.

Conclusions regarding subsidence impacts are reached by comparing groundwater level changes between the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. If groundwater levels decline, subsidence impacts are more likely to occur, due to the potential for compaction of subsurface materials with the loss of groundwater in storage. However, if groundwater levels are similar or slightly decline, the potential for land subsidence to occur is minimal.

AA 31: Major subsidence in the Sacramento Valley, such as up to 4 feet in the Yolo basin area, is discussed in Section 7.3.3 of Chapter 7, Groundwater Resources and Groundwater Quality, of the EIS. The text acknowledges overdraft conditions that could result in subsidence do occur in other portions of the Sacramento Valley, including the West Butte Subbasin in Butte, Glenn, and Sutter Counties.

AA 32: The groundwater water quality analysis described in the EIS consists of comparing the groundwater levels and flow directions under the alternatives as compared to the No Action Alternative and Second Basis of Comparison. Any change in groundwater levels or flow directions due to implementation of the alternatives are further analyzed to determine whether the changes result in conditions that would lead to degradation of groundwater quality (e.g. inducement of migration of poorer quality groundwater into areas of higher quality).

No mitigation measures were included in the EIS for groundwater conditions because groundwater pumping would be similar or decrease and groundwater elevations would be similar or rise under Alternatives 1 through 5 as compared to the No Action Alternative. The Second Basis of Comparison was included in the EIS for informational purposes only, as described in Chapter 3, Description of Alternatives. The Second Basis of Comparison does not comply with the definition of the No Action Alternative under the NEPA guidelines. Therefore, mitigation measures have not been considered for changes under Alternatives 1 through 5 and the No Action Alternative as compared to the Second Basis of Comparison.

The analysis in the EIS assumes compliance with ongoing surface water and groundwater quality programs by 2030 under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5, including the Grassland Bypass Project in the San Joaquin Valley.

As described in the response to Comment AA 29, the EIS analysis assumes compliance with all requirements for water transfers, including transfers with provisions for groundwater substitution, that involve either CVP and SWP water contract water supplies or facilities are described in Section 5.4.2.1.3 of

Chapter 5, Surface Water Resources and Water Supplies, to protect other groundwater uses and groundwater quality under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

AA 33: The EIS analysis is conducted to evaluate the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 comparative conditions in Year 2030. Historic data, including streamflow depletion values, were used to develop the input values and assumptions used in the CVHM model, as described in Appendix 7A, Groundwater Model Documentation. The existing conditions maps are included in the reference cited in the EIS, the 2009 U.S. Geological Survey report entitled *Groundwater Availability of the Central Valley Aquifer, California,* which used the CVHM model for the evaluation of the Central Valley aquifer conditions. It is recognized that the U.S. Geological Survey is currently updating this report.

AA 34: The analysis includes an estimated 10 percent cost increase in groundwater pumping to include other additional economic costs (lower groundwater tables, subsidence, streamflow depletion, depreciation, well replacement, and increased treatment costs). This estimate was based on a review of water management studies with projected costs for a range of water resource supplies during the development of Chapter 19, Socioeconomics, and Appendix 19A, California Water Economics Spreadsheet Tool (CWEST) Documentation. Relevant information was reviewed and considered to reach the 10 percent conclusion. General information is available in the literature, but the information necessary to accurately assign a unique and representative cost to each individual contractor does not exist. The additional costs of lower groundwater tables, subsidence, streamflow depletion, depreciation, well replacement, and increased treatment costs are influenced by regional factors and should not be entirely attributed to the amount of water pumped. Variations among regions in precipitation, recharge patterns, and groundwater hydraulics, and technology may have more influence on these additional costs than the amount of groundwater pumped. For example, in some regions, close connectivity between groundwater and surface water might allow a large rainfall event to eliminate lower groundwater levels. In other regions, lower groundwater tables might be sustained indefinitely. Some regions experience subsidence and streamflow depletion, others do not. Depreciation of wells and pumps is related to age of the equipment and changing technology as well as the amount of water pumped. In most regions, changes in groundwater costs, other than the direct pumping costs, are a very small fraction of all changes in water operating expenses caused by an alternative.

AA 35: As described in the response to Comment AA 32, no mitigation measures were included in the EIS for groundwater conditions because groundwater pumping would be similar or decrease and groundwater elevations would be similar or increased under Alternatives 1 through 5 as compared to the No Action Alternative. The Second Basis of Comparison was included in the EIS for informational purposes only, as described in Chapter 3, Description of Alternatives. The Second Basis of Comparison does not comply with the definition of the No Action Alternative under the NEPA guidelines. Therefore, mitigation measures have not been considered for changes under Alternatives 1 through 5 and the No Action Alternative as compared to the Second Basis of Comparison.

AA 36: The cumulative effects do include water transfers. The discussion of cumulative effects associated with water transfers in Chapter 7, Groundwater Resources and Groundwater Quality, has been modified in the Final EIS.

AA 37: Continuation of the Lower Yuba River Accord water transfers is assumed in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. Surface water diversions and flows from this program are included in the CalSim II model and are input into the CVHM model as a diversion node. When surface water transfers occur, the CVHM model automatically adjusts the groundwater pumping to make up for reduced surface water availability used locally in the Feather River and Yuba River watersheds. Therefore, the effects of this transfer program are included in the modeling analysis for each alternative and are independent of the impacts from the alternatives.

AA 38: The Bay Delta Conservation Plan (BDCP) would primarily convey water from North Delta and South Delta intakes in wet water year conditions. During drier years, the intakes could convey less water than under the No Action Alternative and there would be many months when the North Delta intakes would not be allowed to operate, as described in the Draft EIR/EIS for the Bay Delta Conservation Plan (BDCP). The BDCP would be operated in a manner to protect water users and environmental habitat located upstream of and in the Delta in accordance with permits issued by the SWRCB, USFWS, NMFS, and California Department of Fish and Wildlife. As described in the Draft EIR/EIS for the BDCP, the full capacity of the North Delta intakes would only be used during periods with high river flows, such as following a major rainfall event or rapid snow melt event.

AA 39: Section 7.3 of Chapter 7, Groundwater Resources and Groundwater Quality, has been modified to include a discussion of the project referred to in this comment.

AA 40: The projects listed in this comment are either considered to be relatively short-term and may not be implemented in 2030 or speculative.

The cumulative effects analysis in the Final EIS has been modified to include the 2015 *Westlands v. United States* Settlement.

The transfer projects described in this comment are scheduled to be completed before 2030. However, as described in the response to Comment AA 29, it is anticipated that similar programs would continue in the Year 2030 in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. Therefore, these projects are not also included in the cumulative impact analysis.

Future installation of groundwater wells also is considered to continue in the Year 2030 in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. However, it would be speculative to project the details of specific projects. The expansion of wellfields was anticipated in the EIS as groundwater is used to replace reductions in CVP and SWP water deliveries under some alternatives as compared to the No Action Alternative and Second Basis of Comparison. The impacts of the additional withdrawals are included in the impact analysis in Chapter 7, Groundwater Resources and Groundwater Quality. The programs listed in this comment could be part of those actions as CVP water deliveries have been reduced as compared to historical conditions.

AA 41: The District Court required Reclamation to prepare a NEPA document upon the provisional acceptance of the RPA actions in the 2008 USFWS BO and 2009 NMFS BO. Reclamation has consulted DWR on this matter and DWR has stated that there was no state action requiring CEQA.

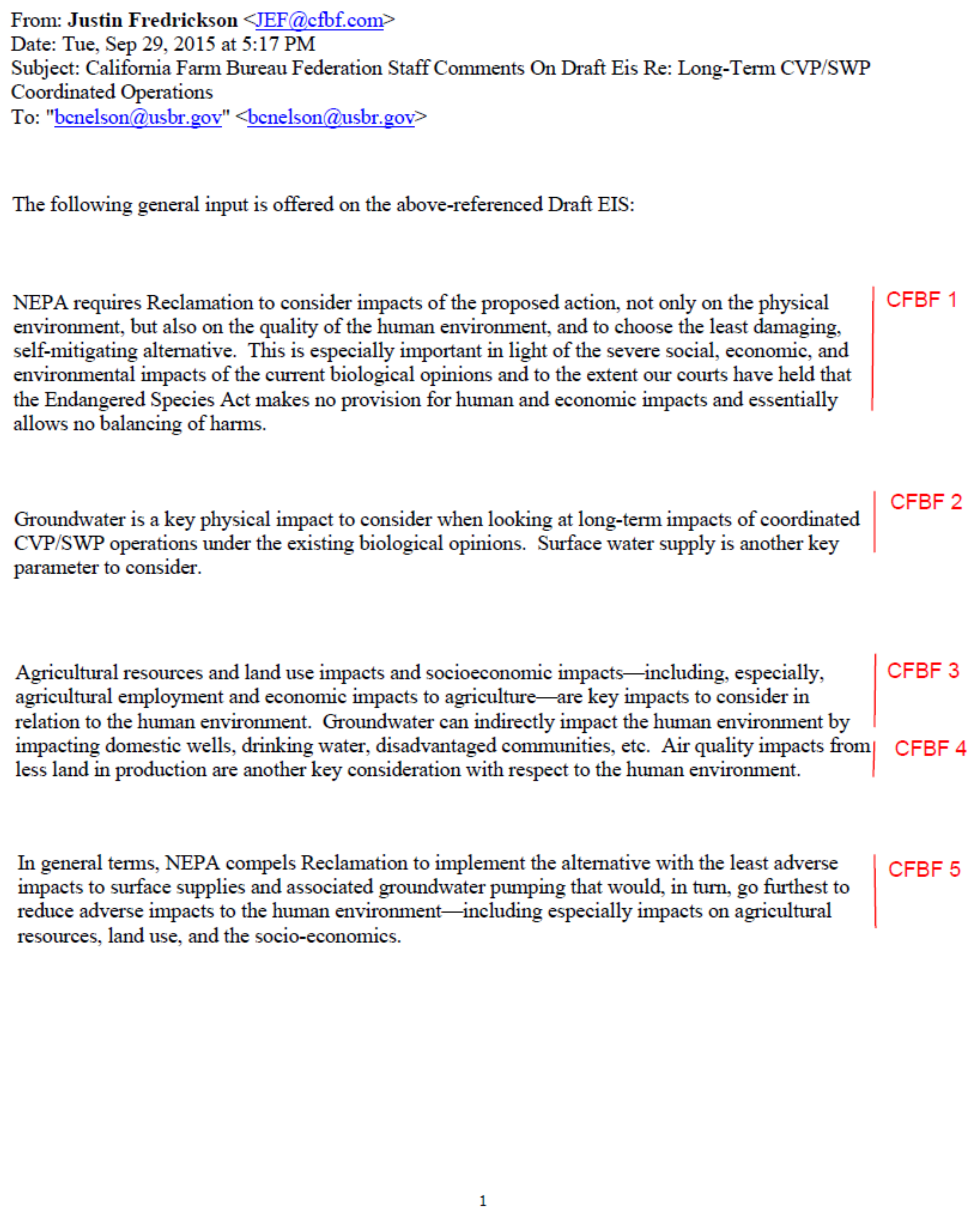
AA 42: The mitigation measures adopted by Reclamation will be included in the Record of Decision.

AA 43: The Preferred Alternative was defined following review of comments on the Draft EIS. The Preferred Alternative is described in Section 1.5 of Chapter 1, Introduction, of the Final EIS.

AA 44: As described in Section 3.3, Reclamation included the Second Basis of Comparison to identify changes that would occur due to actions that would not have been implemented without Reclamation's provisional acceptance of the BOs, as required by the District Court order. Alternative 1 is included in the range of alternatives considered in this EIS because the Second Basis of Comparison is not an alternative under NEPA.

AA 45: Comment noted. The EIS analysis adequately addresses the effects of the coordinated long-term operation of the CVP and SWP.

1D.1.2 California Farm Bureau Federation



From: **Justin Fredrickson** <JEF@cfbf.com>
Date: Tue, Sep 29, 2015 at 5:17 PM
Subject: California Farm Bureau Federation Staff Comments On Draft Eis Re: Long-Term CVP/SWP Coordinated Operations
To: "bcnelson@usbr.gov" <bcnelson@usbr.gov>

The following general input is offered on the above-referenced Draft EIS:

NEPA requires Reclamation to consider impacts of the proposed action, not only on the physical environment, but also on the quality of the human environment, and to choose the least damaging, self-mitigating alternative. This is especially important in light of the severe social, economic, and environmental impacts of the current biological opinions and to the extent our courts have held that the Endangered Species Act makes no provision for human and economic impacts and essentially allows no balancing of harms.

CFBF 1

Groundwater is a key physical impact to consider when looking at long-term impacts of coordinated CVP/SWP operations under the existing biological opinions. Surface water supply is another key parameter to consider.

CFBF 2

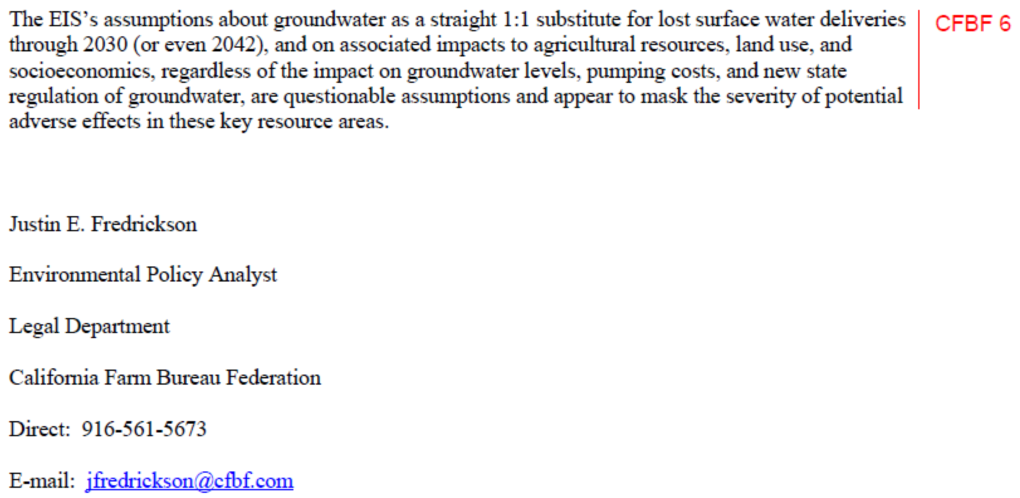
Agricultural resources and land use impacts and socioeconomic impacts—including, especially, agricultural employment and economic impacts to agriculture—are key impacts to consider in relation to the human environment. Groundwater can indirectly impact the human environment by impacting domestic wells, drinking water, disadvantaged communities, etc. Air quality impacts from less land in production are another key consideration with respect to the human environment.

CFBF 3

CFBF 4

In general terms, NEPA compels Reclamation to implement the alternative with the least adverse impacts to surface supplies and associated groundwater pumping that would, in turn, go furthest to reduce adverse impacts to the human environment—including especially impacts on agricultural resources, land use, and the socio-economics.

CFBF 5



The EIS's assumptions about groundwater as a straight 1:1 substitute for lost surface water deliveries through 2030 (or even 2042), and on associated impacts to agricultural resources, land use, and socioeconomics, regardless of the impact on groundwater levels, pumping costs, and new state regulation of groundwater, are questionable assumptions and appear to mask the severity of potential adverse effects in these key resource areas.

CFBF 6

Justin E. Fredrickson

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1D.1.2.1 Responses to Comments from California Farm Bureau Federation

CFBF 1: The Council of Environmental Quality regulations provide for the lead agency (Reclamation for this EIS) to identify the preferred alternative that will fulfill the statutory mission and responsibilities, with consideration to physical, environmental, human resource, and economic factors. The preferred alternative does not need to be the least damaging, self-mitigating alternative. The Preferred Alternative is described in Section 1.5 of Chapter 1, Introduction, of the Final EIS.

CFBF 2: The changes in groundwater and surface water conditions under the alternatives in this EIS as compared to the No Action Alternative and the Second Basis of Comparison can be used to differentiate between the alternatives, including the No Action Alternative, as described in Chapter 5, Surface Water Resources and Water Supplies, and Chapter 7, Groundwater Resources and Groundwater Quality, of this EIS.

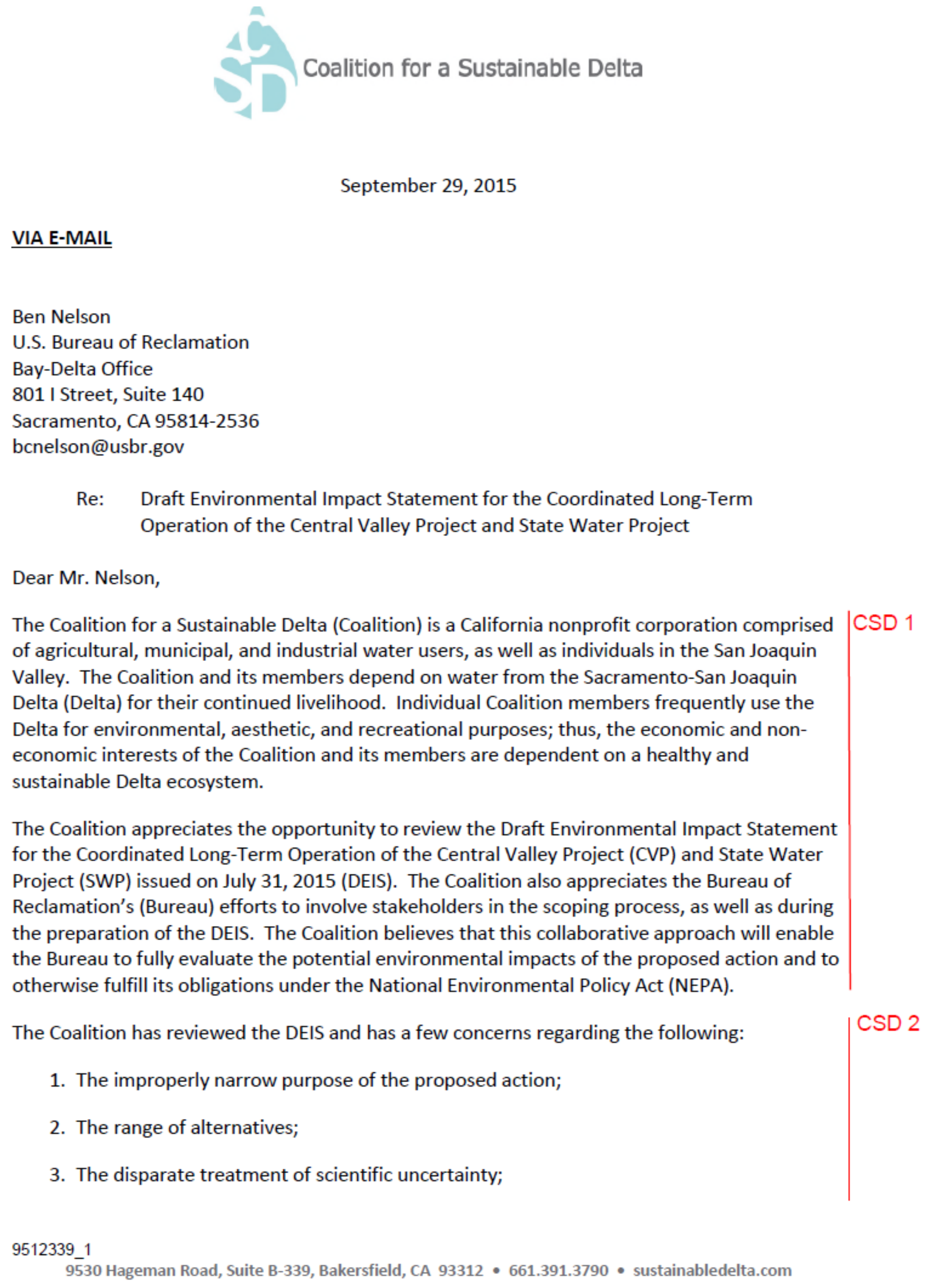
CFBF 3: The EIS analysis includes an evaluation of changes in CVP and SWP water deliveries based on the CalSim II models and the related changes in groundwater elevations, agricultural land uses, and agricultural economics in the CVP and SWP water service areas, as described in Chapter 5; Chapter 7; and Chapter 12, Agricultural Resources, in the EIS. As described in Chapter 12, changes in CVP and SWP surface water deliveries and groundwater use would result in no substantial changes in agricultural land use and employment.

CFBF 4: The EIS analysis indicates that agricultural land use would not substantially change under the Alternatives 1 through 5 as compared to the No Action Alternative, and under the No Action Alternative and Alternatives 1 through 5 as compared to the Second Basis of Comparison. Therefore, there are no changes in dust generation from agricultural lands, as described in Chapter 16, Air Quality and Greenhouse Gas Emissions.

CFBF 5: As described in the response to Comment CFBF 1, the Council of Environmental Quality regulations provide for the lead agency (Reclamation for this EIS) to identify the preferred alternative that will fulfill the statutory mission and responsibilities, with consideration to physical, environmental, human resource, and economic factors. The preferred alternative does not need to be the alternative with the least adverse impacts to surface water supplies, groundwater, agricultural production, land use, and socioeconomics.

CFBF 6: The SWAP model, a regional agricultural production and economic optimization model that simulates the decisions of farmers across 93 percent of agricultural land in California, was used to determine changes in agricultural land use and employment based upon changes in CVP and SWP water deliveries and cost-effective water supplies, as described in Appendix 12A, Statewide Agricultural Production Model (SWAP) Documentation, of the EIS. The SWAP model simulates changes in Year 2030 based upon economic optimization factors related to crop selection, water supplies, and other factors to maximize profits with consideration of resource constraints, technical production relationships, and market conditions. The model indicated that even with the cost of groundwater pumping from greater depths, the overall agricultural production could be maintained. The analysis assumes changes occur under the No Action Alternative and Second Basis of Comparison between the recent conditions and Year 2030 with or without implementation of the 2008 USFWS BO and the 2009 NMFS BO; and the EIS evaluates changes in 2030 under the alternatives discussed Chapter 5 through 21 of the EIS.

1D.1.3 Coalition for a Sustainable Delta



Coalition for a Sustainable Delta

September 29, 2015

VIA E-MAIL

Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536
bcnelson@usbr.gov

Re: Draft Environmental Impact Statement for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Dear Mr. Nelson,

CSD 1

The Coalition for a Sustainable Delta (Coalition) is a California nonprofit corporation comprised of agricultural, municipal, and industrial water users, as well as individuals in the San Joaquin Valley. The Coalition and its members depend on water from the Sacramento-San Joaquin Delta (Delta) for their continued livelihood. Individual Coalition members frequently use the Delta for environmental, aesthetic, and recreational purposes; thus, the economic and non-economic interests of the Coalition and its members are dependent on a healthy and sustainable Delta ecosystem.

The Coalition appreciates the opportunity to review the Draft Environmental Impact Statement for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) issued on July 31, 2015 (DEIS). The Coalition also appreciates the Bureau of Reclamation's (Bureau) efforts to involve stakeholders in the scoping process, as well as during the preparation of the DEIS. The Coalition believes that this collaborative approach will enable the Bureau to fully evaluate the potential environmental impacts of the proposed action and to otherwise fulfill its obligations under the National Environmental Policy Act (NEPA).

CSD 2

The Coalition has reviewed the DEIS and has a few concerns regarding the following:

1. The improperly narrow purpose of the proposed action;
2. The range of alternatives;
3. The disparate treatment of scientific uncertainty;

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CSD 2 continued

4. The assumptions regarding groundwater;
5. The lack of factual support for the Bureau's conclusions as respects ocean harvest; and
6. The failure to fully incorporate relevant, high quality scientific information.

The Coalition encourages the Bureau to consider these concerns, which are discussed in further detail below, as it moves forward in preparing the final environmental impact statement (EIS).

I. Purpose of the Proposed Action.

CSD 3

As noted by the Coalition in its prior letter to the Bureau dated July 13, 2015, the purpose of the proposed action is defined too narrowly, so as to preclude evaluation of potentially significant changes to CVP and SWP operations. In pertinent part, the DEIS states that the purpose of the proposed action is to continue the operation of the CVP and SWP in a manner that "[i]s similar to historic [sic] operational parameters with certain modifications." DEIS at 2-1. This statement improperly restricts the scope of the Bureau's environmental review, and precludes consideration of alternatives that would alter operations from those implemented in the past. This statement also does not reflect the "underlying" purpose of the proposed action, which is more general in nature. *See* 40 C.F.R. § 1502.13; *see also City of Carmel-By-The-Sea v. U.S. Dept. of Transp.*, 123 F.3d 1142, 1155 (9th Cir. 1997) (it is an abuse of discretion to define project objectives in unreasonably narrow terms because "[t]he stated goal of a project necessarily dictates the range of 'reasonable' alternatives.") (citation omitted). Thus, the Coalition urges the Bureau to revise the purpose of the proposed action to omit any reference to "historical operational parameters."

II. Description of Alternatives.

CSD 4

The Coalition recognizes and appreciates that the Bureau has developed Alternatives 3 and 4 based on scoping comments submitted by the Coalition. However, the Coalition has concerns regarding two of the Bureau's conclusions relating to the Coalition's proposed suite of actions.

A. San Joaquin River Inflow.

Action IV.2.1 of the Reasonable and Prudent Alternative (RPA) included in the National Marine Fisheries Service's (NMFS) 2009 Biological Opinion (BiOp) imposes an inflow to export (I:E) ratio requirement on San Joaquin River flows during certain periods of the year. As reflected in Table 3.1 of the DEIS, the Coalition suggested that these flow criteria be modified as follows:

> Flows in San Joaquin River at Vernalis (7-day running average shall not be less than 7 percent of the target requirement) shall be based on the New Melones

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CSD 4 continued

Index (as described in [NMFS BiOp] RPA Action IV.2.1) as follows for January 1 through June 15:

a) If the Index is 999 TAF or less - no minimum flow requirement[;]

b) If the Index is 1000-1399 TAF - minimum flow is the greater of the SWRCB D-1641 requirement or 1500 cfs[;]

c) If the Index is 1400-1999 TAF - minimum flow is the greater of the SWRCB D-1641 requirement or 3000 cfs[;]

d) If the Index is 2000-2499 TAF - minimum flow is 4500 cfs[;]

e) If the Index is above 2499 TAF - minimum flow is 6000 cfs.

DEIS at 3-25, 3-26. The DEIS states, however, that "this criteria is not implementable following the completion of the Vernalis Adaptive Management Program [VAMP]." *Id.* at 3-25. The Bureau's explanation with respect to this issue is confusing. Is the Bureau asserting that it will not have sufficient water to satisfy the Coalition's proposed flow criteria without implementation of VAMP? If so, this would appear to mean that, while the Bureau believes there is enough water to satisfy the current I:E ratio requirements, the Bureau believes there is not enough water (without VAMP) to satisfy the proposed inflow requirements, with no limitations on exports. This would suggest that the export limitation component of the I:E ratio is the driving factor allowing the Bureau to satisfy that requirement. Thus, according to the Bureau, inflow requirements alone, as proposed by the Coalition, cannot be satisfied without VAMP.

The Bureau's reasoning with respect to this issue in unclear. Please provide additional details regarding why the Bureau believes that the proposed modifications are not implementable. In the alternative, please analyze the Coalition's proposed alternative without adjusting the inflow requirement.

B. Wastewater Treatment Plants.

CSD 5

As set forth in Table 3.1, the Coalition suggested that water quality improvement programs at two water treatment plants—the Sacramento Regional Wastewater Treatment Plant and the Fairfield-Suisun Sewer District treatment plant—be expedited to allow for earlier realization of the expected benefits. DEIS at 3-28, 3-29. According to the Bureau, however, "both of these actions would be complete by 2030, the study period considered in [the DEIS]." DEIS at 3-43. That is, "[b]ecause the Environmental Consequences analysis in this EIS is conducted as a 'snapshot' in time at 2030, inclusion of a provision to require compliance with the discharge requirements prior to 2020 [c]ould not be evaluated." *Id.* The Bureau's reasoning with respect

CSD 5 continued

to this issue is problematic. The fact that the proposed actions would be completed prior to 2020 should not preclude the Bureau's consideration of them.[1] The proposal could ultimately improve conditions in the Delta prior to 2030. That is, the proposal could result in different—likely better—baseline conditions in 2030. Thus, the Bureau could consider the benefits that would result from the proposal, and be present in the Delta, in 2030. This would be consistent with the Bureau's "snapshot" approach.

The flaws in the Bureau's reasoning are also apparent in other sections of the DEIS. For example, in Chapter 6, with respect to Alternative 4, the DEIS states: "Water quality under Alternative 4 would be identical to conditions under the Second Basis of Comparison." DEIS at 6-105. But, this is only the case because the Bureau has rejected the Coalition's water treatment plant proposal. Nothing in the Bureau's "snapshot" approach precludes the Bureau from taking into account the benefits of the Coalition's proposal. The Bureau could simply analyze the extent to which water quality conditions would improve under Alternative 4 (qualitatively, if necessary), and then continue its analysis from there.

This issue arises in other contexts as well, including with respect to invasive species. The DEIS states that a Total Maximum Daily Load (TMDL) addressing impairment due to invasive species is expected to be complete by 2019. DEIS at 6-73. Yet the water quality benefits of the TMDL, which should be included within the No Action Alternative and the Second Basis of Comparison, are not part of the baseline. *See* Daniel R. Mandelker, NEPA Law and Litig. § 10:33.20 (2014) (EIS must contain "an adequate compilation of relevant data and information, including baseline data) (citing, among others*, Northern Plains Resource Council, Inc. v. Surface Transp. Bd.*, 668 F.3d 1067 (9th Cir. 2011) (baseline data inadequate)).

Moreover, in general, the Bureau's "snapshot" approach is concerning. DEIS at 3-43; *see also id.* at 4-1 (describing that the DEIS does "not address interim changes that would occur between now and 2030"); *id.* at 1-11 ("this EIS analyzes future conditions projected for 2030"); *id.* at 3-4 ("[c]hanges that will occur over the next 15 years without implementation of the alternatives are not analyzed in this EIS."). While agencies have discretion to establish the temporal scope of NEPA analyses, this discretion is not unlimited. *See Selkirk Conservation Alliance v. Forsgren*, 336 F.3d 944, 962 (9th Cir. 2003) (NEPA does not impose a requirement that federal agencies analyze impacts of actions for any particular length of time). An agency cannot select a temporal scope that allows them to "shirk their responsibilities under NEPA." *Id.* Here, as a practical matter, the EIS ignores significant impacts that could occur in the Delta in the near-term, and only analyzes impacts in the long-term. It is not clear that this approach

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[1] To the extent that the Bureau is asserting that the proposal could not be evaluated because it could not be quantitatively modeled, the Bureau should have at least analyzed the proposal qualitatively. This is consistent with qualitative analyses already performed by the Bureau with respect to the alternatives. *See, e.g.,* DEIS at 7-122.

CSD 5 continued

satisfies the Bureau's obligations to take a "hard look" at the environmental consequences of the proposed action. *Id.* at 959.

Thus, the Coalition requests that the Bureau incorporate the Coalition's wastewater treatment plant proposal into Alternative 4. The Coalition further requests that the Bureau ensure that its "snapshot" approach is applied in a manner that is consistent with NEPA, including with respect to invasive species.

III. Disparate Treatment of Scientific Uncertainty

CSD 6

The Bureau appears to have concluded that the benefits associated with the non-operational components of Alternatives 3 and 4 (i.e., ocean harvest restrictions, predator control measures, and trap and haul requirements) are uncertain. *See,* e.g., DEIS at 9-402 ("Overall, given the small differences between Alternative 3 and the No Action Alternative conditions and the *uncertainty regarding the non-operational components*, distinguishing a clear difference is not possible) (emphasis added); *see also* 9-281, 9-287, 9-296, 9-300 (same). The Coalition has several concerns regarding these conclusions.

As an initial matter, and as more fully set forth below in Section V with respect to ocean harvest, the analyses in the DEIS do not support the Bureau's conclusions that benefits associated with non-operational components are uncertain. For example, with respect to trap and haul, the DEIS states:

> "To assess the potential benefits and risks of a transportation [trap and haul] program for salmonids in the San Joaquin River, an analysis of [coded-wire-tag] recovery rates for Chinook Salmon reared at the Feather River Hatchery and the Mokelumne River Hatchery was performed. Based on this analysis, *Alternative 3 is expected to directly benefit juvenile fall-run Chinook Salmon and steelhead smolts originating from the San Joaquin River basin by comparison to the No Action Alternative*. The program would also benefit spring-run Chinook Salmon if these fish become established as part of the San Joaquin River Restoration Program, or as part of the New Melones fish passage project."

DEIS at 316 (emphasis added). Yet, on multiple occasions, the Bureau characterizes these benefits as "uncertain." *Id.* at 9-281, 9-287, 9-296, 9-300, 9-402; *see also* Section V., *infra*. In doing so, the Bureau has failed to comply with bedrock principles of administrative law, which require agencies to provide a rational connection between the facts found and the choices made. *Motor Vehicles Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto Ins. Co.*, 463 U.S. 29, 43 (1983).

CSD 7

Even assuming that the benefits associated with the non-operational components of Alternatives 3 and 4 are in fact uncertain, the Bureau has failed to take into account or

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CSD 7 continued

otherwise address uncertainty in a consistent manner in the DEIS. In particular, many of the Bureau's conclusions with respect to measures quantitatively analyzed, including Old and Middle River (OMR) measures, are expressed without any acknowledgement of the associated uncertainty.

For example, in Appendix 9G, the DEIS explains that the delta smelt entrainment analysis is based on regression equations that take into account combined OMR flows and the location of X2.[2] The analysis is premised on the assertion that X2 is an indicator of suitable abiotic habitat for delta smelt. Yet, in other chapters, the DEIS acknowledges that this conclusion has been questioned. DEIS at 9-64, 9-66. Agencies are required to discuss areas of controversy and opposing points of view, 40 C.F.R. §§ 1502.9(b), 1502.12, in order to provide the public with a "full and fair discussion" of significant environmental impacts. *Id.* at § 1502.1. Here, a more even-handed approach would be to revise Appendix 9G to acknowledge the inherent uncertainty that arises when using a formula that relies on a hypothesis that is scientifically questionable.

In sum, the Bureau's conclusions ignore the inherent uncertainty found in all scientific modeling. The fact that certain measures are capable of quantitative analyses does not make the conclusions derived therefrom less uncertain, particularly where, as here, there are significant, unproved assumptions that are incorporated into the modeling. Yet, the Bureau emphasizes the uncertainty associated with non-operational proposals, but does not do the same with respect to operational measures. The Bureau's analyses in the DEIS should be revised to correct the disparate treatment of scientific uncertainty.

IV. Groundwater Assumptions.

CSD 8

The DEIS contains several inaccurate assumptions relating to groundwater. For example, Chapter 5, relating to Surface Water Resources and Water Supplies, states: "The No Action Alternative and the Second Basis of Comparison assume that groundwater would continue to be used even if groundwater overdraft conditions continue or become worse." DEIS at 5-68. The DEIS acknowledges that the Sustainable Groundwater Management Act (SGMA) was enacted in 2014, but concludes that: "[T]o achieve sustainable conditions in many areas, measures could require several years to design and construct water supply facilities to replace groundwater, such as seawater desalination. Therefore, it does not appear to be reasonable and foreseeable that sustainable groundwater management would be achieved by 2030; and it is assumed that groundwater pumping will continue to be used to meet water demands not fulfilled with surface water supplies or other alternative water supplies in 2030." DEIS at 5-69.

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[2] X2 refers to the point in the Delta where the isohaline is two parts per thousand.

CSD 8 continued

Notably, the DEIS expressly acknowledges the significant adverse effects that are caused by groundwater overdraft. *See, e.g.,* DEIS at 7-15, 7-18, 7-21, 7-31, 7-45 (describing concerns regarding subsidence, increased water supply well drilling, and significant drops in groundwater levels between 2010 and 2014 due to drought (up to 40 feet in Kern County)). Thus, contrary to the Bureau's conclusions, it is unreasonable to assume that affected agencies and stakeholders will continue to rely on groundwater, given all of the deleterious impacts associated with groundwater exploitation. *See id.* at 7-116.

Moreover, the groundwater assumptions in the DEIS with respect to agriculture are particularly concerning. Chapter 12, relating to Agricultural Resources, states: "The analysis does not restrict groundwater withdrawals based upon groundwater overdraft or groundwater quality conditions....Therefore, it was assumed that Central Valley agriculture water users would not reduce groundwater use by 2030, and that groundwater use would increase in response to reduced CVP and SWP water supplies." DEIS at 12-24. Based on these assumptions, the Bureau concludes that there will be no changes in conditions for agricultural resources under Alternatives 1 through 5 because, according to the Bureau, decreases in CVP and SWP water supplies will be made up with groundwater. DEIS at 12-57.

The Bureau's conclusions are simply not supported by the facts. Indeed, the analysis in Chapter 12 includes several examples of how agriculture has been significantly impacted by reduced CVP and SWP water supplies. These examples include:

- "In extreme dry periods, such as 2014 when there were no deliveries of CVP water to San Joaquin Valley water supply agencies with CVP water service contracts, permanent crops were removed because the plants would not survive the stress of no water or saline groundwater (Fresno Bee 2014)." DEIS at 12-10.
- Due to the increased frequency of water supply reductions, especially in drier years ..., the amount of fallowed and non-harvested lands has increased as a percentage of total lands within Westlands Water District. *Id.* at 12-12.
- Since 2000, farmers have increased the amount of fallowed and non-harvested acres to 10 to 34 percent of the total land in the [Westlands water] district. *Id.* at 12-15.

If the Bureau's assumptions were correct – that loss of CVP and SWP water supplies would be made up with groundwater – these conditions would not have occurred. The fact that agricultural production has decreased significantly over the past several years undermines the Bureau's conclusions.

CSD 9

Furthermore, the Bureau's assumptions with respect to groundwater use and agriculture are not necessary. Using the same Statewide Agricultural Production Model utilized in the DEIS, DEIS at 12-23, the Bureau could have modeled alternative ranges of groundwater pumping.

CSD 9 continued

This approach was employed in 2009, under similar drought conditions. *See* Richard E. Howitt, Duncan MacEwan, and Josue Medellin-Azuara, *Economic Impacts of Reductions in Delta Exports on Central Valley Agriculture*, AGRICULTURAL AND RESOURCE ECONOMICS, Vol 12, No. 3 (Jan/Feb 2009). In assessing the economic impacts of reductions in CVP and SWP exports on Central Valley agriculture, Howitt et al. expressly acknowledged: "[T]he ability of farmers to pump additional groundwater depends on both its availability and the cost of pumping. Due to uncertainty in the ability of farmers to increase pumping in the short run, results are calculated for a range of groundwater pumping increases of 25, 50, 75, and 100%." The results of their analyses therefore reflect this range of groundwater pumping. *Id.* at 2 ("Revenue losses for Central Valley farmers range from $1.2 to $1.6 billion for 2009, depending on farmer groundwater pumping response."); *id.* ("Depending on the ability of farmers to increase groundwater pumping, gross revenue losses could range as high as $1.6 billion.").

Not only do Howitt et al. provide an alternative approach by which the Bureau could analyze agricultural impacts,[3] but they demonstrate that the Bureau's current assumptions with respect to groundwater are flawed. And it is improper for the Bureau to rely on incorrect assumptions. *See Natural Res. Def. Council v. U.S. Forest Serv*., 421 F.3d 797, 812 (9th Cir. 2005) (rejecting U.S. Forest Service's conclusions in an EIS because they were based on incorrect data and assumptions). Moreover, courts do not hesitate to reject methodologies that are clearly flawed. *See, e.g., Conservation Nw. v. Rey*, 674 F. Supp. 2d 1232, 1249 (W.D. Wash. 2009) (holding the "Agencies' methodology [as respects forest plans] is flawed enough to be a violation of NEPA"). In short, Howitt et al.'s results directly contradict the Bureau's conclusions that agricultural resources will not be impacted under Alternatives 1 through 5. Howitt et al. at 3-4 ("SWAP model results show that substantial reductions in available water from CVP and SWP deliveries … will severely reduce Central Valley income, employment, revenues, and cropped acres.").

CSD 10

Nor do the Bureau's conclusions make sense as a practical matter. It is well established that CVP and SWP exports will be significantly reduced under the No Action Alternative, as compared to the Second Basis of Comparison, due to implementation of the RPAs included in 2008 U.S. Fish and Wildlife BiOp and the 2009 NMFS BiOp. *See* DEIS at ES-20 ("Long-term average annual exports would be 1,051 [thousand acre feet] (22 percent) more under Alternative 1 [Second Basis of Comparison] as compared to the No Action Alternative"); *see also*

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[3] Other publications also suggest that alternative groundwater modeling approaches are available to assess the impacts of CVP and SWP export reductions on agriculture. *See* Nicholas Brozovic, David Zilberman, and David Sunding, *On The Spatial Nature of the Groundwater Pumping Externality,* RESOURCE AND ENERGY ECONOMICS 32(2010): 154-164*;* Steven Buck, Maximillian Auffhammer, and David Sunding, *Land Markets and the Value of Water Supply: Hedonic Analysis using Panel Data,* AMERICAN JOURNAL OF AGRICULTURAL ECONOMICS 96(2014): 953-969.

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CSD 10 continued

State Water Project Final Delivery Reliability Report (2011) at 38-39 (showing a decrease in SWP exports from 2005 to 2011 of 10.4% due to implementation of the RPAs); State Water Project Final Delivery Reliability Report (2013) at 30-32 (showing a decrease in SWP exports from 2005 to 2013 of 9.4% due to implementation of the RPAs). It is simply not reasonable to assume that farmers will be able to pump over a thousand acre feet of groundwater to recoup this loss. As explained by Howitt et al., there is significant doubt associated with groundwater availability and cost, and the Bureau has altogether ignored this uncertainty. [4]

In sum, the Bureau's assumptions with respect to groundwater are fundamentally flawed. Not only are local agencies subject to the requirements of the SGMA, which requires Groundwater Sustainability Plans by 2020, but it is simply unreasonable to assume that agencies will exploit groundwater resources in the manner suggested. The Bureau's analysis should be revised to better reflect the range of groundwater pumping that could occur under Alternatives 1 through 5, and the impacts that this range would have on agricultural resources.

V. Ocean Harvest Conclusions are Unsupported by the Facts.

CSD 11

In the context of a NEPA challenge, an agency's decision is arbitrary and capricious if the agency (1) relied on factors Congress did not intend it to consider, (2) entirely failed to consider an important aspect of the problem, or (3) *offered an explanation that runs counter to the evidence before the agency*. *Ctr. for Biological Diversity v. Salazar*, 695 F.3d 893, 902 (9th Cir. 2012) (emphasis added); *Friends of Endangered Species, Inc. v. Jantzen*, 760 F.2d 976, 986 (9th Cir. 1985) (agency must engage in "a reasoned analysis of the evidence before it").

Alternatives 3 and 4 include an action to modify ocean harvest for the purpose of minimizing mortality of natural original Central Valley Chinook Salmon. DEIS at 3-37, 3-40. The DEIS explains that, although approximately 75-90 percent of harvested salmon are hatchery fish, the

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[4] Notably, the recently released Partially Recirculated Draft Environmental Impact Report/Supplemental Draft EIS for the Bay Delta Conservation Plan/California WaterFix (RDEIR/SDEIS) includes statements inconsistent with those found in the DEIS. For example, with respect to agricultural resources, the RDEIR/SDEIS states: "The responses of water agencies to extended droughts provide good insights into the effects of *further reductions in exports of Delta water supplies*. The 1987–1992 drought had severe impacts on water agencies. Many purchased water from alternative sources to offset reduced Delta supplies, often at very high costs that some clients were unable to afford. Farmers responded to the resultant higher costs by increasing their own groundwater pumping and reducing their purchases from water agencies, *but also fallowed large acreages of both annual and permanent crop land*." RDEIR/SDEIS at 4.2-9 (emphasis added). Thus, while increased groundwater pumping may occur as a result of reduced Delta exports, it is unreasonable to assume that agricultural resources will not be impacted.

CSD 11 contined

fishery is often required to protect ESA-listed stocks, which include runs of Central Valley Chinook salmon. *Id.* at 9-277. The Bureau notes that "the impact of ocean harvest varies considerably by stock, but all stocks are impacted by harvest …." *Id.* The Bureau further explains: "We have the tools, the knowledge and the ability to manage Chinook ocean harvest in whatever way is needed. As such, Alternative 3 is, from a technical and scientific level, entirely feasible." *Id.*

Noting the intense harvest pressure on the various Chinook runs, the Bureau goes on to detail the benefits that would occur from reduced ocean harvest. DEIS at 9-278 ("reduced ocean harvest [for spring-run] would contribute substantially to age at-maturity diversity (certainly demographically, if not genetically) and thereby enhance population viability"); *id.* at 9-279 ("in the absence of this harvest, winter-run Chinook Salmon would have a larger fraction of their population maturing at age-4 or possibly older [which would] enhance demographic population viability, but also benefit the population by more effectively spawning in coarse substrates, and producing more, larger, and more thermally tolerant eggs); *id.* at 279-280 (noting "harvest of natural origin fall-run Chinook Salmon appears to occur at a much higher rate than population productivity can sustain" and concluding "[c]hanges in harvest strategies which could more effectively target hatchery origin fall Chinook while better protecting natural origin fish would yield substantial benefits"). The Bureau concludes: "Managing ocean salmon harvest as described in Alternative 3 would contribute to the abundance, productivity and diversity viability criteria for natural origin spring-run, winter-run, and fall-run Chinook Salmon." *Id.* at 9-280.

Inexplicably, however, the benefits of the ocean harvest action are simply not reflected in the Bureau's conclusions. After stating that ocean harvest restrictions "could" benefit winter-run, spring-run, and fall-run, the Bureau concludes that, due to "uncertainty regarding the non-operational components [including ocean harvest restrictions], distinguishing a clear difference between alternatives is not possible." *Id.* at 9-280, 9-287, 9-296. This conclusion is unsupported by the Bureau's earlier analysis, in which it noted that the proposed harvest restrictions were technically feasible and would benefit the populations. The Bureau's conclusions should be revised to better reflect its analyses, which indicate that the ocean harvest restrictions will benefit listed Chinook salmon. To do otherwise would be contrary to the administrative mandate that agencies provide a rational connection between the facts found and the choices made. *See Motor Vehicles Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto Ins. Co.*, 463 U.S. at 43.

CSD 12

It should also be noted that, with respect to Alternative 4, which includes the same ocean harvest action as Alternative 3, there is no alternatives analysis whatsoever. In one conclusory sentence, the DEIS states: "Conditions related to salmonid survival could be improved under Alternative 4 as compared to the No Action Alternative due to implementation of: trap and haul program, changes in bag limits, and changes in PMFC/NMFS harvest limits." *Id.* at 342. This is

CSD 12 continued

certainly not a reasoned scientific analysis sufficient to satisfy NEPA. *See Friends of Endangered Species, Inc. v. Jantzen,* 760 F.2d at 986.

VI. Full Incorporation of New Scientific Information.

CSD 13

In the Coalition's previous letter dated July 13, 2015, the Coalition included an exhibit setting forth a list of publications that the Bureau should consider in its analyses. The Coalition appreciates that the Bureau has revised certain sections of the DEIS to reflect this list of publications. *E.g.,* DEIS at 9-64, 9-73, 9-141.

However, the Coalition is concerned that only certain sections have been updated, while other relevant sections are still based on incomplete information. For example, Section 9.4.1.3.5, the analysis on page 9-194, and Appendix 9G, which all relate to delta smelt, should be updated to reflect new, relevant scientific information.

NEPA requires information contained within an EIS to be of "high quality." 40 C.F.R. § 1500.1(b). "Accurate scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA." *Id.* Agencies must "insure the professional integrity, including scientific integrity, of the discussions and analyses in [an EIS]." 40 C.F.R. § 1502.24.

Thus, the Coalition requests that the Bureau revise the EIS to ensure that all relevant analyses are updated to reflect the new, relevant scientific information previously identified by the Coalition.

V. Conclusion.

CSD 14

In sum, the Coalition urges the Bureau to address the foregoing items prior to issuance of the final EIS. We would be happy to discuss these issues further at your convenience.

Sincerely,

William D. Phillimore
Board Member

cc: Patricia Aaron, U.S. Bureau of Reclamation

1D.1.3.1 Attachments to Comments from Coalition for a Sustainable Delta

Attachments to the Coalition for a Sustainable Delta letter are included in Attachment 1D.1 located at the end of Appendix 1D.

1D.1.3.2 Responses to Comments from Coalition for a Sustainable Delta

CSD 1: Comment noted.

CSD 2: Please see responses to Comments CSD 3 through CSD 20.

CSD 3: Reclamation was directed by the District Court to remedy its failure to conduct a NEPA analysis when it accepted and implemented the 2008 USFWS BO RPA and the 2009 NMFS BO RPA pursuant to the Federal Endangered Species Act of 1973 (ESA) as amended (United States Code [U.S.C.] 1531 et. seq.). In order to satisfy the Court's directive, Reclamation has analyzed operation of the CVP, in coordination with the operation of the SWP, consistent with the BOs, as well as alternatives which represent potential modifications to the continued long-term operation of the CVP in coordination with the SWP. The purpose of the action, as described in Chapter 2, Purpose and Need, considers the purposes for which the CVP was authorized, as amended by CVPIA, as well as the regulatory limitations on CVP operations, including applicable state and federal laws and water rights. This purpose statement does not limit the analysis of the range of alternatives which includes alternatives with CVP and SWP operational assumptions substantially different than historic operational parameters. Because existing facilities were designed and constructed to operate under a variety of hydrologic conditions, Reclamation's operation of the CVP facilities is within the original designed range of operations.

CSD 4: The limited water supply available to Reclamation on the Stanislaus River through water rights associated with the New Melones Reservoir, are fully committed to multiple beneficial uses, including those on the Stanislaus River. The Vernalis Adaptive Management Program allowed for additional sources of water, other than available water within New Melones Reservoir to be used to maintain flow in the San Joaquin River. After the completion of this program, Reclamation does not have sufficient supply available in New Melones Reservoir to meet inflow targets suggested by CSD. Therefore, the I:E ratio can only be met through export limitations, and not through releases from New Melones Reservoir.

CSD 5: The wastewater treatment plant improvements for the Sacramento Regional Wastewater Treatment Plant are under construction. The final facilities, the tertiary treatment plant facilities, are scheduled to be completed in 2023. Because construction is underway on a site that requires continuous operation of existing facilities, it would be difficult for Reclamation to require an accelerated construction schedule. The new facilities are anticipated to be operated at least seven years prior to the Year 2030. Therefore, it is assumed that these facilities will be constructed and in operation in the same manner under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 in the Year 2030. The EIS analysis does not compare conditions under the existing conditions to conditions under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

The EIS analysis is a comparative analysis of conditions at Year 2030 that compares Alternatives 1 through 5 to the No Action Alternative, and No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. Implementation of the Total Maximum Daily Load and other existing water quality objectives by 2020 in accordance with identified schedules would be consistent under the No Action Alternative, Alternatives 1 through 5, and Second Basis of Comparison. Therefore, the results of the comparison of the alternatives would not be affected by implementation of these criteria.

CSD 6: Additional details of the analysis of the trap and haul program associated with Alternatives 3 and 4 is included in the Final EIS as Appendix 9O and Section 9.4.1 of Chapter 9, Fish and Aquatic Resources. Text revisions to page 9-316 of the Draft EIS indicate an improvement in survival and clarify uncertainty by describing the potential for unintended consequences associated with the trap and haul program. Text was also added to pages 9-287, 9-296, and 9-300 of the Draft EIS to indicate the potential for improved survival due to the non-operational measures included in Alternative 3.

CSD 7: The text on page 9G-2 of Appendix 9G, Smelt Analysis, has been modified to reflect the uncertainty associated with using X2 as an indicator of suitable habitat for Delta Smelt. Text has been added to Chapter 9 of the Final EIS related to uncertainty regarding analysis of operational measures.

CSD 8: It is impossible to exactly predict how groundwater users would respond to changes in surface water deliveries in Year 2030. The Sustainable Groundwater Management Act does not prevent increased groundwater withdrawals until the Groundwater Sustainability Plans are completely implemented in 2040 to 2042. The SWAP model, as described in Chapter 12, Agricultural Resources, of the EIS, indicates that groundwater elevations under the No Action Alternatives, the Second Basis of Comparison, and Alternatives 1 through 5 would not result in adverse economic impacts on a regional basis. As described in Section 12.4.3 of Chapter 12, reduced cultivation of agricultural lands could occur within individual farms; however, the amount of lands affected would be relatively small on a regional basis. The EIS analysis compares conditions in Year 2030 under the No Action Alternative with conditions under Alternatives 1 through 5; and conditions in 2030 under the Second Basis of Comparison with conditions under the No Action Alternative and Alternatives 1 through 5. The EIS analysis does not compare conditions under the alternatives and Second Basis of Comparison to the existing conditions in the NEPA analysis.

CSD 9: The cited Howitt et al. drought impact study was updated and revised in later months as more information became available, resulting in substantially lower estimated impacts (see Howitt et al., “Drought, Jobs, and Controversy: Revisiting 2009”, Agricultural and Resource Economics, Vol 14, No. 6, Jul/Aug 2011). Importantly, the analysis in that drought impact study did not include a detailed groundwater modeling analysis to assess the physical effects of reduced water supplies on groundwater conditions. Therefore, it relied on a set of assumptions about how pumping might change. In contrast, the analysis in this EIS includes a detailed groundwater modeling analysis (as described in Chapter 7, Groundwater Resources and Groundwater Quality). The agricultural analysis in Chapter 12, Agricultural Resources, was performed based on and consistent with the results of the groundwater analysis. Based on the estimated pumping lift changes (and therefore pumping costs) relative to the value of agricultural production, the SWAP model estimates that changes in irrigated acreage and value of production would be less than 1 percent (relative to the 2030 No Action Alternative) on a regional basis. As described in Section 12.4.3 of Chapter 12, reduced cultivation of agricultural lands could occur within individual farms with more limited access to groundwater.

CSD 10: The Sustainable Groundwater Management Act does not prevent increased groundwater withdrawals until the Groundwater Sustainability Plans are completely implemented in 2040 to 2042. Therefore, groundwater use is not limited in the EIS groundwater analysis. It should be noted that Figures 7.15 through 7.60 in Chapter 7, Groundwater Resources and Groundwater Quality, have been modified in the Final EIS to correct an error that increased the changes in groundwater elevation by a factor of 3.25. This miscalculation was due to an error in a model post-processor that generates the figures related to changing the values from CVHM Model output from meters to feet. Therefore, the results in these figures and the related text in Chapter 7 are less than reported in the Draft EIS. The figures and the text have been revised in the Final EIS. No changes are required to the CVHM model.

The revised results in the figures and the text in Chapter 7 are consistent with the findings of the SWAP model.

CSD 11: The summary for winter-run Chinook Salmon effects under Alternatives 3 and 4 have been modified in Section 9.4 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to provide additional details regarding the level of uncertainty associated with harvest restrictions. The modified text indicates that the harvest restrictions would likely benefit salmon.

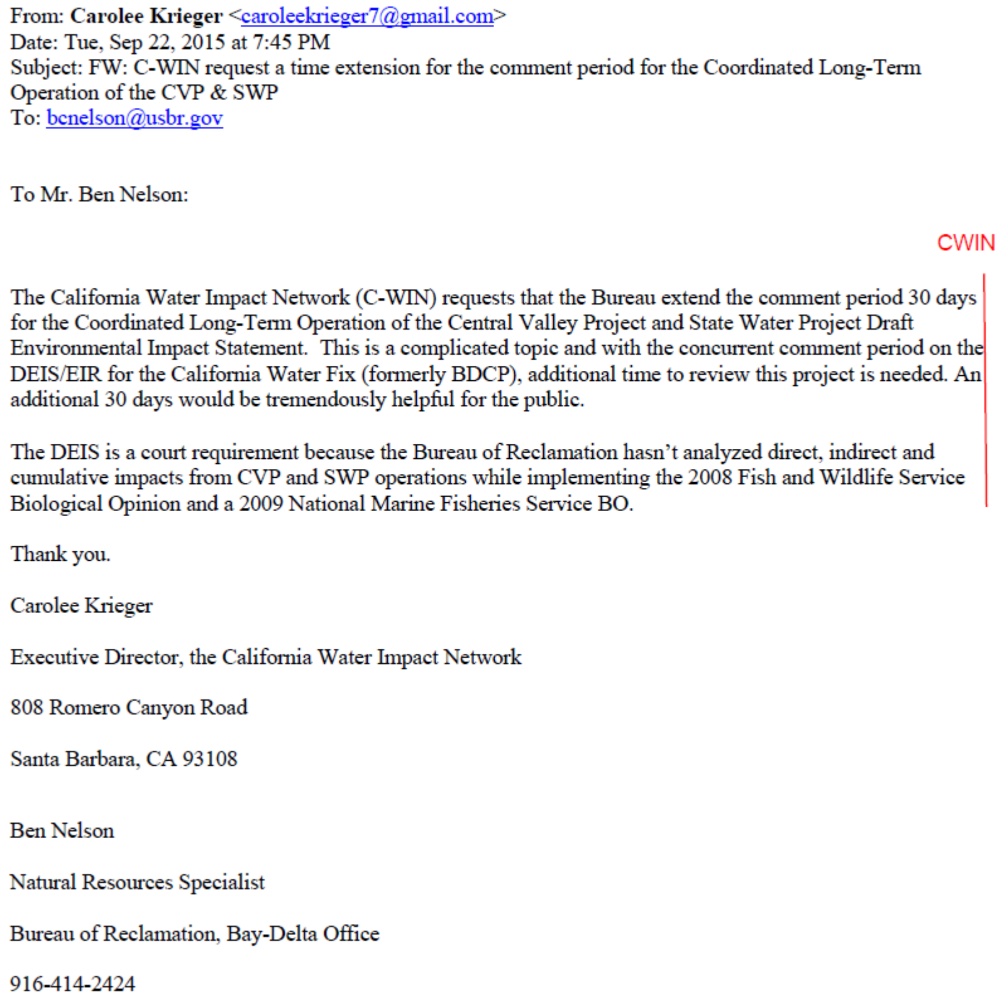
CSD 12: As described in Appendix 9I, Onchorhynchus Bayesian Analysis (OBAN) Model Documentation, the analysis presents changes in Alternatives 3 and 4 as compared to the No Action Alternative and Second Basis of Comparison, including changes related to harvest restrictions and Old and Middle River criteria.

CSD 13: A wide range of reference materials were evaluated in the preparation of the aquatic resource analysis in the EIS, as noted in Section 9.5 of Chapter 9, Fish and Aquatic Resources. The reference materials were used to develop the affected environment sections and to consider the results of the impact analyses. During preparation of the Final EIS, the references identified in the exhibit attached to the Coalition for a Sustainable letter dated July 13, 2015 were examined and included as appropriate, as described below.

- Numerous references to the Anderson et al. papers (cited as Independent Review Panel) were included in the Draft EIS (including pages 9-75 and 9-79 regarding Delta smelt, pages 9-76 and 9-78 regarding fish passage and entrainment, and page 9-139 regarding the Pelagic Organism Decline.
- The Draft EIS already contains numerous references to Glibert (2010) and Glibert et al. (2011 and 2014). Note that the 2011 citation in the Draft EIS is the correct form of Glibert et al. (2012) in the list of references provided. The first Glibert et al. (2014) citation in the comment should be Glibert et al. (2013) and would add little to the discussion presented in the Draft EIS. The paper identified as Glibert et al. (2013) in the comment concerns modeling of plankton dynamics that was not conducted for the Draft EIS.
- The Manly et al. (2015) paper was included in the Draft EIS on page 9-64 in the Draft EIS and has been added to the discussion on page 9-115 and in Appendix 9G, Smelt Analysis.
- The life cycle models of Maunder and Deriso (2011) were identified in the Draft EIS on page 9-115 and numerous times in Appendix 9B, Aquatic Species Life History Accounts.
- Merz et al. (2011) is included in the list of studies on page 9-63 of the Draft EIS. Additional information from this reference was added to page 9B-126 in Appendix 9B. Longfin smelt distribution information from Merz et al. (2013) has been added to Sections 9B.11.2 and 9B.11.3 in Appendix 9B.
- Miller et al (2012) is included in the references for Delta smelt related to food webs on page 9-65 in the Draft EIS.
- The Murphy and Hamilton (2013) paper is included in the description of the Delta smelt distribution on page 9-63 and 9-64 of the Draft EIS. Murphy and Weiland (2011) concerns agency obligations during ESA consultation, and is not directly applicable to the analysis under NEPA. Similarly, Murphy et al. (2011) is a critique of the use of surrogate species when making management decisions and proposed actions during agency consultation and formulation of BOs by the management agencies and is not directly applicable to the NEPA analysis of alternatives in the Draft EIS. Murphy and Weiland (2014) also concerns the use of surrogates as proxies for the amount or extent of anticipated take, which again concerns ESA consultation and determination of jeopardy by the management agencies. The second Murphy and Weiland (2014) paper concerns the use of adaptive management which is outside the scope of the Draft EIS.
- The Weston et al. (2015) paper documents that certain insecticides are found in urban and agricultural creeks tributary to Suisun Marsh and that these compounds pose a risk of toxicity to aquatic organisms in the creeks, but not necessarily once diluted in the marsh. This type of impact could be important to Suisun Marsh conditions; however, it may not be discernable at the regional level analyzed in this EIS.

CSD 14: Comment noted.

1D.1.4 California Water Impact Network



From: **Carolee Krieger** <caroleekrieger7@gmail.com>
Date: Tue, Sep 22, 2015 at 7:45 PM
Subject: FW: C-WIN request a time extension for the comment period for the Coordinated Long-Term Operation of the CVP & SWP
To: bcnelson@usbr.gov

To Mr. Ben Nelson:

CWIN 1

The California Water Impact Network (C-WIN) requests that the Bureau extend the comment period 30 days for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project Draft Environmental Impact Statement. This is a complicated topic and with the concurrent comment period on the DEIS/EIR for the California Water Fix (formerly BDCP), additional time to review this project is needed. An additional 30 days would be tremendously helpful for the public.

The DEIS is a court requirement because the Bureau of Reclamation hasn't analyzed direct, indirect and cumulative impacts from CVP and SWP operations while implementing the 2008 Fish and Wildlife Service Biological Opinion and a 2009 National Marine Fisheries Service BO.

Thank you.

Carolee Krieger

Executive Director, the California Water Impact Network

808 Romero Canyon Road

Santa Barbara, CA 93108

Ben Nelson

Natural Resources Specialist

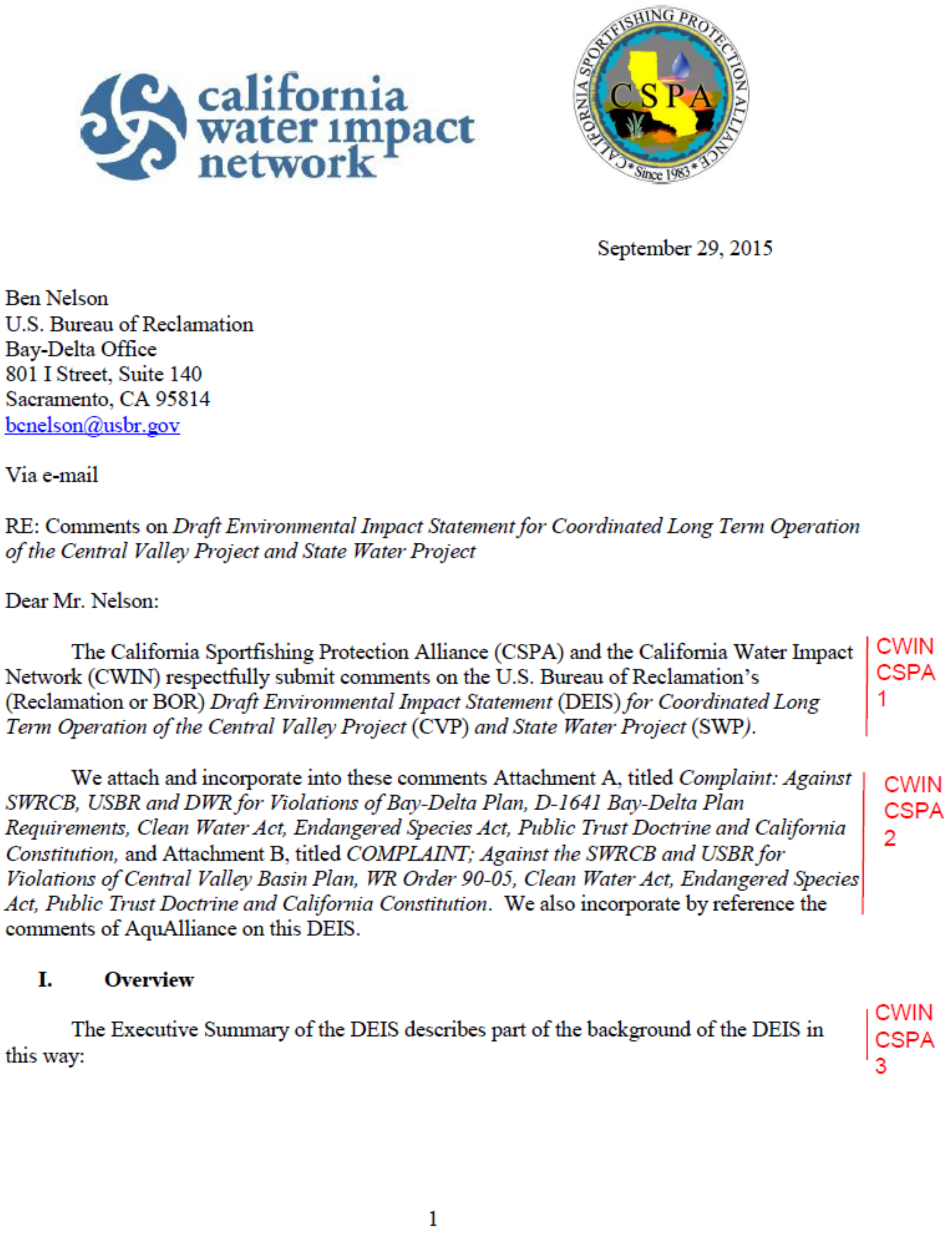
Bureau of Reclamation, Bay-Delta Office

916-414-2424

1D.1.4.1 Responses to Comments from California Water Impact Network

CWIN 1: At the time the request for extension of the public review period was submitted, the Amended Judgement dated September 30, 2014 issued by the United States District Court for the Eastern District of California (District Court) in the *Consolidated Delta Smelt Cases* required Reclamation to issue a Record of Decision by no later than December 1, 2015. Due to this requirement, Reclamation did not have sufficient time to extend the public review period. On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to extend public review period.

1D.1.5 California Water Impact Network and California Sportfishing Protection Alliance



california water impact network

CALIFORNIA SPORTFISHING PROTECTION ALLIANCE
CSPA
Since 1983

September 29, 2015

Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814
bcnelson@usbr.gov

Via e-mail

RE: Comments on *Draft Environmental Impact Statement for Coordinated Long Term Operation of the Central Valley Project and State Water Project*

Dear Mr. Nelson:

The California Sportfishing Protection Alliance (CSPA) and the California Water Impact Network (CWIN) respectfully submit comments on the U.S. Bureau of Reclamation's (Reclamation or BOR) *Draft Environmental Impact Statement* (DEIS) *for Coordinated Long Term Operation of the Central Valley Project* (CVP) *and State Water Project* (SWP). CWIN CSPA 1

We attach and incorporate into these comments Attachment A, titled *Complaint: Against SWRCB, USBR and DWR for Violations of Bay-Delta Plan, D-1641 Bay-Delta Plan Requirements, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution*, and Attachment B, titled *COMPLAINT; Against the SWRCB and USBR for Violations of Central Valley Basin Plan, WR Order 90-05, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution*. We also incorporate by reference the comments of AquAlliance on this DEIS. CWIN CSPA 2

I. Overview

The Executive Summary of the DEIS describes part of the background of the DEIS in this way: CWIN CSPA 3

CWIN CSPA 3 continued

> The Appellate Court confirmed the District Court ruling that Reclamation must conduct a NEPA review to determine whether the acceptance and implementation of the RPA actions cause a significant effect to the human environment.[1]

Chapter 2 of the DEIS further describes the background of the DEIS, stating in part:

> As described in Chapter 1, Introduction, the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) concluded in their 2008 and 2009 Biological Opinions (BOs), respectively, that coordinated long-term operation of the CVP and SWP, as described in the 2008 Reclamation Biological Assessment, jeopardizes the continued existences of listed species and adversely modifies critical habitat. To remedy this, USFWS and NMFS provided Reasonable and Prudent Alternatives (RPAs) in their BOs.
>
> The U.S. Court of Appeals for the Ninth Circuit confirmed the U.S. District Court for the Eastern District of California ruling that Reclamation must conduct a NEPA review to determine whether the RPA actions cause a significant impact on the human environment. Potential modifications to the coordinated operation of the CVP and SWP analyzed in the EIS process should be consistent with the intended purpose of the action, be within the scope of Reclamation's legal authority and jurisdiction, be economically and technologically feasible, and avoid the likelihood of jeopardizing listed species or resulting in the destruction or adverse modification of critical habitat in compliance with the requirements of Section 7(a)(2) of the Endangered Species Act.[2]

The remand thus set up the requirement for a NEPA analysis of whether implementation of the RPA's would cause a significant impact on the human environment. However, since the Ninth Circuit also upheld the RPA's as necessary under the Endangered Species Act to protect listed species and their critical habitats, simply eliminating part of an RPA is not an option unless equally protective or more protective measures are substituted (and analyzed). Thus, while the "Alternative Basis of Comparison" helps to demonstrate the relative effects (largely related to socioeconomic and water supply issues) of implementing the RPA's, it cannot stand as a viable alternative under NEPA on its own, because NMFS and USFWS have stated in their BiOps, and the Ninth District Court of Appeals has upheld them, that without the RPA's the operation of the SWP and the CVP jeopardize listed species and/or adversely affect their critical habitat.

CWIN CSPA 4

An RPA is a measure required under the Endangered Species Act to limit the effects of a federal action so that the action does not cause jeopardy or adversely affect critical habitat. The DEIS does not recommend a preferred alternative.[3] Thus it appears that BOR may incorporate in its Record of Decision any combination of the elements analyzed in any of the DEIS's NEPA alternatives. This highly unusual approach under NEPA makes it very difficult to comment on the DEIS. It is particularly difficult to provide comments that address whether effects of ultimate modifications to any of the RPA's taken under the Action will cause jeopardy or adversely affect critical habitat.

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[1] DEIS, p. ES-6.
[2] DEIS, p. 2-2.
[3] See DEIS, p. 1-9.

CWIN CSPA 5

Below, we maintain that some elements that are analyzed under project alternatives would, on their face, cause jeopardy or adversely affect critical habitat. We also argue that in aggregate baseline conditions (the No Action Alternative) are already doing so. However, an additional round of analysis by BOR in a recirculated DEIS or in an FEIS will be needed in order to evaluate whether the any modifications to RPA's that BOR ultimately proposes, considered in aggregate, comply with the requirements of the ESA. No such analysis is present in the DEIS.

CWIN CSPA 6

In any case, the DEIS does not specify significant impacts or specific mitigations for such impacts insofar as the DEIS concerns reduced water supply that might be attributable to the RPA's.[4] Instead, the DEIS assumes that urban water supplies will be met by paying relatively nominal increased costs and that increased use of groundwater will replace agricultural supplies lost because of the implementation of the RPA's.[5]

In short, there is no compelling argument in the DEIS that the RPA's in whole or part are not "economically or technologically feasible."

CWIN CSPA 7

Nonetheless, the DEIS describes several alternatives that could be substituted for the parts of the RPA's. The apparent assumption is that actions proposed under these alternatives, including elimination of certain elements of the RPA's and substitution of alternative elements, would meet the requirements of the ESA and would have added benefits that might make them preferable.

Alternative 1 would eliminate RPA actions that would not otherwise occur without the RPA's, and revert to operations and flow requirements that existed prior to issuance of the BiOps. However, it would retain non-operational RPA requirements that have already been implemented or are in the process of being implemented.

Alternative 2 would eliminate a series of physical measures included in the RPA's, including fish passage at CVP dams, temperature improvements at CVP dams on the American River, actions to reduce entrainment at CVP and SWP export facilities, and others.[6]

Alternative 3 would eliminate RPA actions that would not otherwise occur without the RPA's. It would weaken Old and Middle River (OMR) export restrictions from the present restrictions in the BiOps, implement a suite of actions on the Stanislaus River that substantially reduce flow requirements, and eliminate the use of Stanislaus River flow releases to meet D-1641 water quality and pulse flow requirements. It would establish a "predator control

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[4] See e.g. DEIS p. 19-57: average annual increased cost of M&I water supplies to Southern California is $34 Million. See also p. 19-49: average increased regional loss of San Joaquin Valley revenue in Dry and Critical Dry years is $34.4 Million.

[5] In what appears to be an incomplete analysis, the DEIS also does not analyze whether reduced levels of groundwater, particularly on the west side of the San Joaquin Valley, are attributable to the Action and must be mitigated. See DEIS pp. 7-140 and 7-141. We would argue that the impacts arise not from the Action (the RPA's), but from excessive cultivation without a reliable water supply, a baseline condition. However, the DEIS does not state the basis for which it declines to consider whether groundwater impacts to the San Joaquin Valley are attributable to the action or whether they are potentially significant.

[6] See DEIS p. 3-32.

program," trap and haul a portion of salmonid outmigrants in the San Joaquin River from March through June, and reduce ocean harvest of salmon.

CWIN CSPA 7 continued

Alternative 4 would eliminate RPA actions that would not otherwise occur without the RPA's. It would limit development in floodplains, replace levee riprap with vegetation, establish a "predator control program," trap and haul a portion of salmonid outmigrants in the San Joaquin River from March through June, and reduce ocean harvest of salmon.

Alternative 5 would implement the RPA's and additionally require positive OMR flows in April and May. It would also require April and May pulse flows from the Stanislaus River, whose volume would be determined by water year type and the location of X2.[7]

II. The DEIS fails to present a reasonable range of alternatives.

A. None of the alternatives analyzed in the DEIS, including the No Action Alternative, are sufficient to avoid jeopardy to Delta smelt and listed salmonids or to protect other public trust fishery resources consistent with applicable law.

1. The DEIS and RPAs ignore the recent condition of pelagic and salmonid species.

CWIN CSPA 8

Since 1967, the California Department of Fish and Wildlife's (DFW) Fall Midwater Trawl abundance indices for striped bass, Delta smelt, longfin smelt, American shad, splittail and threadfin shad have declined by 99.7, 97.8, 99.9, 91.9, 98.5 and 97.8 percent, respectively.[8] Abundance indices of these species have continued to decline despite the existence of RPA's.

For example, between 2008 and 2014, DFW's 2014 Fall Midwater Trawl abundance index of Delta smelt declined by 60.7 percent, and the 2014 index was the lowest in in the forty-eight year history of the trawl. The 2015 20mm Survey Delta smelt abundance index declined 89.7 percent since 2008 and was the lowest in the twenty-one year history of the survey.[9] The 2015 Spring Kodiak Trawl abundance index for Delta smelt declined 42.7 percent since 2008 and was the lowest in the thirteen-year history of the trawl.[10] The 2015 Summer Townet Delta smelt abundance index was 0.0 (100 percent decline), the lowest in the fifty-six year history of the survey.[11] Survey results for Delta smelt led U.C. Davis fisheries professor Peter Moyle to warn state officials to prepare for the extinction of Delta smelt.[12]

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[7] See DEIS Table 3.5, p. 3-42.

[8] http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT

[9] See Bibliography: https://www.wildlife.ca.gov/Conservation/Delta/20mm-Survey.

[10] See Bibliography: https://www.wildlife.ca.gov/Conservation/Delta/Spring-Kodiak-Trawl.

[11] See Bibliography: https://www.wildlife.ca.gov/Conservation/Delta/Townet-Survey.

[12] http://www.capradio.org/44478, http://californiawaterblog.com/2015/03/18/prepare-for-extinction-of-delta-smelt/, http://news.nationalgeographic.com/2015/04/150403-smelt-california-bay-delta-extinction-endangered-species-drought-fish/.

CWIN
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Other species may be in equal or worse shape. The 2014 Fall Midwater Trawl abundance index of longfin smelt declined by 88.5 percent since 2008.[13]

The USFWS Anadromous Fisheries Restoration Program (AFRP) documents that, since 1967, in-river natural production of Sacramento winter-run Chinook salmon and spring-run Chinook salmon have declined by 98.2 and 99.3 percent, respectively, and are only at 5.5 and 1.2 percent, respectively, of doubling levels mandated by the Central Valley Project Improvement Act, California Water Code and California Fish & Game Code.[14]

The 2013 brood years of Sacramento River winter-run, spring-run and fall-run Chinook salmon were seriously impacted by excessive temperatures in the Sacramento River below Keswick Reservoir. In 2014, lethal temperatures below Keswick led to the loss of 95% of winter-run, 98% of fall-run and virtually all of the spring-run 2014 year classes.[15] Daily average and daily maximum temperatures during critical spawning, incubation and alevin life stages at the Above-Clear-Creek-Compliance-Point during May, June and July 2015 significantly exceeded temperatures of the corresponding months of 2014.[16] The loss of a third brood year would likely jeopardize the continued existence of these species.

The DEIS ignores the continuing decline of pelagic and salmonid species following construction of the SWP and the accelerating decline in recent years despite the BOs. This continuing decline of fisheries jeopardizes the existence of species already on the brink of extinction. The failure to acknowledge and analyze the continuing decline of fisheries and impending extinction of one or more species, despite the RPAs, renders the DEIS deficient as a NEPA document.

2. The DEIS and RPAs fail to account for the SWRCB's pattern and practice of serially weakening fish and wildlife and water quality standards, with the concurrence of USFWS and NMFS.

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The State Water Resource Control Board's (SWRCB) San Francisco/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan) and the Central Valley Regional Water Quality Control Board's (Regional Board) Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) are issued pursuant to requirements of the federal Water Pollution

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[13] The USFWS has found that longfin smelt, as a candidate species, warrants protection under the Endangered Species Act but the Service is precluded from adding the species at the present time because of a lack of resources and the extensive list of other species warranting listing. http://www.fws.gov/sfbaydelta/species/longfin_smelt.cfm

[14] See http://www.fws.gov/lodi/afrp/.

[15] State Water Resource Control Board, *Order Conditionally Approving a Petition for Temporary Urgency Changes in License and Permit Terms and Conditions Requiring Compliance with Delta Water Quality Objectives in Response to Drought Conditions*, 3 July 2015, pp. 15,16:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/tucp_order070315.pdf
And
NRDC, TBI, *Drought Operations Will Cause Additional Unreasonable Impacts on Fish and Wildlife in 2015,* 20 May 2015, slide 2:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/workshops/nrdc_tbi_pres.pdf.

[16] http://cdec.water.ca.gov/cgi-progs/staMeta?station_id=ccr, and
CSPA, presentation before the State Water Resource Control Board 25 June 2015 Workshop, slides 4-7:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/workshops/062415cspa_pres.pdf

CWIN
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Control Act (Clean Water Act). The SWRCB's D-1641 and Water Rights Orders 90-05, 91-01, 91-03 and 92-02 implement the Bay-Delta Plan and Basin Plan as terms and conditions in Reclamation's CVP. The BO's and RPA's are predicated on compliance with Delta water quality and flow criteria and Sacramento River temperature criteria contained in the SWRCB's D-1641 and WR Orders.

However, the SWRCB has succumbed to a pattern and practice of waiving (i.e., weakening) water quality, flow and temperature criteria whenever requested. Over the last two years, the SWRCB has weakened water quality, flow and/or temperature criteria some 35 times.[17] In 2014, the SWRCB reduced regulatory Delta outflow by 43% and increased Delta exports by 18%. In 2015, the SWRCB reduced regulatory outflow by 78% in order to increase exports by 32%. These changes shifted more than one million acre-feet of water from fisheries protection to agricultural and urban use.[18]

D-1641 Table 1, 2 and 3 water quality standards have been routinely exceeded. For example, salinity standards protecting south Delta agricultural beneficial uses have been exceeded thousands of days since 2006, and there were over 400 exceedances at Vernalis, Brandt Bridge, Old River Near Middle River, and Old River Near Tracy in calendar year 2015 alone. Delta outflow standards protecting fish and wildlife and agriculture, Vernalis flow standards protecting salmon and steelhead, and Collinsville salinity standards protecting Delta smelt habitat were exceeded numerous times in 2015, as were the Emmaton, Threemile Slough and Jersey Point salinity standards protecting agricultural beneficial uses. The narrative salmon protection doubling standard has been violated every day since D-1641 became operative.

This pattern and practice of weakening critical Delta flow and water quality standards has replicated itself over decades. For example, between 1988 and 1991, Bay-Delta standards were violated 246 times. The SWRCB's refusal to enforce Bay-Delta water quality and flow standards is more fully described in Attachment A titled *Complaint: Against SWRCB, USBR and DWR for Violations of Bay-Delta Plan, D-1641 Bay-Delta Plan Requirements, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution* and incorporated into these comments.

As previously noted and described more fully in Attachment B titled *COMPLAINT; Against the SWRCB and USBR for Violations of Central Valley Basin Plan, WR Order 90-05, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution*, the Regional Board established temperature criteria in the Sacramento River, pursuant to the CWA, and the SWRCB implemented the temperature criteria in Reclamation's permits and licenses in WR Order 90-05. In doing so, the SWRCB implemented temperature criteria based on average daily temperatures without determining whether average daily temperatures were protective of aquatic life. As discussed at length in pages 19-23 of Attachment B, a 56°F daily

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[17] Pubic Policy Institute of California, *What if California's Drought Continues?* August 2015, page 7: http://www.ppic.org/content/pubs/report/R_815EHR.pdf and the Technical Appendix at page 6: http://www.ppic.org/content/pubs/other/815EHR_appendix.pdf

[18] SWRCB, staff presentation at the 20 May 2015 public workshop on drought activities in the Bay-Delta: http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/workshops/swrcb_staff_pres_session1b.pdf

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average temperature criterion is not protective of Chinook salmon spawning, egg incubation and fry emergence.[19]

Additionally, the SWRCB exempted almost 43% of identified fish spawning habitat from temperature requirements. The SWRCB then ignored the Basin Plan's Controllable Factors Policy and its own admonition to Reclamation that water necessary to meet water quality criteria was not available for delivery. When the National Marine Fisheries Service (NMFS) listed winter-run Chinook salmon as threatened under the ESA, the SWRCB inexplicably relocated the temperature compliance point further upstream to Bend Bridge, eliminating another 15 miles of spawning habitat.

Over the next 23 years, the SWRCB participated in back-room temperature management group meetings that recommended ever-changing temperature compliance points for winter-run Chinook salmon, based upon the quantities of water BOR had remaining in storage after deliveries to its water contractors. The SWRCB subsequently approved the recommendations of the temperature management group of which it is a participating member. These approvals generally relocated temperature compliance points further and further upstream, often eliminating as much as 90% or more of spawning habitat protected by the Basin Plan. For example, Clear Creek has been the designated temperature compliance point over the last two years, which has compressed spawning into the upper 10 miles of the Sacramento River downstream of Keswick Reservoir and led to superimposition of redds and conflict with other species.

Despite these yearly concessions, BOR has violated temperature criteria in nearly every year. In 2015, the SWRCB approved Reclamation's request to increase the temperature compliance requirement from a daily average of 56°F to 58°F. This despite the fact that the NMFS pointed out that an increase to 58°F would result in adverse impacts to incubating winter-run eggs and alevin in redds and that 58°F was identified in the scientific literature as lethal to incubating salmon eggs and emerging fry. In the subsequent concurrence letter, NMFS noted that "these conditions could have been largely prevented through upgrades in monitoring and modeling and ***reduced Keswick releases in April and May***" but concurred because "the plan provides a ***reasonable possibility*** that there will be ***some juvenile winter-run survival*** this year."[20] However, this is an unacceptable and illegal standard of compliance with the BO and ESA.

Drought cannot be employed as an excuse for ignoring or weakening promulgated water quality standards. Drought is normal in California's Mediterranean climate. According to DWR, there have been 10 multi-year drought sequences of large-scale extent in the last 100 years, spanning 41 years. Below normal years occur more than half the time. Agencies cannot

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[19] The U.S. Environmental Protection Agency, the states of Washington, Oregon and Idaho, both North Coast and Central Valley Regional Water Quality Control Boards, NMFS, DFW, the Pacific Fishery Management Council and the majority of the scientific literature have either adopted or recommended more restrictive temperature criteria based upon a daily maximum and/or a seven-day mean of daily maximums.

[20] NMFS, *Contingency Plan for Water Year 2015 Pursuant to Reasonable and Prudent Alternative Action I.2.3.C of the 2009 Coordinated Long-term Operation of the Central Valley Project and State Water Project Biological Opinion, Including a Revised Sacramento River Water Temperature Management Plan,* p. 9. Emphasis added.

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CWIN CSPA 9 continued

be surprised, be unprepared for, or claim emergency exemptions for something that occurs more than 40% of the time.

CWIN CSPA 10

However, Reclamation and DWR have continued to maximize water deliveries in the initial years of drought sequences and failed to maintain sufficient carryover storage to protect fisheries, water quality and public trust resources. The pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards has been extensively discussed and documented in previous CSPA presentations, protests, objections and complaints before the SWRCB.[21] As Reclamation is aware, CSPA and CWIN have filed a lawsuit in federal court regarding Reclamation's failure to comply with the Clean Water Act and filed a lawsuit in state court against the SWRCB's de facto weakening of CWA water quality standards. We incorporate by reference the allegations contained in those amended complaints into these comments.[22]

The continuing exceedances of water quality and flow criteria jeopardize the continued existence of species. Yet the DEIS fails to acknowledge, discuss or analyze the pattern and practice of serially weakening legally promulgated water quality and flow standards established to protect fish and water quality. It further fails to incorporate the serial failure to comply with water quality and flow standards in its modeling and assessment of the project's ability to deliver water and evaluation of alternatives. Consequently, the DEIS is deficient as a NEPA document.

3. The RPAs have failed to protect fisheries and other public trust resources.

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The continuing decline of fisheries, degraded water quality, and serial exceedance of water quality and flow criteria are both a track record and report card of the RPA's. Their existence and implementation has failed to protect fisheries and has brought several species to the brink of extinction. Any weakening or elimination of the RPA's would only exacerbate an already unacceptable situation.

The DEIS must candidly acknowledge, discuss and analyze the failure of the RPA's to protect fisheries, water quality and public trust resources. Failure to do so would render the DEIS deficient as a NEPA document.

4. The DEIS makes no showing that Alternatives 1-4 are as protective as D-1641 with the RPA's.

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The DEIS makes no showing that any of the alternatives, including the No Action alternative, meets the purpose and need of the proposed action, including most specifically the need to conform to the requirements of the ESA and to other applicable law that protects public

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[21] See CSPA workshop presentations, protests and objections of Temporary Urgency Change Petitions and complaints over the last two years at the SWRCB's State Water Project and Central Valley Project Temporary Urgency Change Petition website, http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/index.shtml

[22] http://calsport.org/news/

trust resources. It also makes no showing that any of the elements proposed in the alternatives will productive positive benefits for fisheries and other public trust resources.

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a. Alternative 1

Alternative 1 would eliminate the RPA's except those elements that would otherwise be implemented pursuant to voluntary actions or other regulatory requirements.

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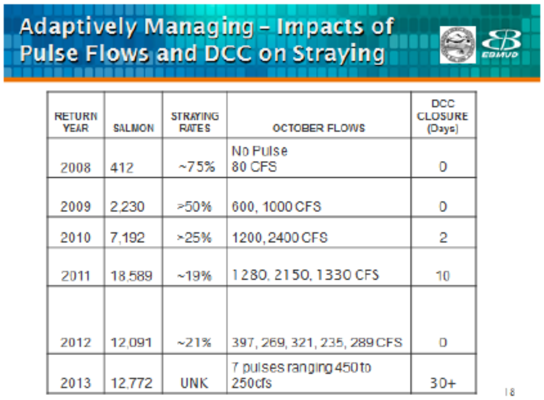
i. Fall pulse flows

Alternative 1 would eliminate fall attraction pulse flows in the Stanislaus River for fall-run Chinook, a proven, effective and cost-efficient measure to stimulate upstream migration and reduce straying. While consultants for irrigation districts on the Stanislaus have discerned no correlation between fall pulse flows and upstream migration in that river, pulse flows on the Mokelumne have been extremely effective in reducing straying and have shown clear correlation to upstream migration. (Figures 1 and 2).



Adaptively Managing – Impacts of Pulse Flows and DCC on Straying

RETURN YEAR	SALMON	STRAYING RATES	OCTOBER FLOWS	DCC CLOSURE (Days)
2008	412	~75%	No Pulse 80 CFS	0
2009	2,230	>50%	600, 1000 CFS	0
2010	7,192	>25%	1200, 2400 CFS	2
2011	18,589	~19%	1280, 2150, 1330 CFS	10
2012	12,091	~21%	397, 269, 321, 235, 289 CFS	0
2013	12,772	UNK	7 pulses ranging 450 to 250cfs	30+

Figure 1: Effects of pulse flows on straying rates and adult migration in the Mokelumne River 2008-2013.[23]

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[23] East Bay Municipal Utility District staff presentation to MokeWISE stakeholder group, April, 2014.

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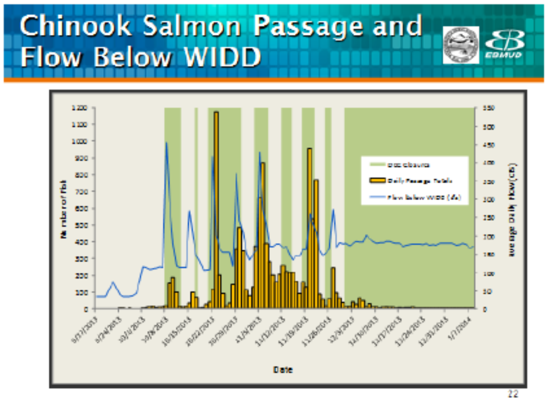

Chinook Salmon Passage and Flow Below WIDD

Figure 2: Relation of 2013 pulse flows and upstream migration of Mokelumne fall-run Chinook past Woodbridge Dam.[24]

More specific to the San Joaquin tributaries including the Stanislaus, Carl Mesick of the U.S. Fish and Wildlife Service found in 2001: "migration rates of adult salmon are substantially higher when Vernalis flows exceed about 3,000 cfs and total exports are less than 100% of Vernalis flows."[25]

The Bureau of Reclamation, recognizing the value and importance of fall pulse flows, ordered them for the Stanislaus in 2014 even in the face of severe drought conditions, and appears prepared to do so again in even worse storage conditions in 2015.

ii. Spring flows and pulse flows

Alternative 1 would also reduce spring flows in the Stanislaus River and eliminate spring pulse flows in the San Joaquin River sourced in the Stanislaus. High spring flows and pulse flows in the San Joaquin River at Vernalis are clearly and strongly correlated to successful outmigration of juvenile salmon.

The California Department of Fish and Game (now Department of Fish and Wildlife,) identified spring pulses in the San Joaquin River needed to double salmon in the San Joaquin river system in Exhibit 3 of its submittals in the State Water Resources Control Board's 2010 Delta Flow Criteria proceeding (Figure 3).

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[24] Id.

[25] Carl Mesick, *The Effects of San Joaquin River Flows and Delta Export Rates During October on the Number of Adult San Joaquin Chinook Salmon that Stray*, 2001, Fish Bulletin 179: Volume Two, p. 159.

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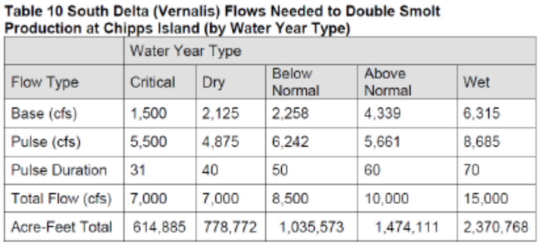
Table 10 South Delta (Vernalis) Flows Needed to Double Smolt Production at Chipps Island (by Water Year Type)

	Water Year Type				
Flow Type	Critical	Dry	Below Normal	Above Normal	Wet
Base (cfs)	1,500	2,125	2,258	4,339	6,315
Pulse (cfs)	5,500	4,875	6,242	5,661	8,685
Pulse Duration	31	40	50	60	70
Total Flow (cfs)	7,000	7,000	8,500	10,000	15,000
Acre-Feet Total	614,885	778,772	1,035,573	1,474,111	2,370,768

Figure 3: DFW recommendations for spring pulse flows at Vernalis[26]

Swanson et al made similar findings and recommendations in the submittal of the Bay Institute ("*Delta Inflows*," Exhibit TBI-3) to the Delta Flow Criteria proceeding, showing a positive correlation between spring flows and salmon abundance and between a declining rate of escapement and spring flows at Vernalis of less than 5000 cfs.[27] Numerous documents by Carl Mesick (U.S. Fish and Wildlife Service and on behalf of CSPA) similarly stress the importance of high spring flows in various tributaries of the San Joaquin. [28]

Staff of the State Water Resources Control Board, in its 2010 *Delta Flow Criteria Report*, concluded:

> Following are the San Joaquin River inflow criteria based on analysis of the species specific flow criteria and other measures:
>
> 1) San Joaquin River at Vernalis: 60% of 14-day average unimpaired flow from February through June
> 2) San Joaquin River at Vernalis: 10 day minimum pulse of 3,600 cfs in late October
>
> … San Joaquin River inflow criterion 1 and 2 are Category A criteria because they are supported by sufficiently robust scientific information.[29]

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[26] California Department of Fish and Game, *Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island,* 2010, p. 35. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/dfg/dfg_exh3.pdf

[27] Swanson et al., *Exhibit TBI-3: Delta Inflows, SWRCB Public Trust Flow Criteria Proceedings, February 16, 2010,* p. 16, p. 23. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/bay_inst/tbi_exh3.pdf

[28] See, for example, Carl Mesick, 2009, *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases* http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/exhibits/cspa/cspa_exh14.pdf
Carl Mesick, 2010, *The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Merced River due to Insufficient Instream Flow Releases*.
http://calsport.org/doc-library/pdfs/57.pdf

[29] State Water Resources Control Board, *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem; Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of* 2009, August 3, 2010, p. 119.

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The *Delta Flow Criteria Report* further summarized existing information:

> Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow, though the time periods are somewhat different (AFRP is for February through May and DFG is for March 15 through June 15).[30]

State Water Board staff also emphasized: "it is important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted to over time, including variations in flows and continuity of flows."[31]

The flow regime for the Stanislaus River required in NMFS's RPA's contains a significant degree of weekly and monthly variability, although less variability than the percent-of-unimpaired approach recommended by State Water Board staff would require. Alternative 1 would revert the Stanislaus to significantly lower spring flows than RPA flows, with far less variability. Alternative 1 would reduce March-June flows in the Stanislaus River by up to 52.9% in all years and by 59.6% in Dry and Critical Dry years.[32] Overall, this flow reduction would substantially reduce the frequency and duration of floodplain inundation

iii. Restrictions on reverse flows in Old and Middle rivers (OMR)

Alternative 1 would eliminate OMR protections in the RPA's, allowing greater exports at state and federal facilities in the south Delta. The DEIS claims that this would increase exports up to about 1 million acre-feet per year.[33]

The RPA's require limits on net negative tidal flows in Old and Middle Rivers in the South Delta to protect listed winter-run and spring-run Chinook salmon, steelhead, and Delta smelt. Old and Middle River net flows are closely related to total south Delta exports. The OMR limits are not restrictive to higher exports when San Joaquin River Delta inflows are high and provide more positive net OMR. OMR limits allow restrictions on exports when Sacramento River Delta inflows are high and San Joaquin River flows are low. Without OMR limits, exports have been very high (pre-2009) when Sacramento River flows were high. High OMR reverse flows and exports can draw salmon and smelt into the central and south Delta in the winter-spring period during high Sacramento River flows.[34] Under the RPA's, the presence

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[30] Id.

[31] Id., p. 120

[32] DEIS, p. 5-239.

[33] DEIS, p. 5-253. See Section IV of these comments below for discussion of why this figure may be overstated.

[34] The Delta Cross Channel is closed during most of the winter-spring period, and under such conditions Sacramento River flows contribute minimally to lower San Joaquin River and OMR flows. San Joaquin salmon and steelhead smolts that enter the Delta via Georgiana and Threemile sloughs, and smelt living in or moving into the central Delta are at risk to south Delta exports during the winter-spring period. Their presence in the central Delta or export

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of listed species can trigger OMR restrictions to -5000 cfs or less negative. Whichever BO RPA is the most restrictive governs operations at any given time. The RPA's prescribe an elaborate review process and triggering criteria for a Smelt Working Group (SWG[35]) and Delta Salmon and Steelhead Group (DOSS[36]) to make operations recommendations to Water Operations Management Team (WOMT), which may or may not adopt recommendations.

Old and Middle River (OMR) flow management (Actions IV.2 and IV.3) is prescribed for the period January 1 to June 15 in the NMFS BO RPA. The RPA describes the purpose of these requirements as follows: "Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta. … Curtail exports when protected fish are observed near the export facilities to reduce mortality from entrainment and salvage."[37]

The USFWS's BO prescribes similar measures to protect smelt:

> The objective of Component 1 is to reduce entrainment of pre-spawning adult delta smelt during December to March by controlling OMR flows during vulnerable periods.[38]
>
> … The objective [of Component 2] is to improve flow conditions in the Central and South Delta so that larval and juvenile delta smelt can successfully rear in the Central Delta and move downstream when appropriate.[39]

The RPA's provide essential protection in the winter-spring period by limiting exports and reducing losses of salmon, steelhead, sturgeon, and smelt that would otherwise be drawn to the south Delta export pumps under the D-1641 65% export/inflow limit in December-January and 35% export/inflow limit February-June. The restrictions reduce entrainment of listed species into the central and south Delta in both dry and wet years, especially in December-January period. Even in drought years like winter-spring 2014-2015, OMR restrictions in winter reduced potential exports. Lack of prescriptions for December under the NMFS RPA did allow high negative OMR flows and exports. However, concerns for adult smelt led to voluntary reductions in exports and OMR negative flows in mid-December 2014 that subsequently were maintained through the winter.

Prior to the RPA's' OMR restrictions, salmon and smelt protections were generally limited to "take limits" in the form of salvage counts, and water quality standards that included export limits, Delta outflow requirements, and agricultural salinity standards in state water quality standards (D-1641). When these standards proved ineffective in protecting the listed salmon and smelt[40], the new biological opinions were issued, which added the OMR restrictions as well as other non-flow actions to preserve the species.

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salvage can trigger OMR restrictions that otherwise would not occur under the regular D-1641 export/inflow restrictions.

[35] http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm

[36] http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/doss.html

[37] NMFS OCAP BO, p. 630.

[38] FWS OCAP BO, p. 280.

[39] Id., p. 282.

[40] Take limits proved irrelevant as populations dropped to new low levels.

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In recent drought years, the OMR restrictions in the RPA's have been more important than ever because D-1641 water quality standards have been weakened by the State Water Board, with the consent of NMFS and USFWS.

A better level of protection than the RPA's would be a combination of stricter OMR restrictions and substantially improved Delta outflow and salinity standards that further limit risks to salmon and smelt.

iv. Non-flow measures that Alternative 1 would eliminate

Alternative 2 is specifically constructed to evaluate elimination of the major non-flow measures of the RPA's. These measures would also be eliminated by Alternative 1. For purposes of document organization, we analyze the consequences of eliminating the major non-flow measures of the RPA's in analyzing Alternative 2.[41]

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b. Alternative 2

Alternative 2 would eliminate the major non-flow elements of the RPA's except those elements that would otherwise be implemented pursuant to voluntary actions or other regulatory requirements, and also eliminate floodplain inundation flows on the Stanislaus River.

That said, it is extremely difficult to discern exactly which actions from the RPA's Alternative 2 (or overlapping actions from Alternative 1) would eliminate and which ones would remain. The DEIS should have listed the eliminated and retained actions specifically. The DEIS should also have described how any actions could be eliminated and still meet protection requirements of the ESA and other legal requirements to protect public trust resources. Absent this, the lack of clarity does not support the requirement that NEPA analysis support informed decision-making.

As we understand it, Alternative 2 would eliminate the following actions from the NMFS and USFWS RPS's:

- 2009 NMFS BO RPA Action I.2.5, Winter-Run Passage and Re-Introduction Program at Shasta Dam.
- 2009 NMFS BO RPA Action II.3, Structural Improvements for Temperature Management on the American River.
- 2009 NMFS BO RPA Action II.5, Fish Passage at Nimbus and Folsom Dams.
- 2009 NMFS BO RPA Action II.6, Implement Actions to Reduce Genetic Effects of Nimbus and Trinity River Fish Hatchery Operations.

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[41] NMFS modified the RPA in 2011. See http://www.westcoast.fisheries.noaa.gov/publications/Central_Valley/Water%20Operations/Operations,%20Criteria%20and%20Plan/040711_ocap_opinion_2011_amendments.pdf

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- 2009 NMFS BO RPA Action III.2.1, Increase and Improve Quality of Spawning Habitat with Addition of Gravel.
- 2009 NMFS BO RPA Action III.2.2, Conduct Floodplain Restoration and Inundation Flows in Winter or Spring to Inundate Steelhead Juvenile Rearing Habitat on Stanislaus River.
- 2009 NMFS BO RPA Action III.2.3, Restore Freshwater Migratory Habitat for Juvenile Steelhead on Stanislaus River.
- 2009 NMFS BO RPA Action III.2.4, Fish Passage at New Melones, Tulloch, and Goodwin Dams.
- 2009 NMFS BO RPA Action IV.4, Tracy Fish Collection Facility Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency.
- 2009 NMFS BO RPA Action IV.4.2 Skinner Fish Collection Facility Improvements to Reduce Pre-Screen Loss and Improve Screening Efficiency.
- 2009 NMFS BO RPA Action IV.4.3 Tracy Fish Collection Facility and the Skinner Fish Collection Facility Actions to Improve Salvage Monitoring, Reporting and Release Survival Rates.[42]

The DEIS makes no effort to describe how these RPA actions could be eliminated and still conform to the ESA. It does not address the rationales for these measures provided in the NMFS RPA's. It does not address the removal of fish passage actions at Shasta, Nimbus-Folsom, and Goodwin-Tulloch-New Melones dams in the context of the 2014 NMFS Recovery Plan.[43]

In a "Public Stakeholder Seminar" on September 24, 2015 convened by Reclamation, Reclamation and representatives of state and federal agencies reaffirmed the link between the need for passage past Shasta and the recent poor survival of winter-run downstream of Lake Shasta.[44] However, the DEIS does not discuss this linkage.

Equally, it is likely that a substantial portion of the cohort of fall-run Chinook will be lost in 2015 on the American River due to high water temperatures. It is also likely that substantial mortality of juvenile steelhead and resident O. mykiss in the American and Stanislaus rivers will occur due to high water temperatures. Yet Alternative 2 makes no effort to place fish passage past dams on these rivers in the context of mortality of listed and non-listed salmonids confined in these rivers to the valley floor.

The "salvage rates" of listed and non-listed species at the Skinner and Tracy "Fish Collection Facilities" is notorious, as is the inefficiency of these facilities. Between 2000 and

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[42] DEIS, p. 3-32.

[43] National Marine Fisheries Service, 2014, *Final Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead.* Available at: http://www.westcoast.fisheries.noaa.gov/publications/recovery_planning/salmon_steelhead/domains/california_central_valley/final_recovery_plan_07-11-2014.pdf

[44] Presentation to be posted at http://www.usbr.gov/mp/BayDeltaOffice/Documents/Shasta_Fish_Passage/

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2011, more than 130 million fish were salvaged at the CVP and SWP water export facilities in the South Delta.[45] Actual losses are far higher. Recent estimates indicated the 5-10 times more fish are lost than salvaged, largely due to the high predation losses in and around water export facilities.[46] The fish screens are unable to physically screen eggs and larval life states of fish from diversion pumps.[47] The present South Delta fish screens are based on 1950's technology. Only about 11-18% of salmon and steelhead entrained at Clifton Court Forebay survive.[48] Losses to pelagic species such as Delta smelt are much higher.

The California "Water Fix" would add points of diversion to the south Delta export facilities, but the existing infrastructure would be used about half the time. However the "Water Fix" includes no plans to upgrade the existing south Delta fish screens. The NMFS BO extensively documents the inadequacy of the existing screens, and describes the facilities at Tracy as follows:

> … 45 percent of the time, the appropriate velocities in the primary channel and the corresponding bypass ratio are not being met and fish are presumed to pass through the louvers into the main collection channel behind the fish screen leading to the pumps. The lack of compliance with the bypass ratios during all facility operations alters the true efficiency of louver salvage used in the expansion calculations and therefore under-estimates loss at the TFCF.[49]

Since the BO's were issued, there have been no physical improvements to the fish salvage facilities at the state and federal export facilities. Yet in spite of the known loss of millions of fish annually at these facilities, Alternative 2 blithely proposes to forego improvements to this infrastructure.

In short, Alternative 2 is effectively a throwaway alternative with no justification in fact or law, without even a perfunctory let alone substantial rationale in the DEIS.

c. Alternative 3

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Alternative 3 is focused on weakening Stanislaus River flow requirements and OMR requirements. It would dramatically lower flow requirements for the Stanislaus River, particularly in the spring and particularly in drier water years, allowing greater diversions, and would exempt (without legal explanation) the Stanislaus River from responsibility for complying with various aspects of D-1641, including Vernalis flow and pulse flow requirements and Delta water quality standards.[50] It would move the compliance point for the D-1422 dissolved oxygen requirement (also without legal explanation) from Ripon upstream to Orange Blossom Bridge. It

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[45] DFW annual salvage reports for the SWP and CVP fish facilities, 2000-2011.

[46] Larry Walker Associates, 2010, *A Review of Delta Fish Population Losses from Pumping Operations in the Sacramento-San Joaquin River Delta*, p. 2. http://www.srcsd.com/pdf/dd/fishlosses.pdf

[47] DWR, 2011, *Delta Risk Management Strategy, final Phase 2 Report, Section 15, Building Block 3.3: Install Fish Screens*, pp 15-18.

[48] Id.

[49] NMFS OCAP BO, pp. 341-342. See also following pages through p. 350 for description of other facility deficiencies and associated mortality.

[50] For proposed Stanislaus River flows and changes to D-1641 and D-1422, see DEIS, p. 3-36.

CWIN CSPA 15 continued

would implement a "predator control program" in the Stanislaus River and the Delta. It would tie OMR requirements to turbidity levels, to location of X2, and to the proximity of Delta smelt to Old and Middle rivers, thus at times allowing greater levels of export. It would attempt to mitigate for the potential of additional entrainment of San Joaquin watershed salmonids under the new conditions by implementing a trap and haul program of San Joaquin River salmonids; it would seek to capture 10%-20% of outmigrating juvenile salmonids at the head of Old River, place them in barges, and release them at Chipps Island. Like the No Action Alternative, it would restore 10,000 acres of tidally influenced wetlands. It would also reduce opportunities for commercial and sport ocean harvest of salmon by placing the burden of proof on fisheries managers to limit ocean harvest based on "consistency with Viable Salmonid Population Standards, including harvest management to show that abundance, productivity, and diversity (age-composition) are not appreciably reduced."[51]

As discussed in Section II(A)(4)(a)(ii) of these comments above, the best available science suggests that greater flows are needed in the Stanislaus River, not lower flows. The DEIS attempts to justify flow requirements for the Stanislaus based on Weighted Usable Area for spawning and egg viability. Neither of these factors would be appreciably changed by Alternative 3 compared to the No Action Alternative, in significant part because the most critical flow reductions under Alternative 3 would take place at times of year when spawning and egg incubation were not occurring, at least in the case of fall-run Chinook.

To the degree that water temperatures under Alternative 3 would not change appreciably compared to the No Action Alternative, this is likely attributable to the fact that some of the water presently used for instream flow, particularly in spring, would be devoted to storage or simply held longer in storage. Temperature increases downstream of Goodwin Dam stemming from decrease in flow would be partially offset by lower release temperatures and increased releases for irrigation from New Melones to Goodwin and Tulloch dams; the latter would tend to create lower release temperatures from Goodwin Dam into the lower Stanislaus.

This apparent wash in impacts to water temperature would occur at the expense of floodplain inundation, juvenile rearing habitat for salmonids, and flow variability that the State Water Board and numerous others have identified as key life stages and limiting factors in juvenile salmon survival. See section II(A)(4)(a)(ii) above. The DEIS does not respond to the analysis in the RPA that supports measures that provide these elements, and the DEIS does not evaluate impacts according to these metrics.

The DEIS notes about predation reduction measures that no one has shown that predation reduction measures could have an appreciable population level effect on the success of juvenile salmonid outmigrants from the Stanislaus and lower San Joaquin rivers.[52] We agree.

There is no showing that capture and transport of 10%-20% of San Joaquin River salmonid outmigrant will make a population level difference for fall-run Chinook or for steelhead. Though the program is likely worth at least a stand-alone pilot effort, and a similar

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[51] DEIS, p. 3-37.

[52] "It remains uncertain, however, if predator management actions under would benefit fall-run Chinook Salmon." DEIS, p. 3-78. See also DEIS, p. 9-275.

effort has been initiated by East Bay Municipal Utility District on the Mokelumne,[53] the DEIS provides no quantification that shows that trap and haul of downstream migrants will mitigate for the Alternative's proposed reduction in Stanislaus River flow and/or the weakening of OMR standards. There is no quantification in the DEIS of current (No Action) and projected (Alternative 3) survival of outmigrating salmonids between head of Old River and Chipps Island. Nor is there any analysis in the DEIS of existing or desired levels of juvenile salmonid survival between Oakdale and Caswell and between Caswell and head of Old River. It is likely that the relative effect of trap and haul between head of Old River and Chipps Island is limited in the face of very poor survival between spawning grounds in the Stanislaus and the head of Old River, which would likely become worse under Alternative 3. CWIN CSPA 15 continued

Alternative 3's proposed changes in OMR flows based on real time monitoring of Delta smelt are likely infeasible because Delta smelt abundance has dropped so low that they are virtually undetectable. See Section II(A)(1) above.

The analysis in Chapter 19 of economic impacts related to loss of commercial and salmon fishing opportunities that would occur with the enactment of the limitations on salmon fishing proposed in Alternative 3 (and 4) is perfunctory. There should be more analysis based on several scenarios of reduced salmon seasons in various locations, and analysis of secondary impacts on coastal communities. In the limiting case, the placement on harvesters or salmon of the burden to demonstrate no impact to listed species could eliminate harvest of salmon altogether. The DEIS should have analyzed the economic impact of the effective closure of salmon fishing in waters where California-born salmon are present.

d. Alternative 4

CWIN CSPA 16

Alternative 4 contains many of the elements contained in Alternative 3. Like Alternative 3, Alternative 4 would substitute non-flow measures ostensibly to make up for flow reductions. However, the flow measures are different; Alternative 4 would simply eliminate the RPA flows for the Stanislaus River. D-1641 and D-1422 flow and water quality requirements would remain in place. The proposed change in OMR flow requirements in Alternative 3 is not repeated in Alternative 4.

Alternative 4 would add a series of actions relating to levees and floodplains. "Under Alternative 4, trees and shrubs would be planted along the levees; and vegetation, woody material, and root re-enforcement material would be installed on the levees instead of riprap for erosion protection." [54] In addition, Alternative 4 would limit development in Central Valley floodplains through a set of administrative and planning requirements. However, the DEIS makes no showing that these requirements would "protect salmonids and Delta smelt," and in particular would not devote a drop of additional water to activate these floodplains or transform them with more frequency or duration into anything other than officially unoccupied terrestrial habitat. On the contrary, the increment of floodplain inundation along the Stanislaus River and

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[53] East Bay MUD's trap and haul of juvenile salmon outmigrants in the Mokelumne River was initiated in the Critically Dry year 2015. In submittals and presentations to the State Water Board in 2015 drought workshops, the present commenters supported a similar effort in Sacramento River tributaries as an interim drought measure.
[54] DEIS, p. 3-39.

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CWIN CSPA 16 continued

the lower San Joaquin under the existing RPA's would be reduced by the flow reductions proposed under Alternative 4.

5. The DEIS makes no showing that the OMR flows and the Stanislaus pulse flows proposed in Alternative 5 are sufficient to protect either smelt or salmonids.

CWIN CSPA 17

Unlike Alternatives 3 and 4, whose development and definition the DEIS attributes in substantial part to irrigation districts on the Stanislaus River and the inaptly named "Coalition for a Sustainable Delta," the DEIS does not describe the derivation of Alternative 5. Alternative 5 proposes increases in Stanislaus River flows and Vernalis River pulse flows, and additionally proposes a requirement for long-term average positive OMR flows in April and May of all water year types. The Vernalis pulse flow requirements would vary depending on the location of X2; however, the DEIS provides no rationale for reducing pulse flow magnitudes based on X2 location. Except where the RPA's conflict with these measures under Alternative 5, the RPA's would otherwise be left in place (same as the No Action Alternative).

The analysis in Chapter 9 of the fisheries impacts of this alternative that was apparently designed to be beneficial to fisheries does not indicate appreciable benefit. Whether this is an artifact of modeling or the result of specific design of the alternative, the apparent lack of benefit calls into question the details of the alternative and the basis for its definition.

The present commenters, as well as the Bay Institute and the State Water Board in its *Delta Flow Criteria Report*, have made numerous recommendations that would substantially improve survival of listed and non-listed species in the Sacramento and San Joaquin rivers, their tributaries, and the Delta. The DEIS apparently made no review of these recommendations or any effort to synthesize specific recommendations or proposals that would comprehensively protect and recover listed species and other fishery resources. The organizing principle of Alternative 5 appears to be inclusion of two elements of historic recommendations at a level that would have relatively small impact on water supply. While the measures proposed in Alternative 5 might make small incremental improvements in the condition of fisheries, the DEIS makes no showing that Alternative 5 is a serious "environmental" option or that its implementation would make a substantial difference in the condition of fisheries affected by the CVP and SWP.

B. The Alternatives in the DEIS are not sufficiently distinct and are not legally or factually defensible.

CWIN CSPA 18

As described in sections 1-3 above, D-1641 and the RPA's from the USFWS and NMFS BO's (the No Action Alternative) have not protected listed species or critical habitat from the effects of project operations. Delta smelt have gone almost undetected in 2015 in the extensive sampling performed in the Delta. 95% of the 2014 cohort of winter-run Chinook did not survive to Red Bluff, and water temperature targets for the Sacramento River were again exceeded throughout the summer of 2015. Other species have exhibited precipitous declines.

CWIN CSPA 18

Alternatives 1-4 would substantially weaken the already inadequate existing RPA's. The DEIS makes no argument for how the elements analyzed in Alternatives 1-4 would individually or in aggregate improve existing conditions or protect listed species and other public trust resources. Alternative 5 would make a token, weak incremental improvement that even analysis in the DEIS suggests would do little to improve conditions affected by operation of the state and federal projects.

As discussed above, the No Action Alternative is not accurately characterized as a baseline condition that does not avoid jeopardy to listed species. Each of the other Alternatives presented in the DEIS also shares a common flaw: it would not avoid jeopardy of listed species. The DEIS must be recirculated with a range of alternatives that would achieve the project purpose of conforming to the ESA and other applicable law. A recirculated DEIS must provide the analysis that demonstrates conformance with the ESA, that shows the relative benefits of measures proposed, and that allows reasoned analysis of the best alternative or set of measures to protect fisheries and other public trust resources.

III. The stated "Purpose[s] of the Action" are in conflict.

CWIN CSPA 19

The DEIS states the Purpose of the Action as follows:

> The purpose of the action considered in this Environmental Impact Statement (EIS) is to continue the operation of the Central Valley Project (CVP), in coordination with operation of the State Water Project (SWP), for the authorized purposes, in a manner that:
>
> - Is similar to historical operational parameters with certain modifications
> - Is consistent with Federal Reclamation law; other Federal laws and regulations; Federal permits and licenses; and State of California water rights, permits, and licenses
> - Enables the Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) to satisfy their contractual obligations to the fullest extent possible.[55]

The stated purpose of satisfying contractual obligations to the "fullest extent possible" conflicts with the ESA's requirements to protect listed species and their critical habitat. It routinely jeopardizes listed species because it recklessly prioritizes deliveries to contractors over carryover storage and seeks to constantly skate on the edge of compliance with OMR constraints, making minimal protections the target level of protection. It creates systemic demand to push exports to their maximum legal limit in any given year, even when prudent operation of the system would look to following years and thus operate with a substantial margin of safety. We provide an example below.

CWIN CSPA 20

RPA Action Suite 1.2 in the NMFS BO requires a series of actions in managing Shasta Reservoir, including operations of Shasta to maintain suitable temperatures in the Sacramento River downstream of Shasta Reservoir to protect winter-run and spring-run Chinook, re-

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[55] See DEIS, p. 2-1.

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establishing winter-run Chinook in Battle Creek, and reintroducing winter-run Chinook in rivers upstream of Shasta Reservoir.[56] While re-introduction actions in Battle Creek and upstream of Shasta are clearly not included in the Second Basis of Comparison and Alternatives 1-4, it is unclear whether the operational management of Shasta required in the RPA is included in the Second Basis of Comparison and in these Alternatives.[57]

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continued

The RPA for Shasta operations requires: "Reclamation should operate in any year in which storage falls below 1.9 MAF EOS as potentially the first year of a drought sequence."[58] In discussing such circumstances, the RPA provides the following rationale:

> Notification to the State Water Resources Control Board (SWRCB) is essential. Sacramento Settlement Contract withdrawal volumes from the Sacramento River can be quite substantial during these months. The court has recently concluded that Reclamation does not have discretion to curtail the Sacramento Settlement contractors to meet Federal ESA requirements. Therefore, NMFS is limited in developing an RPA that minimizes take to acceptable levels in these circumstances. Consequently, other actions are necessary to avoid jeopardy to the species, including fish passage at Shasta Dam in the long term.[59]

Thus the RPA punts protection of winter-run to such time as a reintroduction program that achieves fish passage past Shasta Reservoir can be achieved. Passage past Shasta is clearly needed to achieve recovery of winter-run. However, immediate action is required to protect the species downstream of Shasta.

If Reclamation has no discretion to reduce deliveries to Sacramento River Settlement Contractors, then NMFS must otherwise limit discretionary actions by Reclamation to protect winter-run and spring-run and their critical habitat. Sacramento Settlement Contractors are entitled to a minimum of about 1.2 million acre-feet per year. In the face of such demands, the 1.9 million acre-feet end of September storage threshold in Shasta is too low to be protective or winter-run and spring-run, as the mass mortality of winter-run in 2014 (and likely 2015) has demonstrably proven. Thus, NMFS must modify its carryover storage thresholds and further limit discretionary exports and other discretionary deliveries from Shasta in order to protect Shasta storage and the Shasta cold water pool. The RPA cannot improperly defer to the "(n)otification to the State Water Resources Control Board" in the hope that the State Board will order reductions in deliveries to Sacramento Settlement Contractors. Indeed, despite repeated requests to the State Board in 2014 and 2015 by the present commenters and others including the Bay Institute and National Resources Defense Council, the State Board declined to limit deliveries to the Sacramento Settlement Contractors, even in the face of the loss of 95% of the 2014 cohort of Sacramento winter-run Chinook, as discussed in Section II(A)(1) of these comments, above.

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[56] See NMFS BO, p. 590 ff.

[57] As noted above in these comments, the lack of clarity about which elements of the RPA's are and are not included in the Alternatives analyzed in the DEIS is a serious flaw that must be corrected.

[58] NMFS BO, p. 597.

[59] Id., p. 600.

The Central Valley Project Improvement Act (CVPIA) made protection of fishery and other environmental resources an equal purpose of the Central Valley Project in relation to provision of water supply and other developmental purposes.[60] The DEIS's stated purpose of satisfying contractual obligations to the "fullest extent possible" also conflicts with this mandate.

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A recirculated DEIS should restate the purpose of the Proposed Action so that it is consistent with the ESA and the CVPIA, as well as with the Clean Water Act and the public trust doctrine.

IV. Modeling in the DEIS does not accurately depict actual operation in multiple dry year sequences.

CalSim II assumes full compliance with the water quality and flow standards set forth in D-1641. However, in recent dry year sequences including 2007-2009 and 2012-2013, BOR and DWR have often not met some of these standards, with the tacit or de facto approval of the State Water Board. In addition, in 2014 and 2015, BOR and DWR undertook, at their own discretion, a series of temporary urgency change petitions (TUCP's) to weaken D-1641 water quality and flow standards on a large scale.

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CalSim II also assumes that deliveries to the San Joaquin Exchange Contractors will always be met from sources north of Delta. However, in 2014 and 2015, such deliveries, to the extent they were made, were made from Millerton Reservoir on the San Joaquin River.

These modeling artifacts tend to overstate the impacts to CVP and SWP water supply, since water that is modeled as lost e.g. for salinity control is often in reality never released, because the standards are either not met or are explicitly weakened. The amount of water "conserved" because of TUCPs for the CVP and SWP was estimated by DWR to be 450,000 acre-feet in 2014[61] and 793,000 acre-feet in 2015.[62] In these circumstances, CalSim II also tends to under-report cumulative reservoir levels in CVP and SWP reservoirs with the possible exception of Millerton. Finally, CalSim II likely underestimates the impacts to fish, particularly pelagic species, because under weakened standards or conditions of non-compliance with standards, the low salinity zone in the Delta is entrained into the central Delta because of increased salinity and reduced outflow, and Delta hydrodynamics are more heavily influenced by exports. Along with the low salinity zone, Delta smelt in particular are, in such circumstances, more likely drawn into the central Delta, as are outmigrating salmon from the Sacramento River system.

Much of the socioeconomic impact analysis in Chapter 19 of the DEIS places special focus on Dry and Critical Dry years. Traditionally, water purveyors have emphasized economic impacts in dry year sequences in advocating for changes in standards or temporary weakening of

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[60] U.S.C. Title XXXIV, Sections 3402 and 3406.

[61] See http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/accounting_reports/docs/dwr2014nov_droughtacct.pdf

[62] See http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/tucp/docs/dwr2015aug_droughtacct.pdf

waiving of standards, and it is on such dry year sequences that the balance of impacts turns. To the degree that the economic analysis presented in the DEIS relies on CalSim II, the economic impacts may thus be overstated, and in particular they may be overstated in regard to the time periods that generate the greatest controversy.

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continued

V. Conclusion

BOR should recirculate the DEIS with a proposed Action and alternatives that will allow operation of the SWP and CVP to comply with the ESA and other applicable law. The recirculated DEIS should also address the additional issues raised in these comments.

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Thank you for the opportunity to comment on the *Draft Environmental Impact Statement for Coordinated Long Term Operation of the Central Valley Project and State Water Project.*

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Respectfully submitted,

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Attachment A: Complaint: Against SWRCB, USBR and DWR for Violations of Bay-Delta Plan, D-1641 Bay-Delta Plan Requirements, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution

Attachment B: COMPLAINT; Against the SWRCB and USBR for Violations of Central Valley Basin Plan, WR Order 90-05, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution

1D.1.5.1 Attachments to Comments from California Water Impact Network and California Sportfishing Protection Alliance

Attachments to the California Water Impact Network and California Sportfishing Protection Alliance Comment letter are included in Attachment 1D.2 located at the end of Appendix 1D.

1D.1.5.2 Responses to Comments from California Water Impact Network and California Sportfishing Protection Alliance

CWIN CSPA 1: Comment noted.

CWIN CSPA 2: Attachments to the California Water Impact Network and California Sportfishing Protection Alliance Comment letter are included in Attachment 1D.2 located at the end of Appendix 1D.

CWIN CSPA 3: The Council on Environmental Quality guidance describes that a "potential conflict with local or federal law does not necessarily render an alternative unreasonable, although such conflicts must be considered." Therefore, the range of alternatives considered in this EIS does include actions that are not necessarily consistent with existing federal and state requirements for the existing long-term operation of the CVP and SWP. The selection of the range of alternatives considered in the EIS was informed by several factors, including scoping comments.

CWIN CSPA 4: Comment noted.

CWIN CSPA 5: The analysis in the EIS compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for a broad range of physical, environmental, and human resources. The NEPA analysis does not determine if the alternatives would change the findings of the biological opinions in the determination of the likelihood of the alternatives to cause jeopardy to the continued existence of the species, or destroy or adversely affect their critical habitat.

CWIN CSPA 6: Historically, many water users have been cooperatively using surface water and other water supplies, such as conjunctive use that increases groundwater use when CVP and SWP water is reduced. Changes in CVP and SWP water deliveries are within the overall range of projected water supplies in related urban water management plans, as described in Appendix 5D, Municipal and Industrial Water Demands and Supplies. It is anticipated that the communities would change their reliance on alternative water supplies, such as groundwater and recycled water, as described in the urban water management plans.

As is described in Chapter 12, Agricultural Resources, the SWAP model indicated that even with the cost of groundwater pumping from greater depths, the overall agricultural production could be maintained.

The discussion in Chapter 5, Surface Water Resources and Water Supplies, discusses that future surface water supplies and groundwater supplies could be reduced due to climate change, sea level rise, and projected population growth. The EIS analysis compares conditions in 2030 under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. The EIS analysis does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions. The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. This No Action Alternative represents the current management direction and level of management intensity consistent with the explanation of the No Action Alternative included in Council of Environmental Quality's Forty Most Asked Questions (Question 3). NEPA does not require agencies to mitigate impacts, nor does it require agencies to identify mitigation associated with the No Action Alternative.

It should be noted that Figures 7.15 through 7.60 in Chapter 7, Groundwater Resources and Groundwater Quality, have been modified in the Final EIS to correct an error that increased the changes in groundwater elevation by a factor of 3.25. This miscalculation was due to an error in a model post-processor that generates the figures related to changing the values from CVHM Model output from meters to feet. Therefore, the results in these figures and the related text in Chapter 7 are less than reported in the Draft EIS. The figures and the text have been revised in the Final EIS. No changes are required to the CVHM model. The revised results in the figures and the text in Chapter 7 are consistent with the findings of the SWAP model.

CWIN CSPA 7: As discussed in the response to Comment CWIN CSPA 3, the range of alternatives considered in this EIS does include actions that are not necessarily consistent with existing federal and state requirements for the existing long-term operation of the CVP and SWP. The EIS analysis provides a comparison of incremental differences between Alternatives 1 through 5 and the No Action Alternative; and Alternatives 1 through 5 and the No Action Alternative as compared to the Second Basis of Comparison. The description of the alternatives in the comment is consistent with Chapter 3, Description of Alternatives.

CWIN CSPA 8: It is acknowledged that the condition of aquatic resources has deteriorated recently, and it is likely that the current drought in California has undoubtedly resulted in profound effects on aquatic resources, especially on those species with already declining populations. It is recognized that droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources.

CWIN CSPA 9: Reclamation acknowledges that the SWRCB has modified water quality and flow criteria over the past years in response to changing conditions of ecological and physical resources and the protection of all beneficial uses.

CWIN CSPA 10: The Draft EIS acknowledges the temperature challenges for winter-run Chinook Salmon in the Sacramento River downstream of the Shasta Dam. The Draft EIS also acknowledges the value that successfully providing upstream passage for winter-run Chinook Salmon could have for the population, especially in the long term in consideration of increasing temperatures associated with climate change (see pages 9-117 and 9-127).

The results of the impact analysis presented in Chapter 9, Fish and Aquatic Resources, indicates that due to climate change reducing snow pack and increasing air temperatures, water temperature thresholds would be exceeded frequently in the rivers downstream of CVP and SWP reservoirs under Alternatives 1 through 5, the No Action Alternative, and the Second Basis of Comparison.

CWIN CSPA 11: The EIS describes that under the No Action Alternative, benefits from implementation of the 2008 USFWS BO and 2009 NMFS BO RPA actions are anticipated to improve aquatic resources conditions. However, it must be recognized that some of the RPA actions are either under construction, or recently completed construction (e.g., Battle Creek restoration and Red Bluff Pumping Plant, respectively). Other RPA actions are still under development and are not scheduled for full development until 2020 (e.g., fish passage around CVP reservoirs). Therefore, conditions described in the Affected Environment section of Chapter 9 do not represent the anticipated conditions that would occur under the No Action Alternative by the Year 2030 with full implementation of the RPA actions.

CWIN CSPA 12: As described in the response to Comment CWIN CSPA 3, the range of alternatives considered in this EIS does include actions that are not necessarily consistent with existing federal and state requirements for the existing long-term operation of the CVP and SWP.

The EIS does indicate incremental benefits and adverse impacts of implementation of Alternatives 1 through 5 as compared to the No Action Alternative; and Alternatives 1 through 5 and the No Action Alternative as compared to the Second Basis of Comparison.

CWIN CSPA 13: Alternative 1 is included in the range of alternatives to represent an alternative without implementation of the 2008 USFWS BO and 2009 NMFS BO in accordance with the District Court Order.

CWIN CSPA 14: Alternative 2 is included in the range of alternatives to represent the initial Proposed Action as stated in the 2012 Notice of Intent for this EIS. As described in Chapter 3, Description of Alternatives, this alternative represents implementation of the RPAs that affect the CVP and SWP operations without requiring major construction.

The analysis of Alternative 2 as compared to the No Action Alternative (see pages 9-262 to 9-264 in the Draft EIS) indicates that salmonid survival could be less under Alternative 2 due to the lack of fish passage actions to move fish to portions of the Sacramento, American, and Stanislaus rivers that would provide cooler temperatures for spawning and rearing under the No Action Alternative.

Alternative 2 does not include any facilities considered under the Bay Delta Conservation Plan range of alternatives, including the California WaterFix.

The NEPA analysis in Chapter 9 of the DEIS evaluates the potential impacts on aquatic resources that could result from implementation of the various alternatives. The analysis does not evaluate compliance with ESA, which is in the purview of NMFS and USFWS. Chapter 9, however, does provide the rationale of the RPA measures (e.g., see 9.4.2.2.5, Conditions for Fish Passage) or cites the BOs where appropriate.

With regard to the fish passage at New Melones Dam, the Draft EIS (page 142) states that this measure is consistent with the recovery plan (NMFS 2014) and indicates that "salmonid survival could be less under Alternative 2 due to the lack of fish passage actions to move fish to portions of the Sacramento, American, and Stanislaus rivers that would provide cooler temperatures for spawning and rearing under the No Action Alternative" (Draft EIS, page 9-263).

CWIN CSPA 15: As described in Chapter 3, CVP operations on the Stanislaus River under Alternative 3 were suggested as part of a scoping comment.

The Weighted Useable Area methodology was not applied to the Stanislaus River analyses in Chapter 9 of the EIS.

The results of the impact analysis presented in Chapter 9 indicates that in 2030, water temperature thresholds would be exceeded frequently in the rivers downstream of CVP and SWP reservoirs under Alternative 3, the No Action Alternative, and the Second Basis of Comparison. The EIS analysis evaluates the differences in water temperatures between Alternatives 1 through 5 and the No Action Alternative and the Second Basis of Comparison and between the No Action Alternative and the Second Basis of Comparison.

The commenter's discussion of predation control effectiveness is acknowledged.

The description of the trap and haul program assumptions and methodologies presented in Chapter 9 of the Draft EIS were not extensive. Additional information has been included on the text from page 9-316 of the Draft EIS, and additional information has been provided in Appendix 9O of the Final EIS. There are no available and acceptable analytical tools that could be used to project the effectiveness of trap and haul operations primarily due to the lack of observed data. Therefore, the analysis in the EIS is qualitative.

Changes in aquatic resources due to changes in Old and Middle River flow operations under Alternative 3 as compared to the No Action Alternative and the Second Basis of Comparison are presented in Chapter 9.

Additional details have been provided in Chapter 19, Socioeconomics, related to the socioeconomics of freshwater and ocean harvest of fish.

CWIN CSPA 16: The description of Alternative 4 in this comment is consistent with the description presented in Chapter 3 of the EIS.

CWIN CSPA 17: Alternative 5 was developed including portions of scoping comments. The scoping comments suggested other methods to implement flow criteria on the San Joaquin River and to increase Delta outflow. However, the CVP and SWP reservoirs are operated in accordance with regulatory limitations, including applicable state and federal laws, regulations, and water rights first prior to deliver of water to CVP and SWP water contractors. With respect to the San Joaquin River flows, following the completion of the Vernalis Adaptive Management Program, Reclamation does not have the authority to obtain water from other sources to meet water quality requirements on the San Joaquin River. CVP and SWP operations are also constrained on methods to reduce temperatures downstream of the CVP and SWP reservoirs using reservoir storage carryover targets and temperature requirements in the 2009 NMFS BO due to requirements to meet Old and Middle River flow and Delta outflow criteria in the BOs and water rights.

Alternative 5 does include a more positive Old and Middle River flow criteria to reduce entrainment.

CWIN CSPA 18: See the response to CWIN CSPA 5.

CWIN CSPA 19: The purpose and need for the EIS includes a provision to enable Reclamation and DWR to satisfy their contractual obligations to the fullest extent possible in accordance with the authorized purposes of the CVP and SWP, as well as the regulatory limitations on CVP and SWP operations, including applicable state and federal laws and water rights.

Contract deliveries are based upon available water supplies on an annual and monthly basis after all water flow and demand requirements for applicable state and federal laws, regulations, and water rights are met. Full CVP and SWP water contract deliveries are used in the CalSim II model as a maximum delivery volume, but are only met when sufficient water is available.

CWIN CSPA 20: The Second Basis of Comparison, No Action Alternative, and Alternatives 1 through 5 include implementation of restoration actions on Battle Creek which are currently under construction.

The Second Basis of Comparison and Alternatives 1, 3, and 4 do not include Action I.2 of the 2009 NMFS BO for Shasta Lake operations.

As discussed in response to Comment CWIN CSPA 19, the CVP and SWP must operate in accordance with state water rights which reduce the ability to manage the cold water pool in Shasta Lake, especially in 2030 with increased air temperatures.

CWIN CSPA 21: As discussed in the response to Comment CWIN CSPA 19, Reclamation and DWR authorizations include methods to satisfy their contractual obligations to the fullest extent possible in accordance with the authorized purposes of the CVP and SWP, as well as the regulatory limitations on CVP and SWP operations, including applicable federal laws (e.g. Central Valley Project Improvement Act), state laws, and state water rights.

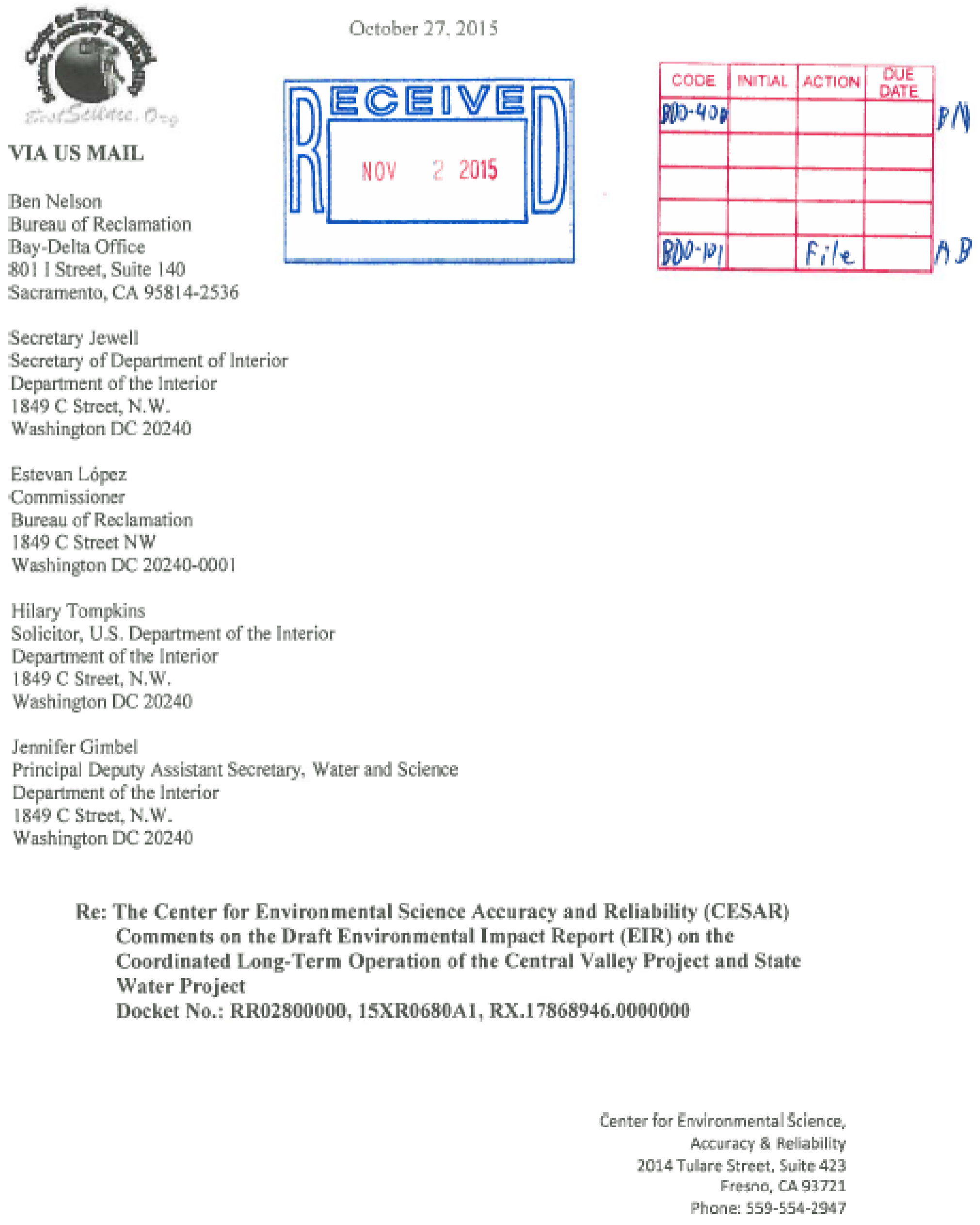
CWIN CSPA 22: The modeling analyses presented in the EIS include these prioritizations for long-term operation of the CVP and SWP using an 82-year hydrology analyzed with the CalSim II model, including delivery of Level 2 refuge water supplies in accordance with the CVPIA. This analytical approach results in low water storage elevations in CVP and SWP reservoirs and low deliveries to CVP agricultural water service contractors located to the south of the Delta in critical dry periods. The modeled operations do not include changes in SWRCB requirements intended to reduce the effects of extreme flood or drought events, such as the recent changes in CVP and SWP drought operations. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions, including recent deliveries of CVP water to the San Joaquin River Exchange Contractors.

CWIN CSPA 23: The 82-year CalSim II analysis of a range of hydrologic conditions with climate change and sea level rise in the Year 2030 provides a wide range of conditions to be evaluated in the agricultural economics analysis presented in Chapter 12, Agricultural Resources, and the municipal and industrial economic analysis presented in Chapter 19, Socioeconomics. This is especially appropriate for municipalities that project water supply resources and costs on an annual basis considering both extremely wet and extremely dry conditions that could last for multiple years. The information considered in the preparation of Chapter 19 water supply cost analysis included the urban water management plans prepared by the CVP and SWP water users which evaluated water supplies for multiple year droughts.

CWIN CSPA 24: Reclamation has modified the Final EIS in response to comments from CWIN CSPA and other commenters; and will use the Final EIS in the development of the Record of Decision.

CWIN CSPA 25: Comment noted.

1D.1.6 The Center for Environmental Science Accuracy and Reliability



October 27, 2015

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VIA US MAIL

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Re: The Center for Environmental Science Accuracy and Reliability (CESAR) Comments on the Draft Environmental Impact Report (EIR) on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project
Docket No.: RR02800000, 15XR0680A1, RX.17868946.0000000

Center for Environmental Science,
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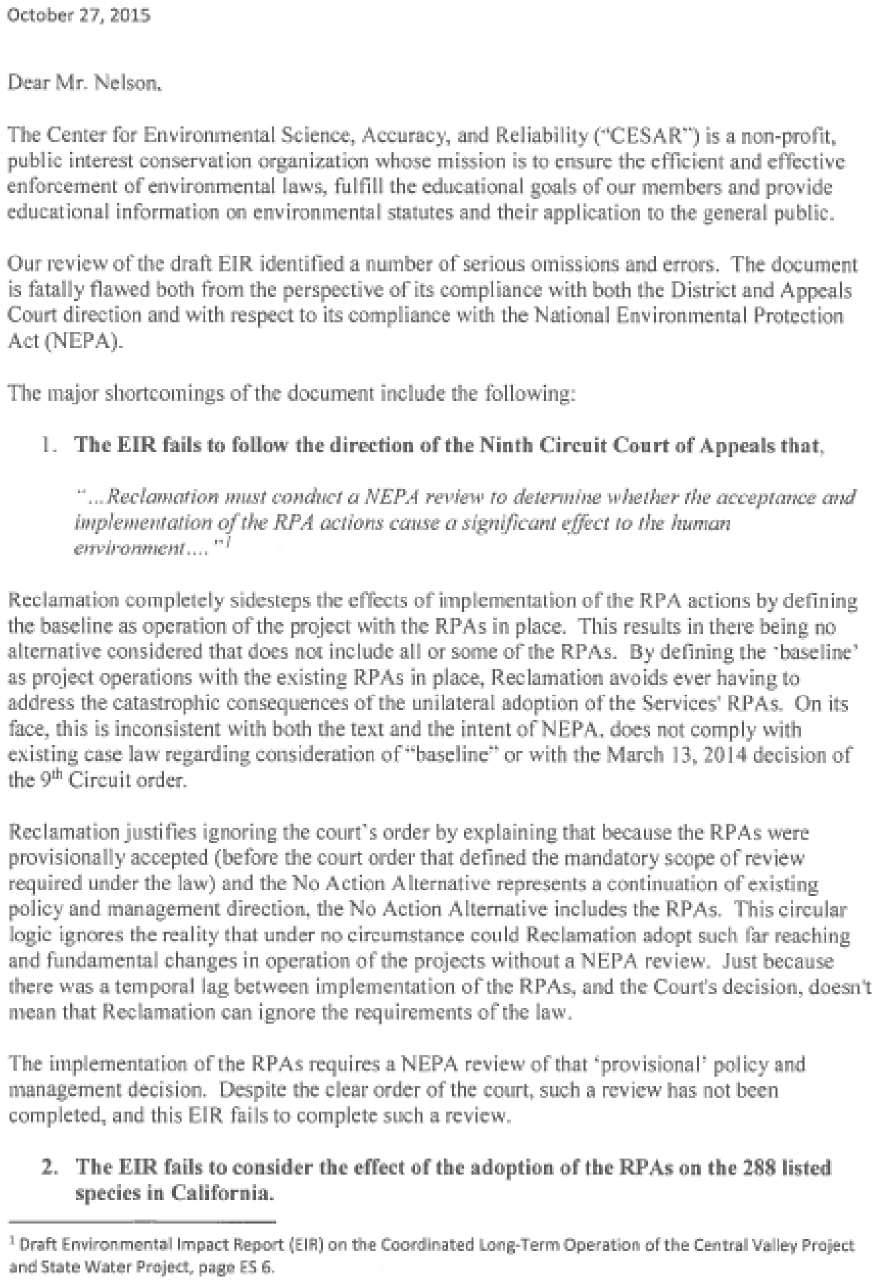

October 27, 2015

Dear Mr. Nelson,

The Center for Environmental Science, Accuracy, and Reliability ("CESAR") is a non-profit, public interest conservation organization whose mission is to ensure the efficient and effective enforcement of environmental laws, fulfill the educational goals of our members and provide educational information on environmental statutes and their application to the general public.

Our review of the draft EIR identified a number of serious omissions and errors. The document is fatally flawed both from the perspective of its compliance with both the District and Appeals Court direction and with respect to its compliance with the National Environmental Protection Act (NEPA).

The major shortcomings of the document include the following:

1. **The EIR fails to follow the direction of the Ninth Circuit Court of Appeals that,**

> *"...Reclamation must conduct a NEPA review to determine whether the acceptance and implementation of the RPA actions cause a significant effect to the human environment...."*[1]

Reclamation completely sidesteps the effects of implementation of the RPA actions by defining the baseline as operation of the project with the RPAs in place. This results in there being no alternative considered that does not include all or some of the RPAs. By defining the 'baseline' as project operations with the existing RPAs in place, Reclamation avoids ever having to address the catastrophic consequences of the unilateral adoption of the Services' RPAs. On its face, this is inconsistent with both the text and the intent of NEPA, does not comply with existing case law regarding consideration of "baseline" or with the March 13, 2014 decision of the 9th Circuit order.

Reclamation justifies ignoring the court's order by explaining that because the RPAs were provisionally accepted (before the court order that defined the mandatory scope of review required under the law) and the No Action Alternative represents a continuation of existing policy and management direction, the No Action Alternative includes the RPAs. This circular logic ignores the reality that under no circumstance could Reclamation adopt such far reaching and fundamental changes in operation of the projects without a NEPA review. Just because there was a temporal lag between implementation of the RPAs, and the Court's decision, doesn't mean that Reclamation can ignore the requirements of the law.

The implementation of the RPAs requires a NEPA review of that 'provisional' policy and management decision. Despite the clear order of the court, such a review has not been completed, and this EIR fails to complete such a review.

2. **The EIR fails to consider the effect of the adoption of the RPAs on the 288 listed species in California.**

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[1] Draft Environmental Impact Report (EIR) on the Coordinated Long-Term Operation of the Central Valley Project and State Water Project, page ES 6.

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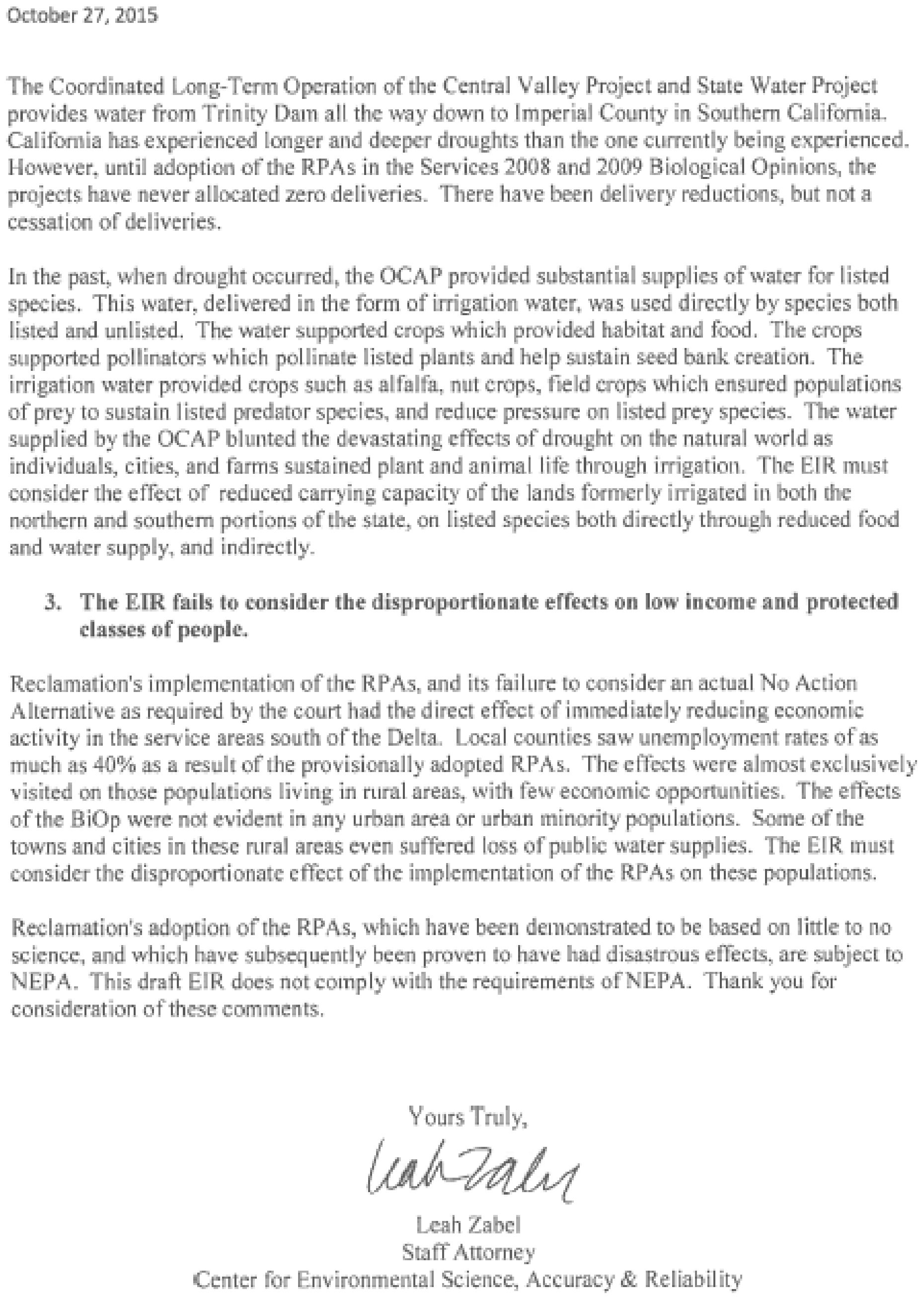


October 27, 2015

The Coordinated Long-Term Operation of the Central Valley Project and State Water Project provides water from Trinity Dam all the way down to Imperial County in Southern California. California has experienced longer and deeper droughts than the one currently being experienced. However, until adoption of the RPAs in the Services 2008 and 2009 Biological Opinions, the projects have never allocated zero deliveries. There have been delivery reductions, but not a cessation of deliveries.

In the past, when drought occurred, the OCAP provided substantial supplies of water for listed species. This water, delivered in the form of irrigation water, was used directly by species both listed and unlisted. The water supported crops which provided habitat and food. The crops supported pollinators which pollinate listed plants and help sustain seed bank creation. The irrigation water provided crops such as alfalfa, nut crops, field crops which ensured populations of prey to sustain listed predator species, and reduce pressure on listed prey species. The water supplied by the OCAP blunted the devastating effects of drought on the natural world as individuals, cities, and farms sustained plant and animal life through irrigation. The EIR must consider the effect of reduced carrying capacity of the lands formerly irrigated in both the northern and southern portions of the state, on listed species both directly through reduced food and water supply, and indirectly.

3. **The EIR fails to consider the disproportionate effects on low income and protected classes of people.**

Reclamation's implementation of the RPAs, and its failure to consider an actual No Action Alternative as required by the court had the direct effect of immediately reducing economic activity in the service areas south of the Delta. Local counties saw unemployment rates of as much as 40% as a result of the provisionally adopted RPAs. The effects were almost exclusively visited on those populations living in rural areas, with few economic opportunities. The effects of the BiOp were not evident in any urban area or urban minority populations. Some of the towns and cities in these rural areas even suffered loss of public water supplies. The EIR must consider the disproportionate effect of the implementation of the RPAs on these populations.

Reclamation's adoption of the RPAs, which have been demonstrated to be based on little to no science, and which have subsequently been proven to have had disastrous effects, are subject to NEPA. This draft EIR does not comply with the requirements of NEPA. Thank you for consideration of these comments.

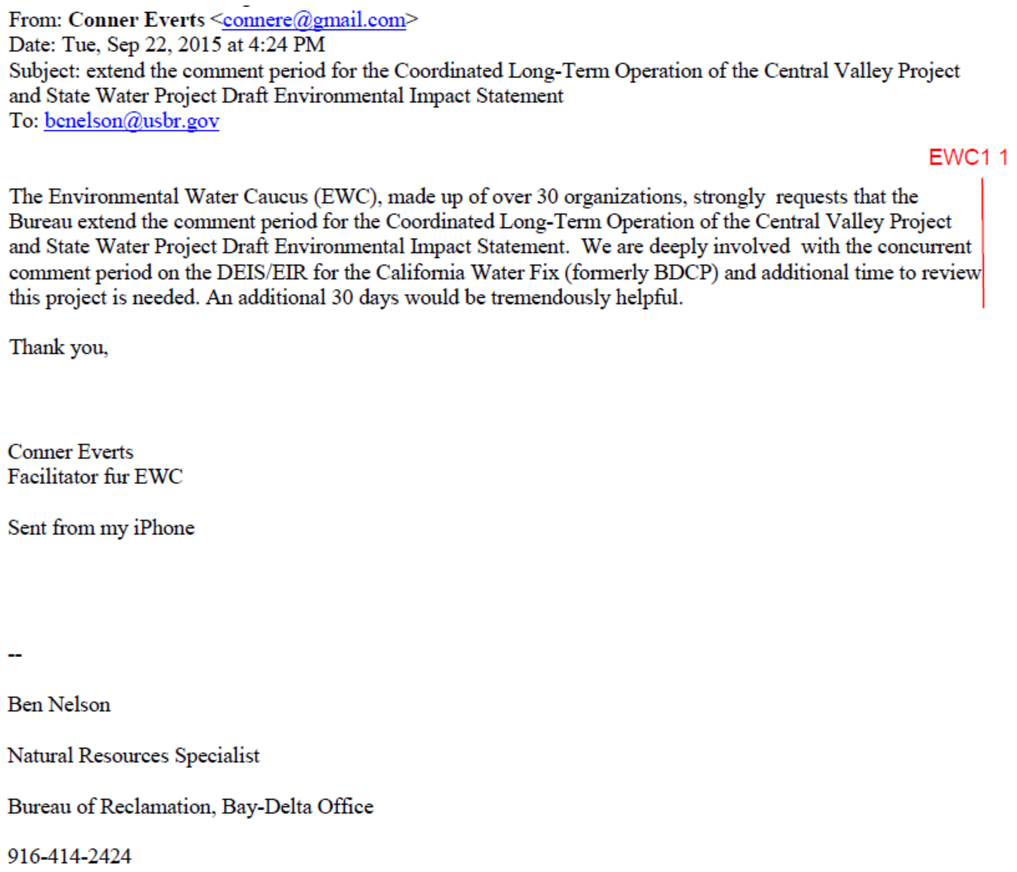
Yours Truly,

Leah Zabel
Staff Attorney
Center for Environmental Science, Accuracy & Reliability

1D.1.6.1 Responses to Comments from The Center for Environmental Science Accuracy and Reliability

The public review period for the Draft EIS ended on September 29, 2015. This letter was received on November 2, 2015, 34 days after the close of the public comment period. Therefore, specific responses were not developed for this comment letter, However, the issues discussed in this comment letter are similar to other comments received by Reclamation.

1D.1.7 Environmental Water Caucus – Number 1 Comment



From: **Conner Everts** <connere@gmail.com>
Date: Tue, Sep 22, 2015 at 4:24 PM
Subject: extend the comment period for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project Draft Environmental Impact Statement
To: bcnelson@usbr.gov

EWC1 1

The Environmental Water Caucus (EWC), made up of over 30 organizations, strongly requests that the Bureau extend the comment period for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project Draft Environmental Impact Statement. We are deeply involved with the concurrent comment period on the DEIS/EIR for the California Water Fix (formerly BDCP) and additional time to review this project is needed. An additional 30 days would be tremendously helpful.

Thank you,

Conner Everts
Facilitator fur EWC

Sent from my iPhone

--

Ben Nelson

Natural Resources Specialist

Bureau of Reclamation, Bay-Delta Office

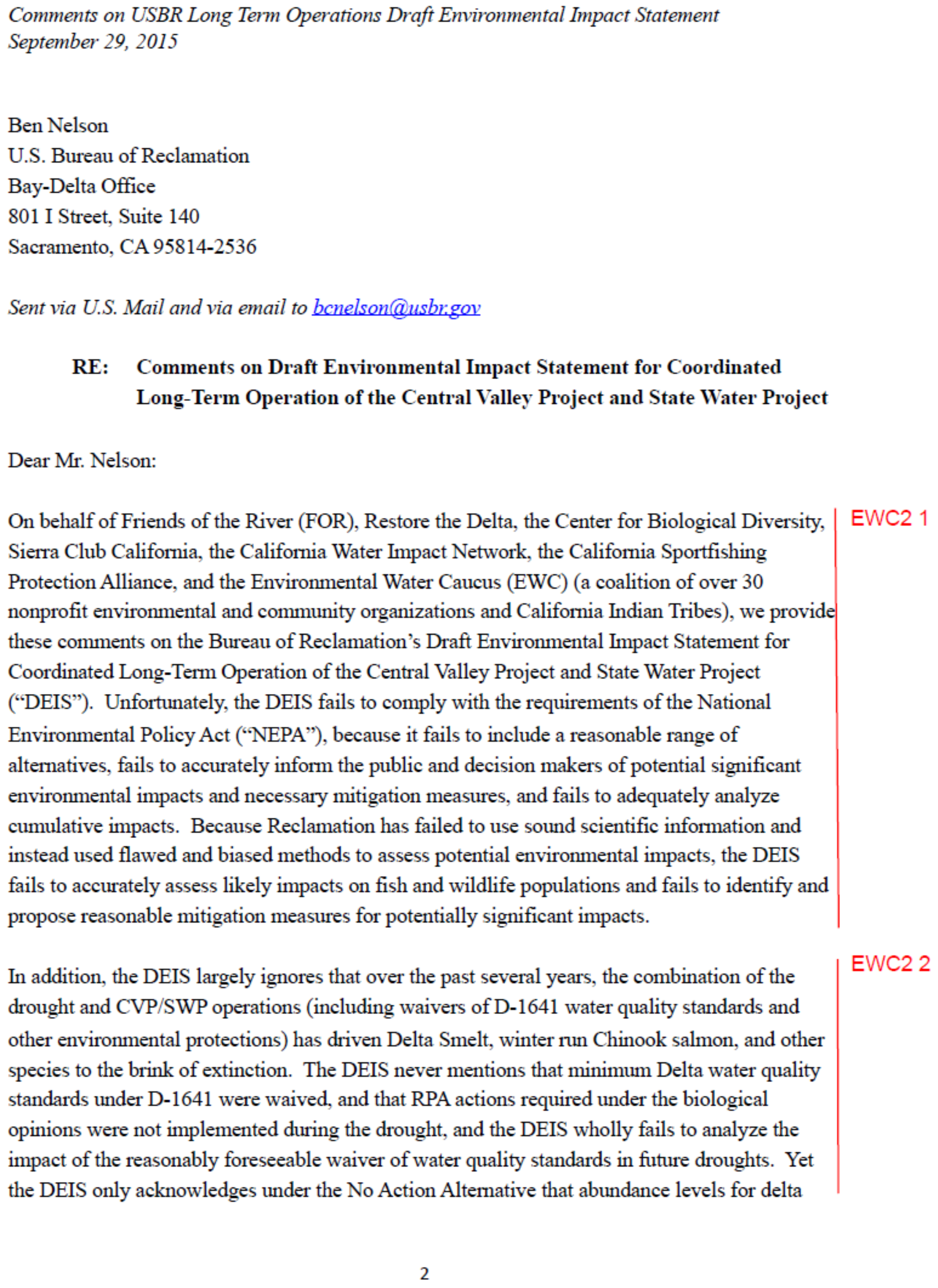
916-414-2424

1D.1.7.1 Responses to Comments from Environmental Water Caucus

EWC1 1: At the time the request for extension of the public review period was submitted, the Amended Judgement dated September 30, 2014 issued by the United States District Court for the Eastern District of California (District Court) in the *Consolidated Delta Smelt Cases* required Reclamation to issue a Record of Decision by no later than December 1, 2015. Due to this requirement, Reclamation did not have sufficient time to extend the public review period. On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to extend the public review period.

1D.1.8 Environmental Water Caucus – Number 2 Comment

ENVIRONMENTAL WATER CAUCUS COMMENTS ON
DRAFT ENVIRONMENTAL IMPACT STATEMENT ON
OPERATIONS AND CRITERIA PLAN FOR CENTRAL VALLEY
PROJECT AND STATE WATER PROJECT, SEPTEMBER 29, 2015



Comments on USBR Long Term Operations Draft Environmental Impact Statement
September 29, 2015

Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536

Sent via U.S. Mail and via email to bcnelson@usbr.gov

RE: Comments on Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Dear Mr. Nelson:

EWC2 1

On behalf of Friends of the River (FOR), Restore the Delta, the Center for Biological Diversity, Sierra Club California, the California Water Impact Network, the California Sportfishing Protection Alliance, and the Environmental Water Caucus (EWC) (a coalition of over 30 nonprofit environmental and community organizations and California Indian Tribes), we provide these comments on the Bureau of Reclamation's Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project ("DEIS"). Unfortunately, the DEIS fails to comply with the requirements of the National Environmental Policy Act ("NEPA"), because it fails to include a reasonable range of alternatives, fails to accurately inform the public and decision makers of potential significant environmental impacts and necessary mitigation measures, and fails to adequately analyze cumulative impacts. Because Reclamation has failed to use sound scientific information and instead used flawed and biased methods to assess potential environmental impacts, the DEIS fails to accurately assess likely impacts on fish and wildlife populations and fails to identify and propose reasonable mitigation measures for potentially significant impacts.

EWC2 2

In addition, the DEIS largely ignores that over the past several years, the combination of the drought and CVP/SWP operations (including waivers of D-1641 water quality standards and other environmental protections) has driven Delta Smelt, winter run Chinook salmon, and other species to the brink of extinction. The DEIS never mentions that minimum Delta water quality standards under D-1641 were waived, and that RPA actions required under the biological opinions were not implemented during the drought, and the DEIS wholly fails to analyze the impact of the reasonably foreseeable waiver of water quality standards in future droughts. Yet the DEIS only acknowledges under the No Action Alternative that abundance levels for delta

EWC2 2 continued

smelt and other fisheries "are difficult to predict" and that "Currently low levels of relative abundance do not bode well for the Delta Smelt or other fish species in the Delta." DEIS at 9-139.[1] Under the Second Basis of Comparison, the DEIS concludes that,

> As described above for the No Action Alternative, abundance levels for Delta Smelt, Longfin Smelt, Striped Bass, Threadfin Shad, and American Shad are currently very low, and abundance and habitat conditions for fish in the Delta in future years are difficult to predict. It is not likely that operations of the CVP and SWP under the Second Basis of Comparison would result in improvement of habitat conditions in the Delta or increases in populations for these fish by 2030, and the recent trajectory of loss would likely continue.

DEIS at 9-150. Despite these acknowledgements that current operations may very well lead to extinction of the species, the DEIS proposes no mitigation measures and does not even conclude that the alternatives result in significant impacts to Delta Smelt. Similarly, for longfin smelt, the DEIS ignores that current operations have resulted in the U.S. Fish and Wildlife Service concluding that listing longfin smelt under the Endangered Species Act is warranted, and continuation of existing spring outflow conditions is likely to result in adverse effects on the species. As a result, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations on Delta Smelt and longfin smelt.

EWC2 3

With respect to salmonids, the DEIS acknowledges that climate change will make it more difficult to achieve water temperature requirements with current upstream reservoir operations, impacting salmon and steelhead. *See, e.g.*, DEIS at 9-126 to 9-127. Yet the DEIS fails to conclude that these excessive temperatures constitute significant environmental impacts and fails to consider any mitigation measures.[2] During the current drought, the failure to meet minimum upstream water temperatures resulted in greater than 95% mortality of the 2014 brood year winter run Chinook salmon cohort, and may result in similar mortality for the 2015 brood year. Increased frequency, duration and intensity of upstream temperature exceedances as a result of climate change in combination with CVP/SWP operations are likely to cause significant

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[1] In part, this conclusion is based on inaccurate assessment of entrainment impacts of the Alternatives on Delta Smelt, as discussed below.

[2] In contrast, Reclamation's revised draft environmental impact statement for the California WaterFix concludes that under the No Action Alternative, upstream reservoir operations will result in significant adverse environmental impacts to winter run Chinook salmon and green sturgeon spawning and egg incubation. *See, e.g.,* USBR, CA WaterFix RDEIS/SDEIR at ES-48.

EWC2 3 continued

environmental impacts. The DEIS also fails to demonstrate whether operations of Shasta Dam under the No Action Alternative are consistent with requirements of the 2009 NOAA biological opinion, which includes performance measures and other requirements to maintain adequate cold water pool for winter run Chinook salmon below the dam. As a result, the DEIS must be revised to analyze compliance with the biological opinion and to consider changes in reservoir operations to mitigate upstream temperature impacts, including reductions in upstream water diversions and deliveries to CVP contractors, including senior contractors. EWC2 4

Despite these short term and long term impacts, the DEIS asserts that with respect to several salmon and steelhead runs, the effects of CVP/SWP operations under Alternative 1 are similar to those under the No Action Alternative and Alternative 2. *See, e.g.,* DEIS at ES-30 to ES-31, 9-397 to 9-398.[3] However, the federal courts have twice held that operations under Alternative 1 would jeopardize the continued existence and recovery of listed salmonids and steelhead, in violation of the Endangered Species Act. The DEIS therefore suggests that operations under the No Action Alternative and under Alternative 2 would also jeopardize these listed salmonid species (primarily because of upstream water temperature impacts). Yet the DEIS does not identify a significant environmental impact from these effects, and it proposes no clearly defined mitigation measures to address these impacts (except for programs for upstream fish passage at major dams, which are already required under the No Action Alternative). EWC2 5

The DEIS is fundamentally flawed, and Reclamation must revise the DEIS to analyze a broader range of alternatives using a credible methodology for assessing environmental impacts, including cumulative impacts.[4] EWC2 6

Adding insult to injury the DEIS assumes up to full contract delivery for CVP contractors. This is contrary to legal obligations required to protect fish and wildlife, and provisions of the San Luis Act, the 1986 Coordination Act and compliance with the feasibility report accompanying EWC2 7

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[3] This is at least In part because of Reclamation's flawed methodology for assessing impacts, particularly with respect to operations in the Delta..

[4] In addition, Reclamation and DWR have not complied with CEQA, and compliance with CEQA is required before the Department of Water Resources could propose any changes to State Water Project operations. Numerous additional permits and approvals would be required before authorizing any changes to operations, including requirements under the federal Endangered Species Act, California Endangered Species Act, and other state and federal laws.

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that act.[5] Assumptions must not only comply with the law, but comport with reality. Assuming up to full contract deliveries at is not realistic. And does not take into account water supply impacts due to predicted weather, rain, snow and temperature changes. EWC2 7 continued

Conclusion

As discussed above, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations, fails to consider a reasonable range of alternatives, and includes alternatives that violate Reclamation's water rights and the purpose and need statement of the DEIS. Reclamation must substantially revise the DEIS to comply with NEPA. EWC2 8

Thank you for consideration of our views.

Sincerely,

Conner Everts *Facilitator, Environmental Water Caucus* *Executive Director,* *Southern California Watershed Alliance*	*Jeff Miller* *Conservation Advocate* *Center for Biological Diversity*
Dr. C. Mark Rockwell *Pacific Coast Representative* *Endangered Species Coalition*	*Jonas Minton* *Senior Water Policy Advisor* *Planning and Conservation League*
Chief Caleen Sisk *Spirtual Leader* *Winnemen Wintu Tribe*	*Kathryn Phillips* *Director* *Sierra Club California*
Jim Martin *Conservation Director* *Berkley Conservation Institute, Pure Fishing*	*Robyn DiFalco* *Executive Director* *Butte Environmental Council*

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[5] The 1960 San Luis Act authorized irrigating only 500,000 acres in total in Merced, Fresno and Kings Counties and required fish and wildlife mitigations and compliance with the Fish and Wildlife Coordination Act's continuing jurisdiction due to impacts to salmon and fishery resources that rely on the Delta Estuary. See PL 86-488 and the feasibility report: http://cdm15911.contentdm.oclc.org/cdm/ref/collection/p15911coll10/id/2106
And Public Law 99-546 [H.R. 3113]; October 27, 1986.

Comments on USBR Long Term Operations Draft Environmental Impact Statement
September 29, 2015

Larry Hanson
Manager
California River Watch

Lloyd Carter
President
California Save Our Streams Council

Bill Jennings
Executive Director
California Sportfishing Protection Alliance

Carolee Krieger
Executive Director
California Water Impact Network

Jim Cox
President
California Striped Bass Association

Alan Levine
Director
Coast Action Group

Siobahn Dolan
Director
Desal Response Group

Colin Bailey
Executive Director
Environmental Justice Coalition for Water

Amber Shelton
Conservation Advocate
Environmental Protection Information Center

Adam Scow
California Campaign Director
Food and Water Watch

Eric Wesselman
Executive Director
Friends of the River

Roger Thomas
President
The Golden Gate Fishermen's Association

John McManus
Executive Director
Golden Gate Salmon Association

Pietro Parravano
President
Institute for Fisheries Resources

Roger Mammon
President
Lower Sherman Island Duck Club

Michael Martin, Ph.D.
Director
Merced River Conservation Committee

Lowell Ashbaugh
Vice President, Conservation
Northern California Council Federation of Fly Fishers

Frank Egger
President
North Coast Rivers Alliance

Tim Sloane
Executive Director
Pacific Coast Federation of Fishermen's Associations

Huey Johnson
Founder and President
Resource Renewal Institute

1

Comments on USBR Long Term Operations Draft Environmental Impact Statement
September 29, 2015

Barbara Barrigan-Parrilla
Executive Director
Restore the Delta

Diana Jacobs
Chair, Board of Directors
Sacramento River Preservation Trust

Lynne Plambeck
Executive Director
Santa Claritans for Planning and the Environment

Larry Collins
President
San Francisco Crab Boat Owners Association

Stephen Green
President
Save the American River Association

Dick Pool
President
Water4Fish

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1D.1.8.1 Responses to Comments from Environmental Water Caucus

EWC 2 1: Comment noted. Please see responses to Comments EWC 2 2 through EWC 2 8.

EWC 2 2: Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources.

Conditions that have led to consideration of the federal listing of Longfin Smelt are discussed on page 9-67 of the Draft EIS.

EWC 2 3: The discussion in Chapter 9, Fish and Aquatic Resources, does find that increased air temperatures and reduced snowfall would result in water temperatures that would result in substantial adverse impacts to salmonids and sturgeon in the rivers downstream of the CVP reservoirs under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 (see subsections "Changes in Exceedance of Water Temperature Thresholds" in Section 9.4.3 of Chapter 9). The EIS analysis compares conditions in 2030 under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. The EIS analysis does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions (as is presented in CEQA documents, such as the Bay Delta Conservation Plan Environmental Impact Report/Environmental Impact Statement).

The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. As described in Section 3.3, Reclamation had provisionally accepted the provisions of the 2008 USFWS BO and 2009 NMFS BO, and was implementing the BOs at the time of publication of the Notice of Intent in March 2012. Under the definition of the No Action Alternative in the National Environmental Policy Act regulations (43 CFR 46.30), Reclamation's NEPA Handbook (Section 8.6), and Question 3 of the Council of Environmental Quality's Forty Most Asked Questions, the No Action Alternative could represent a future condition with "no change" from current management direction or level of management intensity, or a future "no action" conditions without implementation of the actions being evaluated in the EIS. The No Action Alternative in this EIS is consistent with the definition of "no change" from current management direction or level of management. Therefore, the RPAs were included in the No Action Alternative as Reclamation had been implementing the BOs and RPA actions, except where enjoined, as part of CVP operations for approximately three years at the time the Notice of Intent was issued (2008

USFWS BO implemented for three years and three months, 2009 NMFS BO implemented for two years and nine months).

EWC 2 4: As has been the case in the past, Reclamation will continue to work with NMFS and other members of the Sacramento Rivers Temperature Task Group (SRTTG) to manage water temperature in Sacramento River to maximize benefits for the species. However, it should be noted that meeting such objectives may not be possible given current regulatory environment.

The 2009 NMFS BO was written in consideration of project operations as described in the 2008 BA. Since 2008, the projects have been operating to 2008 USFWS and 2009 NMFS RPA actions. These actions include maintaining Old and Middle River flows at certain levels during December through June, increased closure of the Delta Cross Channel compared to those of previous requirements per SWRCB D-1641, export limitations in April and May based on San Joaquin flow at Vernalis, and increased Delta outflow in fall months following wet and above normal years. All of these actions affect project operations and result in increased reservoir releases. These effects include a shift in export patterns from spring to summer months that causes more water to be released from the reservoirs than that is being exported to meet the Delta water quality standards during a season where Delta is more saline, an increased need in supply from the Sacramento River in April and May since San Joaquin River supply is limited, and increased reservoir releases in fall months following wet and above normal years. Therefore, this reduction in flexibility to use available water supply in most efficient way for water supply and water quality needs further limits possibility of meeting storage and temperature performance requirements on upper Sacramento River (namely NMFS BO Actions 1.2.1, 1.2.2, 1.2.3, and 1.2.4.).

These NMFS BO RPA actions (namely NMFS BO Actions 1.2.1, 1.2.2, 1.2.3, and 1.2.4.) are included and benefits are acknowledged in the No Action Alternative, Alternative 2, and Alternative 5; however, in this Draft EIS, it cannot be assumed that full benefits of storage performance criteria would be achieved due to reasons explained above.

More details have been included in Section 9.4.3 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to qualitatively respond to RPA actions not included in the CalSim II model in the No Action Alternative and Alternatives 2 and 5.

EWC 2 5: The EIS analysis is based upon the comparison of conditions in 2030 under different alternatives. The results of those comparisons related to water temperatures show relatively minimal changes under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. However, as described in the response to Comment EWC 2 3, the water temperatures in the rivers downstream of the CVP reservoirs would result in substantial adverse impacts to salmonids and sturgeon under Alternatives 1, 2, 3, and 4 and the Second Basis of Comparison without the addition of fish passage methods that are included in the No Action Alternative and Alternative 5.

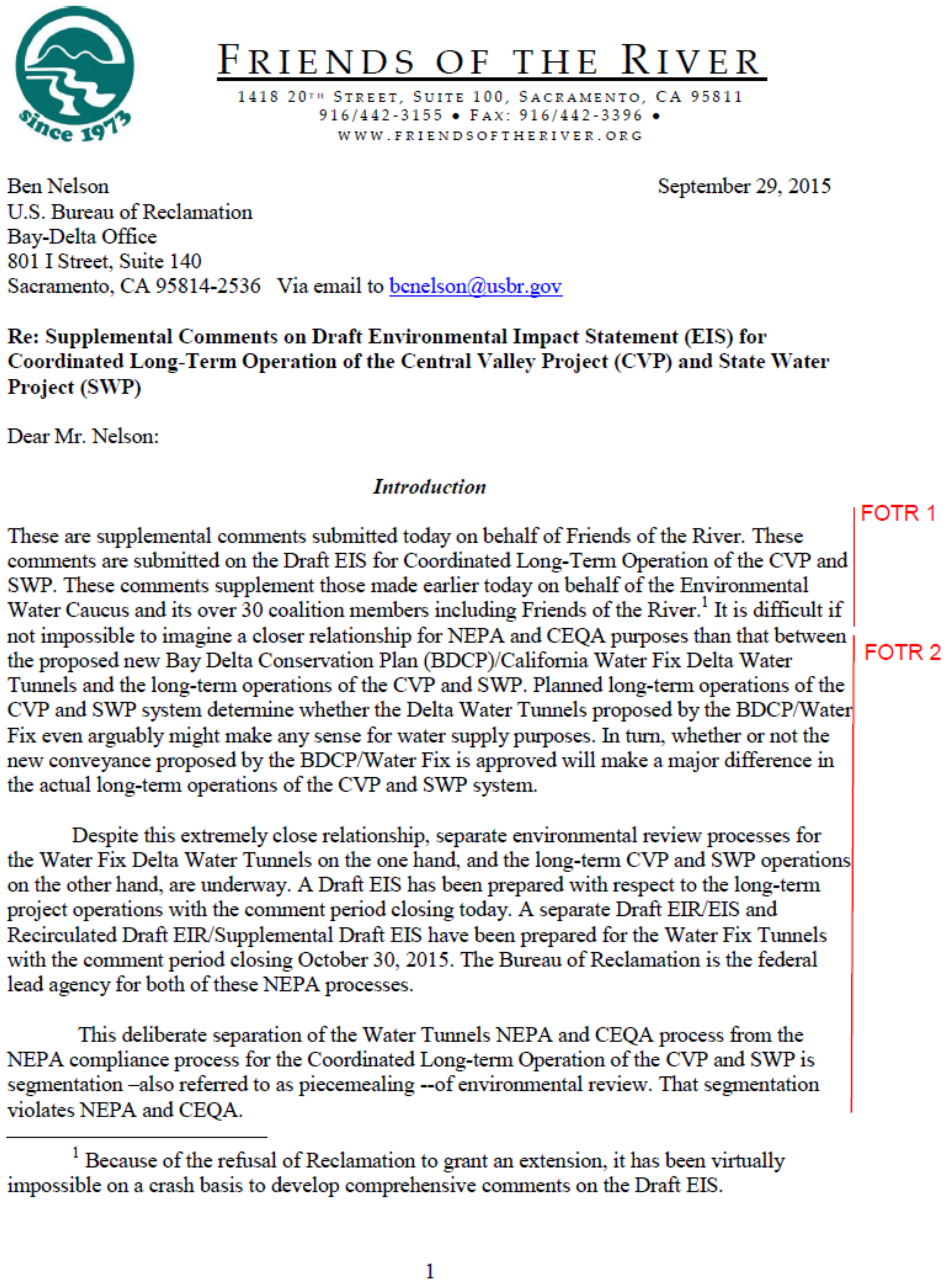
The CVP and SWP reservoirs are operated in accordance with regulatory limitations, including applicable state and federal laws, regulations, and water rights first prior to deliver of water to CVP and SWP water contractors. The CVP and SWP cannot choose to meet the applicable state and federal laws, regulations, and water rights; and, it is not possible to fully meet the temperature thresholds downstream of the CVP and SWP reservoirs in 2030 with climate change. Therefore, fish passage around the CVP and SWP reservoirs is considered to provide habitat with appropriate water temperatures for early lifestages.

EWC 2 6: The analysis in the EIS compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for the range of physical, environmental, and human resources.

EWC 2 7: Contract deliveries are based upon available water supplies on an annual and monthly basis after all water flow and demand requirements for applicable state and federal laws, regulations, and water rights are met. Full CVP and SWP water contract deliveries are used in the CalSim II model as a maximum delivery volume, but are only met when sufficient water is available.

EWC 2 8: Reclamation has modified the Final EIS in response to comments from EWC and other commenters; and will use the Final EIS in the development of the Record of Decision.

1D.1.9 Friends of the River



FRIENDS OF THE RIVER
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Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536 Via email to bcnelson@usbr.gov

September 29, 2015

Re: Supplemental Comments on Draft Environmental Impact Statement (EIS) for Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP)

Dear Mr. Nelson:

Introduction

FOTR 1

These are supplemental comments submitted today on behalf of Friends of the River. These comments are submitted on the Draft EIS for Coordinated Long-Term Operation of the CVP and SWP. These comments supplement those made earlier today on behalf of the Environmental Water Caucus and its over 30 coalition members including Friends of the River.[1] It is difficult if not impossible to imagine a closer relationship for NEPA and CEQA purposes than that between the proposed new Bay Delta Conservation Plan (BDCP)/California Water Fix Delta Water Tunnels and the long-term operations of the CVP and SWP. Planned long-term operations of the CVP and SWP system determine whether the Delta Water Tunnels proposed by the BDCP/Water Fix even arguably might make any sense for water supply purposes. In turn, whether or not the new conveyance proposed by the BDCP/Water Fix is approved will make a major difference in the actual long-term operations of the CVP and SWP system.

FOTR 2

Despite this extremely close relationship, separate environmental review processes for the Water Fix Delta Water Tunnels on the one hand, and the long-term CVP and SWP operations on the other hand, are underway. A Draft EIS has been prepared with respect to the long-term project operations with the comment period closing today. A separate Draft EIR/EIS and Recirculated Draft EIR/Supplemental Draft EIS have been prepared for the Water Fix Tunnels with the comment period closing October 30, 2015. The Bureau of Reclamation is the federal lead agency for both of these NEPA processes.

This deliberate separation of the Water Tunnels NEPA and CEQA process from the NEPA compliance process for the Coordinated Long-term Operation of the CVP and SWP is segmentation –also referred to as piecemealing --of environmental review. That segmentation violates NEPA and CEQA.

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[1] Because of the refusal of Reclamation to grant an extension, it has been virtually impossible on a crash basis to develop comprehensive comments on the Draft EIS.

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The Segmentation of Environmental Review of long-term Operations from the Proposed Delta Water Tunnels Violates NEPA and CEQA

FOTR 2 continued

The NEPA Regulations are codified at title 40 of the Code of Federal Regulations (C.F.R.). The NEPA Regulations specify that "Agencies shall make sure the proposal which is the subject of an environmental impact statement is properly defined. . . Proposals or parts of proposals which are related to each other closely enough to be, in effect, a single course of action shall be evaluated in a single impact statement." (40 C.F.R. § 1502.4(a). [2]

Pursuant to NEPA Regulation 40 C.F.R. § 1508.25(a), multiple federal actions must be evaluated in the same environmental impact statement if they are connected, cumulative, or similar. Here, the long-term operations on the one hand, and proposed Delta Water Tunnels on the other hand, are all three. They are connected, cumulative, and similar. To assist the Bureau in complying with NEPA, we include the full text of the Regulation in the footnote.[3]

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[2] In <u>City of Rochester v. U.S. Postal Serv.</u>, 541 F.2d 967, 972-73 (2d Cir. 1976), the court explained that:

> To permit noncomprehensive consideration of a project divisible into smaller parts, each of which taken alone does not have a significant impact but which taken as a whole has cumulative significant impact would provide a clear loophole in NEPA. [citations omitted]. The guidelines of the Council on Environmental Quality make it clear that the statutory term "major Federal actions" must be assessed "with a view to the overall, cumulative impact of the action proposed, related Federal action and projects in the area, and further actions contemplated." 40 C.F.R. s 1500.6(a) (1975). The transfer decision is plainly a consequential, if not an inseparable, feature of the construction project.

[3] 40 C.F.R. § 1508.25. Scope consists of the range of actions, alternatives, and impacts to be considered in an environmental impact statement. The scope of an individual statement may depend on its relationships to other statements (§§ 1502.20 and 1508.28). To determine the scope of environmental impact statements, agencies shall consider 3 types of actions, 3 types of alternatives, and 3 types of impacts. They include:

(a) Actions (other than unconnected single actions) which may be: (1) Connected actions, which means that they are closely related and therefore should be discussed in the same impact statement. Actions are connected if they: (i) Automatically trigger other actions which may require environmental impact statements. (ii) Cannot or will not proceed unless other actions are taken previously or simultaneously. (iii) Are interdependent parts of a larger action and depend on the larger action for their justification.

(2) Cumulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement.

(3) Similar actions, which when viewed with other reasonably foreseeable or proposed agency actions, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography. An agency may wish to analyze these actions in the same impact statement. It should do so when the best way to

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FOTR 2 continued

The NEPA Regulations also require that agencies "Integrate the requirements of NEPA with other planning and environmental review procedures required by law or by agency practice so that all such procedures run concurrently rather than consecutively." § 1500.2(c). *See also* § 1501.2 ("Agencies shall integrate the NEPA process with other planning at the earliest possible time to insure that planning and decisions reflect environmental values, to avoid delays later in the process, and to head off potential conflicts.").

The rules under CEQA are similar to those under NEPA in prohibiting segmenting environmental review. CEQA requires that "an agency must use its best efforts to find out and disclose all that it reasonably can" about a project being considered and its environmental impacts. *Vineyard Area Citizens v. City of Rancho Cordova*, 40 Cal.4th 412, 428 (2007). Under CEQA a "project" is defined as "the whole of an action, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment. . ." 14 Code Cal. Regs (CEQA Guidelines) § 15378(a). The courts have explained that:

> Theoretical independence is not a good reason for segmenting environmental analysis of the two matters. Doing so runs the risk that some environmental impacts produced by the way the two matters combined or interact might not be analyzed in the separate environmental reviews. Furthermore, if the two matters are analyzed in sequence (which was a situation here) and the combined or interactive environmental effects are not fully recognized until review of the second matter, the opportunity to implement effective mitigation measures as part of the first matter may be lost. *Tuolumne County Citizens for Responsible Growth v. City of Sonora*, 155 Cal.App.4th 1214, 1230 (2007).

Preparing separate environmental impact statements for long-term operation of the CVP and SWP, and the Delta Water Tunnels proposed by the BDCP/Water Fix in the Delta is unlawful segmentation of environmental review under NEPA.

To be crystal clear, if the Bureau of Reclamation proceeds with these separate environmental review processes, the Bureau is truly proceeding in the face of "red flags flying." The U.S. Environmental Protection Agency (EPA) commented last year during the BDCP environmental review process that:

FOTR 3

> <u>Upstream/Downstream Impacts</u>
>
> The Federal and State water management systems in the Delta are highly interconnected, both functionally and physically. The Draft EIS does not address how changes in the Delta can affect resources in downstream waters, such as San Francisco Bay, and *require changes in upstream operations, which may result in indirect environmental impacts that*

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assess adequately the combined impacts of similar actions or reasonable alternatives to such actions is to treat them in a single impact statement.

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FOTR 3 continued

> *must also be evaluated.* We recommend that the Supplemental Draft EIS include an analysis of upstream and downstream impacts. (EPA comments on Draft Environmental Impact Statement for the Bay Delta Conservation Plan, San Francisco Bay Delta, California (CEQ# 20130365), p. 3, August 26, 2014)(emphasis added). [4]

FOTR 4

There would be no proposal to develop the massive and expensive Delta Water Tunnels if there were not to be long-term CVP and SWP operations. Likewise, long-term CVP and SWP long-term operations will be vastly different depending on whether or not the Delta Water Tunnels are developed. The Introduction to the Water Fix RDEIR/SDEIS includes among the Water Tunnels project objectives;

> Restore and protect the ability of the SWP and CVP to deliver up to full contract amounts, when hydrologic conditions result in the availability of sufficient water, consistent with the requirements of state and federal law and the terms and conditions of water delivery contracts held by SWP contractors and certain members of San Luis Delta Mendota Water Authority, and other existing applicable agreements. (Water Fix RDEIR/SDEIS Introduction, p. 1-9).

To proceed in the manner required by NEPA (and CEQA), the Bureau of Reclamation must cease these two separate environmental review processes. The Bureau of Reclamation must instead prepare and issue for public review one new Draft EIS/EIR comprehensively analyzing in one environmental review process and one Draft EIS the environmental impacts of both the Coordinated Long-Term Operation of the CVP and SWP and the proposed BDCP/Water Fix Delta Water Tunnels. Because of the segmentation, the Draft EIS is "so inadequate as to preclude meaningful analysis" in violation of NEPA. 40 C.F.R. § 1502.9(a).

Conclusion

The Bureau of Reclamation, in order to comply with NEPA, must prepare and issue for public and decision-maker review and comment one Draft EIS on both the coordinated long-term operation of the CVP and SWP, and the proposed BDCP Water Fix Delta Water Tunnels.

Sincerely,

/s/ E. Robert Wright
Senior Counsel
Friends of the River

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[4] In its detailed comments attached to the letter, EPA further explained that:

> The Draft EIS does not include a comprehensive description of the CVP and SWP with and without new North Delta intake facilities or through-Delta operations. Such information as needed to assist the reader in understanding how the water delivery system operates under Existing Conditions and how it would change under CM1 [Delta Water Tunnels] alternatives. (Detailed Comments, p. 22).

1D.1.9.1 Responses to Comments from Friends of the River

FOTR 1: Comment noted. Please see responses to the Environmental Water Caucus Letter Number 2 in Section 1D.1.7 of this appendix.

FOTR 2: This EIS addresses the coordinated long-term operation of the CVP and SWP with existing facilities. As described in Section 1.6 of Chapter 1, Introduction, of the Draft EIS, it is anticipated that substantial changes could occur to CVP and SWP operations as future projects are implemented. It is anticipated that most of these future projects have been identified in Section 3.5 of Chapter 3, Description of Alternatives, including the Bay Delta Conservation Plan (BDCP) which includes the WaterFix as one of the BDCP alternatives. Many of these future projects have not been fully defined and are not anticipated to be operational until the late 2020s. For example, operations of the BDCP has been estimated to not occur until at least 10 years following completion of the planning documents in 2016 (see Appendix 8A, Implementation Costs Supporting Materials, of the Draft Bay Delta Conservation Plan published in 2013).

If any of these future projects would substantially change CVP operations, Reclamation would evaluate the need to request for initiation of consultation under the Endangered Species Act (ESA) with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NFMS). For example, a separate consultation is being requested by Reclamation under Section 7 of the ESA for the WaterFix. Following this and/or other new ESA consultations on future projects, coordinated long-term operation of the CVP and SWP described in the Preferred Alternative for this EIS and set forth in the Record of Decision, may or may not be revised and alternative operating parameters be put in place. As described in Chapter 1, that is the reason that the study period for this EIS concludes around 2030.

Because the future operations under future projects (including the WaterFix) have not been finalized at this time; and because projects that would substantially change CVP operations would require future consultations with USFWS and NMFS, it would be pre-decisional to include these projects in the alternatives evaluated in this EIS. This approach does not lead to segmentation of the analyses because the analyses are sequential, and not concurrent.

Reclamation is the lead agency for this action and the environmental document; therefore, the environmental document is being prepared only under the National Environmental Policy Act. Several State of California agencies are cooperating agencies for this EIS. Because compliance with the California Environmental Quality Act (CEQA) would be under DWR’s purview, Reclamation consulted with DWR on this comment. On October 5, 2015, DWR provided the following response: “The District Court required Reclamation to comply with NEPA on the provisional acceptance of the RPA actions. There is no action for the State of California requiring California Environmental Quality Act (CEQA) review.”

FOTR 3: This comment is a comment provided by the U.S. Environmental Protection Agency on the BDCP Draft Environmental Impact Report/EIS, and not on this EIS. This EIS does evaluate the effects of the coordinated long-term operation of the CVP and SWP on areas located upstream and downstream of the Delta, as described in Section 1.5 of Chapter 1, Introduction, of the Draft EIS.

FOTR 4: The CVP and SWP will be operated in accordance with the Preferred Alternative set forth in the Record of Decision for this EIS until future projects are implemented, such as the BDCP. As described in Response to Comment FOTR 2, prior to implementation of future projects, separate environmental documentation would be completed; and, if substantial changes in operation of the CVP occur, separate ESA consultations would be required. The projects that have been identified but not fully defined at this time (including BDCP/WaterFix) are included in the EIS analysis through a cumulative effects analysis in Chapters 5 through 21. Due to the possibility of these future projects, the study period for this EIS is considered to extend only to the 2030 time period.

1D.1.10 Golden Gate Salmon Association and Pacific Coast Federation of Fishermen's Association

GoldenGate
Salmon Association

PACIFIC COAST FEDERATION OF FISHERMEN'S ASSOCIATIONS
PCFFA
STEWARDS OF THE FISHERIES

September 29, 2015

Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536

Sent via U.S. Mail and via email to bcnelson@usbr.gov

RE: Comments on Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Dear Mr. Nelson:

On behalf of the Golden Gate Salmon Association and the Pacific Coast Federation of Fishermen's Associations, we provide these comments on the Bureau of Reclamation's Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project ("DEIS"). Unfortunately, the DEIS fails to comply with the requirements of the National Environmental Policy Act ("NEPA"), because it fails to include a reasonable range of alternatives, fails to accurately inform the public and decision makers of potential significant environmental impacts and necessary mitigation measures, and fails to adequately analyze cumulative impacts. Because Reclamation has failed to use sound scientific information and instead used flawed and biased methods to assess potential environmental impacts, the DEIS fails to accurately assess likely impacts on fish and wildlife populations and fails to identify and propose reasonable mitigation measures for potentially significant impacts.

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1. The DEIS Fails to Accurately Assess Environmental Impacts to Fish and Wildlife

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The DEIS largely ignores that over the past several years, the combination of the drought and CVP/SWP operations (including waivers of D-1641 water quality standards and other environmental protections) has driven delta smelt, winter run Chinook salmon, and other species to the brink of extinction. The DEIS never mentions that minimum Delta water quality standards under D-1641 were waived, and that RPA actions required under the biological opinions were not implemented during the drought, and the DEIS wholly fails to analyze the impact of the reasonably foreseeable waiver of water quality standards in future droughts. Yet the DEIS only acknowledges under the No Action Alternative that abundance levels for delta smelt and other fisheries "are difficult to predict" and that "Currently low levels of relative abundance do not bode well for the Delta Smelt or other fish species in the Delta." DEIS at 9-139.[1] Under the Second Basis of Comparison, the DEIS concludes that,

> As described above for the No Action Alternative, abundance levels for Delta Smelt, Longfin Smelt, Striped Bass, Threadfin Shad, and American Shad are currently very low, and abundance and habitat conditions for fish in the Delta in future years are difficult to predict. It is not likely that operations of the CVP and SWP under the Second Basis of Comparison would result in improvement of habitat conditions in the Delta or increases in populations for these fish by 2030, and the recent trajectory of loss would likely continue.

DEIS at 9-150. Despite these acknowledgements that current operations may very well lead to extinction of the species, the DEIS proposes no mitigation measures and does not even conclude that the alternatives result in significant impacts to delta smelt. Similarly, for longfin smelt, the DEIS ignores that current operations have resulted in the U.S. Fish and Wildlife Service concluding that listing longfin smelt under the Endangered Species Act is warranted, and continuation of existing spring outflow conditions is likely to result in adverse effects on the species. As a result, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations on delta smelt and longfin smelt. All of this bodes poorly for the salmon that the commercial and recreational salmon fishing industry needs to survive. We strongly urge Reclamation to work with the National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and U.S. Environmental Protection Agency to address these scientific and analytic flaws.

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The DEIS fails to consider an alternative that includes increased investments in local and regional water supplies. It fails to accurately assess the likely socioeconomic impacts of

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[1] In part, this conclusion is based on inaccurate assessment of entrainment impacts of the Alternatives on Delta Smelt, as discussed below.
[2] In contrast, Reclamation's revised draft environmental impact statement for the California

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GGSA PCFFA 3 continued

increased restrictions on ocean salmon fishing in Alternatives 3 and 4. It also fails to include any operational measures to adapt to climate change and mitigate its effects upstream.

GGSA PCFFA 4

GGSA PCFFA 5

With respect to salmon, the DEIS acknowledges that climate change will make it more difficult to achieve water temperature requirements with current upstream reservoir operations, resulting in impacts to salmon and steelhead. *See, e.g.*, DEIS at 9-126 to 9-127. Yet the DEIS fails to conclude that these temperance exceedances constitute a significant environmental impacts and fails to consider any mitigation measures.[2] During the current drought, the failure to meet minimum upstream water temperatures resulted in greater than 95 percent mortality of the 2014 brood year winter run Chinook salmon and probably as much, or more, of the fall run salmon our industry relies on. Failure to adequately forecast and manage upstream reservoirs may result in similar mortality for the 2015 brood year. Increased frequency, duration and intensity of upstream temperature exceedances as a result of climate change in combination with CVP/SWP operations are likely to cause significant environmental impacts. The DEIS also fails to demonstrate whether operations of Shasta Dam under the No Action Alternative are consistent with requirements of the 2009 NOAA biological opinion, which includes performance measures and other requirements to maintain adequate cold water pool for winter run Chinook salmon below the dam. As a result, the DEIS must be revised to analyze compliance with the biological opinion and to consider changes in reservoir operations to mitigate upstream temperature impacts.

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GGSA PCFFA 7

Despite these short and long term impacts, the DEIS asserts that with respect to several salmon and steelhead runs, the effects of CVP/SWP operations under Alternative 1 are similar to those under the No Action Alternative and Alternative 2. *See, e.g.,* DEIS at ES-30 to ES-31, 9-397 to 9-398.[3] However, the federal courts have twice held that operations under Alternative 1 would jeopardize the continued existence and recovery of listed salmonids and steelhead, in violation of the Endangered Species Act. The DEIS therefore suggests that operations under the No Action Alternative and under Alternative 2 would also jeopardize these listed salmon species (primarily because of upstream water temperature impacts). Yet the DEIS does not identify a significant environmental impact from these effects, and it proposes no clearly defined mitigation measures to address these impacts (except for programs for upstream fish passage at major dams, which are already required under the No Action Alternative).

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[2] In contrast, Reclamation's revised draft environmental impact statement for the California WaterFix concludes that under the No Action Alternative, upstream reservoir operations will result in significant adverse environmental impacts to winter run Chinook salmon and green sturgeon spawning and egg incubation. *See, e.g.,* USBR, CA WaterFix RDEIS/SDEIR at ES-48.

[3] This is at least In part because of Reclamation's flawed methodology for assessing impacts, particularly with respect to operations in the Delta..

The DEIS is fundamentally flawed, and Reclamation must revise the DEIS to analyze a broader range of alternatives using a credible methodology for assessing environmental impacts, including cumulative impacts.[4]

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Adding insult to injury, the DEIS assumes up to full contract delivery for CVP contractors. This is contrary to existing legal obligations to protect fish and wildlife, as well as provisions of the San Luis Act and compliance with the feasibility report accompanying that act.[5] Assumptions must not only comply with the law but comport with reality. Assuming up to full contract deliveries is not realistic.

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In general, Chapter 9 fails to utilize recent scientific information and utilizes outdated and inaccurate models to assess potential impacts to fish and wildlife populations. As a result, the DEIS fails to accurately assess the likely environmental impacts of the alternatives on fish and wildlife and significantly understates the environmental impacts of some alternatives.

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As with the pelagic species discussed above, the DEIS omits numerous recent scientific studies and analyses, particularly studies that indicate significant impacts of water project operations on salmonid survival and abundance. For instance, recent life cycle models for fall run Chinook salmon and spring run Chinook salmon have been developed and submitted to the Delta Science Program, which conclude that CVP/SWP delta exports significantly reduce spring and fall run salmon survival and abundance. *See* Cunningham *et al* 2015. In addition, Michel *et al* 2015 was recently published in the Canadian Journal of Fisheries and Aquatic Sciences, which reviews five years of acoustic tag data and demonstrates that increased flows dramatically increase survival of migrating salmon through the Sacramento River and Delta. These studies contradict many of the methods and models utilized by Reclamation in the DEIS to assess impacts, such as the Delta Passage model (which predicts very minimal changes in survival and abundance despite significant changes in exports and Old and Middle River reverse flows) and SALMOD.1

For example, Cunningham et al 2015 estimates that increasing exports by 30% above the 1967-2010 average would result in a 16-28% lower median survival rate from egg to adulthood for wild fall run chinook salmon and a 39-59% reduction in median survival for spring run Chinook salmon, concluding that, "[a] 30% increase in exports decreased spring and fall stock survival to the point where they would all decline regardless of the climate scenario." In contrast, the Delta

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[4] In addition, Reclamation and DWR have not complied with CEQA, and compliance with CEQA is required before the Department of Water Resources could propose any changes to State Water Project operations. Numerous additional permits and approvals would be required before authorizing any changes to operations, including requirements under the federal Endangered Species Act, California Endangered Species Act, and other state and federal laws.

[5] The 1960 San Luis Act authorized irrigating only 500,000 acres in Merced, Fresno and Kings Counties and providing fish and wildlife benefits and compliance with the Fish and Wildlife Coordination Act continuing jurisdiction. See PL 86-488 and http://cdm15911.contentdm.oclc.org/cdm/ref/collection/p15911coll10/id/2106

Passage Model predicts "very similar estimates of survival" for spring and fall run Chinook salmon under the No Action Alternative compared to the Second Basis of Comparison, despite the substantial increase in exports under the Second Basis of Comparison. *See* DEIS at 9-169, 9-178.

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In addition, the Delta Passage Model only attempts to estimate survival of salmon smolts, *see* DEIS Appendix 9J at 9J-1, and cannot assess impacts to salmon fry or parr. Yet fry and parr life stages are often the majority of salmon migrating through the Delta, and the DEIS wholly ignores the impacts of CVP/SWP operations on these salmonid life histories.

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Similarly, the DEIS fails to explain the contradictory information from use of the OBAN life cycle model and the Delta Passage Model on salmon survival through the Delta. On page 9-162, the DEIS states that the Delta Passage Model results in similar winter run Chinook salmon survival through the Delta under the No Action Alternative and the Second Basis of Comparison, and on the same page it states that the OBAN life cycle model predicts that median survival through the Delta would be 12 percent higher under the No Action Alternative compared to the Second Basis of Comparison. The DEIS provides no justification for its statement that the OBAN model's survival estimates "suggest a high probability of no difference between these two bases of comparison." DEIS at 9-162. In fact, the model demonstrates a very substantial difference in survival between the two alternatives, and Reclamation's conclusory statement is arbitrary and capricious.

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As a result, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations in the Delta on migrating salmonids, and the conclusions drawn in the DEIS are arbitrary and capricious.

2. The DEIS Fails to Accurately Assess Upstream Water Temperature Impacts to Salmon

The DEIS' analysis of upstream temperature impacts on salmon is flawed and understates the adverse impacts of CVP/SWP operations on salmon (particularly in combination with climate change), and the DEIS fails to explicitly acknowledge that CVP/SWP operations cause significant adverse impacts and to propose mitigation measures to address these impacts in the short term. Reclamation's conclusions in the DEIS are arbitrary and capricious.

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Even using flawed methodology, the DEIS demonstrates that there will be significant adverse effects on salmon from high water temperatures as a result of climate change and CVP/SWP operations, including under the No Action Alternative:

> Under the No Action Alternative, the ability to control water temperatures depends on a number of factors and management flexibility usually ends in October when the cold water pool in Shasta Lake is depleted. With climate

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> change, cold water storage at the end of May in Shasta Lake is expected to be reduced under the No Action Alternative for all water year types. This would further reduce the already limited cold water pool in late summer. **With the anticipated increase in demands for water by 2030 and less water being diverted from the Trinity River, it is expected that it would become increasingly difficult to meet water temperature targets at the various temperature compliance points. It is likely that severe temperature-related effects will be unavoidable in some years under the No Action Alternative.** Due to these unavoidable adverse effects, RPA Action Suite I.2 also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek (see below) which may support a second population of winter-run Chinook Salmon, and a fish passage program at Keswick and Shasta dams to partially restore winter-run Chinook Salmon to their historical cold water habitat.

DEIS at 9-127 to 9-128 (emphasis added).[6] The DEIS also uses Reclamation's salmon mortality model to estimate temperature impacts on salmon production and mortality, concluding that the impacts from the No Action Alternative and the Second Basis of Comparison are similar, *see* DEIS at 9-160, that winter run Chinook salmon mortality is 31.4% in critically dry years under the No Action Alternative, *see* DEIS at Appendix 9C-8, and that Sacramento River spring run Chinook salmon mortality is 21.9% on average, and 84.8% in critically dry years under the No Action Alternative, *see* DEIS at Appendix 9C-7. Similarly, the SALMOD model results in the DEIS estimate that in approximately 10% of years, there would be zero production of spring run Chinook salmon below Shasta Dam. *See* DEIS at Figure B-3-1. And the DEIS estimates that under both the No Action Alternative and the Second Basis of Comparison, Reclamation will frequently violate temperature standards at Shasta Dam, *see* DEIS at 9-159 to 9-160, and at other reservoirs, *see* DEIS at 9-166 to 9-168. Yet the DEIS fails to explicitly identify upstream temperature mortality as a significant adverse impact, and the only mitigation measure identified in the DEIS (fish passage program) is a long term potential measure that is already required under the No Action Alternative and is therefore part of the baseline. That mitigation measure does not address the ongoing significant adverse impact in the near term, nor does it propose anything that is not already required.

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[6] However, as noted above, the DEIS also fails to demonstrate whether operations of Shasta Dam under the No Action Alternative are consistent with requirements of the 2009 NOAA biological opinion, which includes performance measures and other requirements to maintain adequate cold water pool for winter run Chinook salmon below the dam. *See* DEIS at 9-125 (describing RPA requirements). To the extent that the modeled operations under the No Action Alternative fail to meet the RPA requirements, Reclamation must revise operations to be consistent with those RPA requirements.

Moreover, the DEIS relies on flawed methodologies to assess temperature impacts on salmonids, many of which provide contradictory results, which mislead the public as to the effects of CVP/SWP operations on salmonids. For instance, the DEIS uses the SALMOD model to calculate juvenile production and the extent of temperature related upstream mortality to eggs and fry. The document concludes that the No Action Alternative results in similar impacts to the Second Basis of Comparison. DEIS at 9-162. Yet SALMOD's estimates of mortality and production are wildly inaccurate compared to recent data. For instance, Figure B-4-1 estimates that winter run Chinook salmon production would never drop below 500,000, yet in 2014 there was a total year class failure with over 95% mortality due to water temperatures. Figure B-4-1 also shows that according to the SALMOD model, in approximately 95% of years winter run Chinook salmon production does not vary by more than a few hundred thousand fish. Yet empirical data shows that winter run Chinook salmon egg to fry survival at Red Bluff Diversion Dam from 2002 to 2012 varied substantially, from a low of 15.4% to a high of 48.6%, with a mean of 26.4%. *See* U.S. Fish and Wildlife Service 2015 at Table 6c. Estimates for other salmon runs are similarly inaccurate compared to recent Sacramento River data from the U.S. Fish and Wildlife Service. And this recent data also contradicts the information presented in Reclamation's salmon mortality model, which significantly underestimates mortality compared to the recent data. GGSA PCFFA 14

In addition, the analysis of water temperature impacts looks only at monthly average temperatures. DEIS at 9-109. As the DEIS notes briefly, "the effects of daily (or hourly) temperature swings are likely masked by the averaging process." DEIS at 9-110. This is clearly correct, and may help explain why the modeled results do not show the level of mortality seen from recent empirical data. Yet the DEIS fails to carry forward this caveat elsewhere in the discussion, when it presents the results of modeling. Similarly, the DEIS restricts its use of the IOS model to median escapement estimates and only uses a subset of the years from CALSIM, DEIS at 116, which excludes the highest mortality years in the driest years and therefore does not accurately assess impacts. GGSA PCFFA 15

Finally, the DEIS' analysis of weighted usable area for rearing habitat fail to account for more recent scientific research demonstrating the strong effect of increased flow on downstream salmonid survival in the Sacramento River. *See* DEIS at 9-107 to 9-109. The methodology used in the DEIS does not account for the significant reduction in survival of migrating salmon under lower flow conditions in the Sacramento River. *See* Michel et al 2015. As a result, the DEIS fails to accurately assess the impact of reduced flow on salmon survival in the Sacramento River using this methodology. GGSA PCFFA 16

The DEIS demonstrates that current CVP/SWP operations, including water deliveries to Sacramento River Settlement Contractors and other senior water rights holders, in combination GGSA PCFFA 17

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GGSA PCFFA 17 continued

with climate change, will result in significant adverse effects on salmon caused by violations of water temperature requirements. The DEIS predicts that these impacts will become more severe as a result of climate change and increased demands for water. As a result, the DEIS must consider alternatives and/or mitigation measures that reduce upstream water deliveries, including deliveries to Sacramento River Settlement Contractors and other water rights holders.

3. The DEIS Fails to Accurately Assess Impacts to Salmonids in the San Joaquin Basin

GGSA PCFFA 18

The DEIS fails to accurately assess environmental impacts to salmonids in the San Joaquin Basin because it fails to assess impacts to spring run Chinook salmon and because it fails to assess the impacts from changes in river flows.

First, the DEIS fails to acknowledge that small populations of spring run Chinook salmon have been established in recent years in the Stanislaus and other rivers. NMFS has acknowledged these populations exist, but the DEIS only analyzes impacts to fall run Chinook salmon and mistakenly concludes that spring run have been extirpated. DEIS at 9-87, 9-92. The DEIS wholly fails to analyze impacts to spring run Chinook salmon in the Stanislaus River and other San Joaquin River tributaries.

GGSA PCFFA 19

Second, the DEIS acknowledges some of the studies documenting that salmon survival in the Stanislaus River and other San Joaquin tributaries is driven by river flow conditions. For instance, the DEIS cites Zeug et al 2014 to show that higher flow generally results in higher salmon survival and subsequent abundance. DEIS at 9-92. Yet the DEIS ignores other scientific studies which conclude that flows drive salmonid survival and abundance, including Sturrock et al 2015, Buchanan et al 2015, State Water Resources Control Board 2010, 2012.[7] The DEIS also fails to emphasize that inadequate flow is the dominant factor limiting salmon survival and abundance, instead relying on outdated research from 1982 to assert that survival through the Stockton Deepwater Ship Channel is one of the most limiting factors. DEIS at 9-92.[8]

The DEIS fails to utilize this recent scientific information on the importance of river flow in assessing environmental impacts. Although the DEIS analyzes impacts from changes in operations on water temperatures, it wholly fails to assess the impacts from changes in flows on the Stanislaus River. *See, e.g.,* DEIS at 2-202 to 2-209 (analyzing impacts to fall run Chinook

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[7] The DEIS also cites to 2001 research by Mesick on the effect of fall flows and exports on straying, but ignores Marston et al 2012, which concluded that fall pulse flows and export rates are correlated with higher rates of straying.

[8] The DEIS also incorrectly asserts that flows must exceed 5,000 cfs to mobilize gravel in the Stanislaus River. DEIS at 9-95. That is incorrect; Kondolf 2001 concluded that flows below 5,000 cfs could mobilize the riverbed, particularly in certain reaches of the river.

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salmon and Steelhead).[9] The available scientific evidence demonstrates that a reduction in flows below the minimum requirements of the biological opinion would result in very significant adverse effects on steelhead, fall run Chinook salmon, spring run Chinook salmon. *See, e.g.,* Sturrock et al 2015; Zeug et al 2014; Buchanan et al 2015; State Water Resources Control Board 2010, 2012. And the State Water Resources Control Board, National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and many others have demonstrated that current flow levels on the Stanislaus River and other San Joaquin River tributaries are causing significant impacts to salmon and steelhead, demonstrating a need to substantially increase flows to sustain salmon. GGSA PCFFA 19 continued

GGSA PCFFA 20

This is particularly problematic for Alternative 3, which proposes to substantially reduce Stanislaus River flows. The DEIS wholly fails to analyze the impact of reduced flows and, based solely on temperature modeling, concludes that that Alternative 3 would have slightly beneficial effects on fall run Chinook salmon. DEIS at 9-316. Because the DEIS fails to assess the environmental impacts of reduced flows, which is the dominant factor affecting salmon and steelhead on the Stanislaus, Lower San Joaquin River, and other tributaries, the DEIS fails to accurately assess the environmental impacts of CVP/SWP operations on salmonids in the San Joaquin Basin. Reclamation's conclusions in the DEIS are arbitrary and capricious.

GGSA PCFFA 21

In addition, the DEIS fails to credibly analyze the impacts of the proposed trapping and barging of San Joaquin basin salmonids through the Delta under Alternative 3 and 4. The document makes unsubstantiated conclusions that this action would benefit salmonids without providing any analysis in the document. DEIS at 9-315 to 9-316. As a result, Reclamation's conclusion in the DEIS is arbitrary and capricious. There are substantial uncertainties regarding the effectiveness of capture operations (the stated goal is capturing 10-20% of the population) and potential adverse impacts. Moreover, coded wire tag data from the California Department of Fish and Wildlife show that salmon from the Merced Hatchery have successfully migrated through the Delta in recent years. *See* Kormos et al 2012; Palmer-Zwahlen and Kormos 2013. And in their comments on the ADEIS, NMFS raised substantial concerns that a trap and haul program would cause substantial adverse impacts on salmonids.

GGSA PCFFA 22

The DEIS also fails to assess whether such a program is consistent with Reclamation's obligation to double natural production of salmon populations under the Central Valley Project

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[9] Elsewhere, the DEIS asserts that under the No Action Alternative, Reclamation will not fully implement the biological opinion requirements regarding Stanislaus River and Lower San Joaquin River flows, in order to make water available to contractors, yet asserts with no justification that the impacts would be "similar or reduced relative to recent conditions." DEIS at 9-133. The DEIS reaches a similarly flawed conclusion with respect to the Second Basis of Comparison, concluding that the failure to implement the biological opinion requirements on the Stanislaus River would not improve in the future. DEIS at 9-149.

GGSA PCFFA 22 continued

Improvement Act.[10] Reclamation must substantially revise this section of the DEIS to provide a basis for its conclusions and to respond to the concerns raised by NMFS and others.

GGSA PCFFA 23

4. The DEIS Concludes that the Effects of Predator Control Program are Highly Uncertain and Could Cause Significant Adverse Environmental Impacts

GGSA PCFFA 24

As compared to the administrative draft, the DEIS' analysis of the impacts of predator control programs is substantially improved. For instance, the DEIS cites repeatedly to the Delta Science Program's independent peer review report (Grossman et al 2013) regarding the effects of predation on salmonids and the caveats statements that predator control programs will work as intended. *See* DEIS at 9-274 to 9-275. It also cites work by Peter Moyle suggesting that predator control programs could harm delta smelt, and acknowledges that predator control programs at the Columbia River have not demonstrated population level effects. DEIS at 9-274 to 9-276. As a result, the DEIS concludes that,

> the program may be difficult to implement, may not be effective, and may cause unintended harm to other native Delta fish species. Consequently, the outcome of the predator management program is highly uncertain. Compared to the No Action Alternative, which does not include a predator reduction program, Alternative 3 may or may not provide a benefit to salmonids and may result in an adverse effect on Delta smelt.

DEIS at 9-276.

However, the DEIS fails to acknowledge that USBR's own studies regarding the Head of Old River Barrier on the San Joaquin River have shown that increased flows reduce predation on salmonids, and reduced flows increase predation and reduce survival. *See* Bowen et al 2009 and 2010 (USBR Technical Memorandum 86-68290-10-07 and 86-68290-11). And the DEIS also inconsistently addresses the impact of CVP/SWP operations in contributing to predation by nonnative species, particularly by causing habitat conditions in the Delta and other rivers that favor non-native species. For instance, on page 9-354, the DEIS concludes that Alternative 5 may adversely affect striped bass, but the DEIS does not analyze whether or how that impact to striped bass may subsequently affect salmonids or other species.

5. The DEIS Fails to Accurately Assess Impacts of Fishing Mortality and Greater Restrictions on Salmon Fishing Proposed in Some Alternatives

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[10] More broadly, the DEIS fails to assess whether any of the alternatives meet Reclamation's obligations under section 3406(b).

The DEIS incorrectly assesses the impact of greater restrictions on salmon fishing under Alternatives 3 and 4. For instance, the DEIS downplays the effectiveness of the recent restrictions on salmon fishing as a result of the 2012 winter run Chinook salmon biological opinion, and it does not mention that NMFS' recovery plan for winter run Chinook salmon lists the ocean fishery as a low stressor on the population. *See* DEIS at 9-118, 9-277 to 9-278. The DEIS must be revised to account for this information in assessing impacts. Moreover, mark select fisheries are likely to substantially reduce fishing opportunities and may not improve conditions for wild salmon. The DEIS fails to analyze these potential adverse impacts of mark select fisheries.[11] In addition, as NMFS noted in its comments on the ADEIS, the harvest rule specified in Alternatives 3 and 4 may be less protective of winter run Chinook salmon than the existing biological opinion, given the restrictions on fishing at low levels of abundance. As noted in our prior comments, we strongly recommend that Reclamation work with the Pacific Fishery Management Council regarding these conclusions.

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6. The DEIS Fails to Accurately Assess Impacts of Climate Change on Salmon and Propose Mitigation Measures to Address those Impacts

We appreciate that the DEIS includes the potential effects of climate change on precipitation and temperature, in order to assess how climate change may affect CVP/SWP operations. The DEIS assumes that climate change will reduce reservoir storage and cause increased temperature impacts on salmonids. *See, e.g.,* DEIS at 9-120, 9-123, 9-126 to 9-127, 9-130, 9-132 to 9-133, 9-146. However, the document wholly fails to propose any short term measures to mitigate the effects of CVP/SWP operations in combination with climate change in order to avoid violations of downstream water temperature standards that imperil salmon. As a result, the DEIS predicts more significant impacts on salmonids from increased upstream temperature, without proposing any changes or modifications to operations in order for Reclamation to meet its existing obligations under state and federal law to avoid violating water temperature requirements. The DEIS must be revised to analyze mitigation measures and alternatives that reduce or avoid water temperature violations below dams, consistent with Reclamation's legal obigations to protect and restore salmoninds, including reduced upstream diversions and deliveries to senior water contractors.

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7. Conclusion

As discussed above, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations, fails to consider a reasonable range of alternatives, and includes alternatives that

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[11] In addition, the DEIS fails to analyze the socioeconomic effects of reducing salmon fishing as proposed under Alternatives 3 and 4. *See, e.g.,* DEIS at 19-77.

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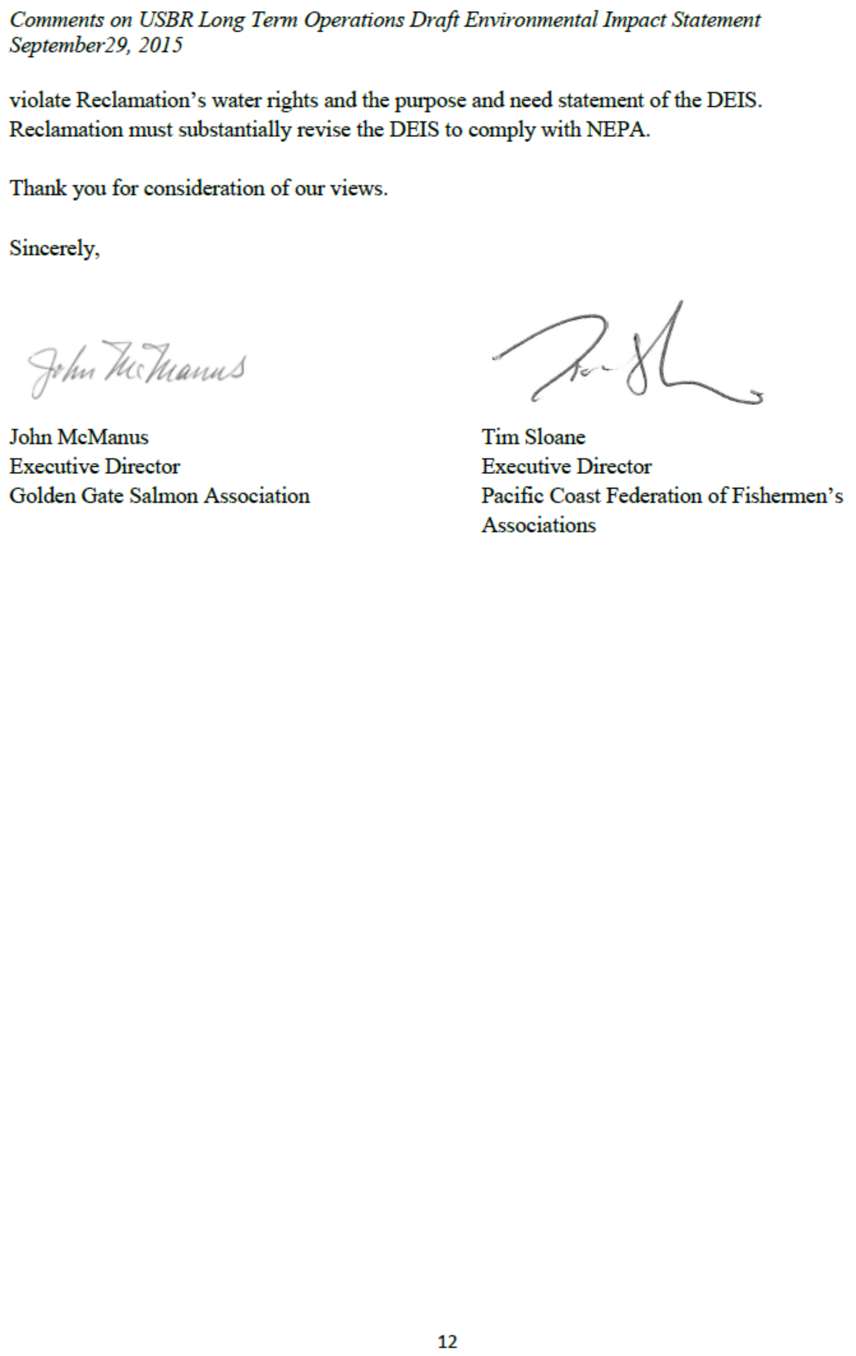

violate Reclamation's water rights and the purpose and need statement of the DEIS. Reclamation must substantially revise the DEIS to comply with NEPA.

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Thank you for consideration of our views.

Sincerely,

John McManus

John McManus
Executive Director
Golden Gate Salmon Association

Tim Sloane
Executive Director
Pacific Coast Federation of Fishermen's Associations

1D.1.10.1 Responses to Comments from Golden Gate Salmon Association and Pacific Coast Federation of Fishermen's Association

GGSA PCFFA 1: Comment noted. Please see responses to Comments GGSA PCFFA 2 through GGSA PCFFA 27.

GGSA PCFFA 2: Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources.

Conditions that have led to consideration of the federal listing of Longfin Smelt are discussed on page 9-67 of the Draft EIS.

GGSA PCFFA 3: Alternative 5 increases fisheries protection related to the Old and Middle River positive flow regime as compared to the Alternatives 1 through 4, No Action Alternative, and Second Basis of Comparison; and increases reliance on increased investments in local and regional water supplies.

Additional details have been provided in Chapter 19, Socioeconomics, related to the socioeconomics of freshwater and ocean harvest of fish.

GGSA PCFFA 4: The EIS alternatives include consistent climate change conditions without consideration of potential regulatory or operational changes due to climate conditions in the future. Potential climate-related operational changes are currently unknown and it would be speculative to develop such assumptions for a NEPA analysis. The impact analysis compares conditions under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. This comparative approach eliminates the effects of climate change from the incremental changes between the alternatives, No Action Alternative, and Second Basis of Comparison.

GGSA PCFFA 5: The discussion in Chapter 9, Fish and Aquatic Resources, does find that increased air temperatures and reduced snowfall would result in water temperatures that would result in substantial adverse impacts to salmonids and sturgeon in the rivers downstream of the CVP reservoirs under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 (see subsections "Changes in Exceedance of Water Temperature Thresholds" in Section 9.4.3 of Chapter 9). The EIS analysis compares conditions in 2030 under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. The EIS analysis has been prepared in accordance with NEPA and does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions (as is presented in CEQA documents, such as the Bay Delta Conservation Plan Environmental

Impact Report/Environmental Impact Statement). The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. This No Action Alternative represents the current management direction and level of management intensity consistent with the explanation of the No Action Alternative included in Council of Environmental Quality's Forty Most Asked Questions (Question 3). NEPA does not require agencies to mitigate impacts, nor does it require agencies to identify mitigation associated with the No Action Alternative.

Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources, including recent impacts to winter-run Chinook Salmon.

GGSA PCFFA 6: As has been the case in the past, Reclamation will continue to work with NMFS and other members of the Sacramento Rivers Temperature Task Group (SRTTG) to manage water temperature in Sacramento River to maximize benefits for the species. However, it should be noted that meeting such objectives may not be possible given current regulatory environment.

The 2009 NMFS BO was written in consideration of project operations as described in the 2008 BA. Since 2008, the projects have been operating to 2008 USFWS and 2009 NMFS RPA actions. These actions include maintaining Old and Middle River flows at certain levels during December through June, increased closure of the Delta Cross Channel compared to those of previous requirements per SWRCB D-1641, export limitations in April and May based on San Joaquin River flow at Vernalis, and increased Delta outflow in fall months following wet and above normal years. All of these actions affect project operations and result in increased reservoir releases. These effects include a shift in export patterns from spring to summer months that causes more water to be released from the reservoirs than that is being exported to meet the Delta water quality standards during a season where Delta is more saline, an increased need in supply from the Sacramento River in April and May since San Joaquin River supply is limited, and increased reservoir releases in fall months following wet and above normal years. Therefore, this reduction in flexibility to use available water supply in most efficient way for water supply and water quality needs further limits possibility of meeting storage and temperature performance requirements on upper Sacramento River (namely NMFS BO Actions 1.2.1, 1.2.2, 1.2.3, and 1.2.4.).

These NMFS BO RPA actions (namely NMFS BO Actions 1.2.1, 1.2.2, 1.2.3, and 1.2.4.) are included and benefits are acknowledged in the No Action Alternative, Alternative 2, and Alternative 5; however, in this Draft EIS, it cannot be assumed that full benefits of storage performance criteria would be achieved due to reasons explained above.

More details have been included in Section 9.4.3 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to qualitatively responses to RPA actions not included in the CalSim II model in the No Action Alternative and Alternatives 2 and 5.

GGSA PCFFA 7: The EIS analysis is based upon the comparison of conditions in 2030 under different alternatives. The results of those comparisons related to water temperatures show relatively minimal changes under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. However, as described in the response to Comment GGSA PCFFA 5, the water temperatures in the rivers downstream of the CVP reservoirs would result in substantial adverse impacts to salmonids and sturgeon under Alternatives 1, 2, 3, and 4 and the Second Basis of Comparison without the addition of fish passage methods that are included in the No Action Alternative and Alternative 5.

The CVP and SWP reservoirs are operated in accordance with regulatory limitations, including applicable state and federal laws, regulations, and water rights first prior to deliver of water to CVP and SWP water contractors. The CVP and SWP cannot choose to meet the applicable state and federal laws, regulations, and water rights; and, it is not possible to fully meet the temperature thresholds downstream of the CVP and SWP reservoirs in 2030 with climate change. Therefore, fish passage around the CVP and SWP reservoirs is considered to provide habitat with appropriate water temperatures for early lifestages.

GGSA PCFFA 8: The analysis in the EIS compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for the range of physical, environmental, and human resources.

GGSA PCFFA 9: Contract deliveries are based upon available water supplies on an annual and monthly basis after all water flow and demand requirements for applicable state and federal laws, regulations, and water rights are met. Full CVP and SWP water contract deliveries are used in the CalSim II model as a maximum delivery volume, but are only met when sufficient water is available.

GGSA PCFFA 10: The results described in Cunningham et al. (2015) was added on page 9-78 (of the Draft EIS) to quantify the effects of exports on salmonid survival. Differences, such as those described by Cunningham in relation to exports, are not exhibited in a comparison of the No Action Alternative with Alternatives 1 through 5 since the impact analyses results for all of the alternatives comparisons do not result in the distinct export regimes (+1 standard deviations of the mean) modeled by Cunningham et al. (2015). Results of the SALMOD model for late fall-run Chinook Salmon in the Sacramento River (Table B-2-5 of Appendix 9D) show comparable results for pre-smolt and smolt mortality due to habitat (flow) as Michel et al. (2015) in that mortality is increased in drier years as compared to wetter years.

GGSA PCFFA 11: Please see Appendix 9M, Salmonid Salvage Analysis, which describes the methods for addressing the effects of export facilities on juvenile salmonids. This analysis, based on coded wire tagged fish, covers a broader range of size classes than does the DPM analysis.

GGSA PCFFA 12: Although the median survival predicted by the OBAN model was 12 percent higher under the No Action Alternative than under the Second Basis of Comparison, the probability intervals indicated that no difference between scenarios was a likely outcome (i.e. the dashed line of no difference lies within the dark gray central 0.50 probability interval in Figure 9I-14). The text on page 9-162 (of the Draft EIS) has been modified for clarity; however, specific degrees of certainty cannot be determined with the existing analytical tools.

GGSA PCFFA 13: Please see response to GGSA PCFFA 7.

GGSA PCFFA 14: SALMOD is not used as a predictive model, it is used as a comparative tool for analyzing differences between alternatives that would occur over a range of hydrologic conditions represented by output from the 82-year CalSim II model (see Appendix 9D, SALMOD Model Documentation). As used, SALMOD output represents the mean values for production and mortality each year with the same initial conditions for population parameters and varying operations simulated by CalSim II. It is not a life-cycle model and does not provide a time trajectory of production. There is no expectation that SALMOD output will mirror recent (or historical) data on production or mortality. However, the comparison of mean values for production and mortality are a valid and appropriate method of comparing possible outcomes among the various alternatives. Similarly, the Reclamation Salmon Mortality Model utilizes CalSim II output through the temperature models and is not expected to mirror recent or historical estimates of mortality (see Appendix 9C, Reclamation's Salmon Mortality Model Analysis Documentation). It too is used as a comparative tool to distinguish potential effects among the alternatives. The results of the impact analysis is to understand the differences in the outcomes of the alternatives as compared to the No Action Alternative and the Second Basis of Comparison.

GGSA PCFFA 15: As described and presented in Appendix 9H of the Draft EIS, the IOS model uses the full 82-year CalSim II simulation period. The impact analysis used in the EIS evaluates the differences between alternatives based on changes in the median annual escapement and the range of escapement values encompassed in the first and second quartiles (25 to 75 percent of years) over the 82-year CalSim II simulation period (see page 9-116 of the Draft EIS). As described in the response to Comment GGSA PCFFA 14, SALMOD is not used as a predictive model to mirror past data, it is used as a comparative tool for analyzing differences between alternatives that would occur over a range of hydrologic conditions represented by output from the 82-year CalSim II model. As used, SALMOD output represents the mean values for production and mortality each year with the same initial conditions for population parameters and varying operations simulated by CalSim II. It is not a life-cycle model and does not provide a time trajectory of production. However, the comparison of mean values for production and mortality are a valid and appropriate method of comparing possible outcomes among the various alternatives under a NEPA analysis. Similarly, the Reclamation Salmon Mortality Model is used as a comparative tool to distinguish potential effects among the alternatives.

While likely effects from water temperature on early life stages occur at a shorter temporal scale than these models, comparative analyses are useful for long-term analyses, as in the EIS, because there is moderate certainty for long-term conditions.

GGSA PCFFA 16: The analysis of weighted usable area (WUA) in the Draft EIS is not intended to describe salmonid survival. The WUA methodology is used as a metric for evaluating changes in physical habitat related to flow as described in Appendix 9E, Weighted Useable Area Analysis, and on page 9-108 of the Draft EIS. The results of the SALMOD model are used to evaluate changes in salmonid survival in the Sacramento River (see Appendix 9D). Results of the SALMOD model for late fall-run Chinook Salmon in the Sacramento River (Table B-2-5 of Appendix 9D) show that mortality for pre-smolts and smolts is increased in drier years as compared to wetter years; this is consistent with Michel et al. (2015).

GGSA PCFFA 17: The EIS alternatives include consistent climate change conditions without consideration of potential regulatory or operational changes due to climate conditions in the future. Potential climate-related operational changes are currently unknown and it would be speculative to develop such assumptions for a NEPA analysis. This comparative approach eliminates the effects of climate change from the incremental changes between the alternatives, No Action Alternative, and Second Basis of Comparison.

The EIS analysis has been prepared in accordance with NEPA and does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions (as is presented in CEQA documents). The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. This No Action Alternative represents the current management direction and level of management intensity consistent with the explanation of the No Action Alternative included in Council of Environmental Quality's Forty Most Asked Questions (Question 3). NEPA does not require agencies to mitigate impacts, nor does it require agencies to identify mitigation associated with the No Action Alternative.

GGSA PCFFA 18: "Spring-running" fish were not analyzed due to uncertainty whether they are genotypically spring-run, and if so, whether they are strays or a distinct population; and their exemption from take related to diverting or receiving water in accordance with the San Joaquin River reintroduction program. In the most recent Recovery Plan (NMFS 2014), it is stated that native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin.

GGSA PCFFA 19: The references included in the comment provide additional information that is consistent with citations already included in the Draft EIS. Many of these reports also indicate that there still remains uncertainty in the flow-survival relationship. Sturrock et al. (2015) did not conclude that flows drive salmonid survival and abundance but did provide evidence that salmon populations fluctuate considerably with river flows experienced during juvenile rearing. The text on page 9-92 of the Draft ESI has been modified to include the reference in the comment, and to indicate that mortality in the Deep Water Ship Channel is one of the limiting factors.

Footnote 8 in the comment regarding Kondolf is not correct. Despite one site having a lower value (i.e., TMI 280 cfs) than 5,000 cfs, Kondolf used a combination of sites to identify that mobility overall occurs beginning at about 5,000 cfs. On page 36 of Kondolf, it states "Results of the bed mobility analysis for five (TMl, RI, RS, R28A, and R78) of nine sites studied suggest that flows around 5,000 to 8,000 cfs are necessary to mobilize the D50 of the channel bed material (Table 7.1 and Appendix C)." There was one site (TMI 1) where flows less than 5,000 cfs (280 cfs) would mobilize gravel, but as Kondolf explains "The mobility of the gravel at TMI probably reflects the smaller diameter of the augmented gravel, rather than the mobility of the gravels that would naturally occur in this steeper reach."

Text has been modified on the page 9-149 of the Draft EIS has been modified in the Final EIS to provide more clarity on the statement referenced in Footnote 9 of this comment.

GGSA PCFFA 20: Long-term average flows are not substantially reduced under Alternative 3 as compared to the No Action Alternative or the Second Basis of Comparison for the Stanislaus River below Goodwin Dam (see Figures 5-68, 5-69, and 5-70 in Chapter 5, Surface Water Resources and Water Supplies). There are anticipated flow reductions generally from March through June and particularly in October under Alternative 3, but flows are anticipated to be increased under Alternative 3 relative to the No Action Alternative and comparable to flows under the Second Basis of Comparison in many months. As described on pages 9-313 through 9-315 of the Draft EIS, water temperatures under Alternative 3 are anticipated to be similar to the No Action Alternative or slightly lower in most months and lead to a slight reduction in egg mortality for fall-run Chinook salmon. The text on page 9-316 of the Draft EIS has been modified to improve the readability.

GGSA PCFFA 21: The description of the trap and haul program assumptions and methodologies presented in Chapter 9 of the Draft EIS were not extensive. Additional information has been included on page 9-316 of the Draft EIS, and additional information has been provided in Appendix 9O of the Final EIS.

GGSA PCFFA 22: Reclamation’s proposed action in the 2008 Biological Assessment included actions developed to contribute to Section 3406(b)(1) of the Central Valley Project Improvement Act (CVPIA) and other requirements of CVPIA. These actions were analyzed as part of the proposed action in the 2008 USFWS BO and 2009 NMFS BO. These actions are therefore also incorporated in the No Action Alternative and Alternative 5. Alternatives 1 through 4 and the

Second Basis of Comparison due not fully contribute to the goals of Section 3406(b)(1).

GGSA PCFFA 23: Please see responses to comments from National Marine Fisheries Service in Appendix 1.A.1.

GGSA PCFFA 24: Text has been added to Section 9.4.3.4 of the FEIS to include the studies by Bowen et al. (2009, 2010) regarding predation on salmonids around a Head of Old River barrier.

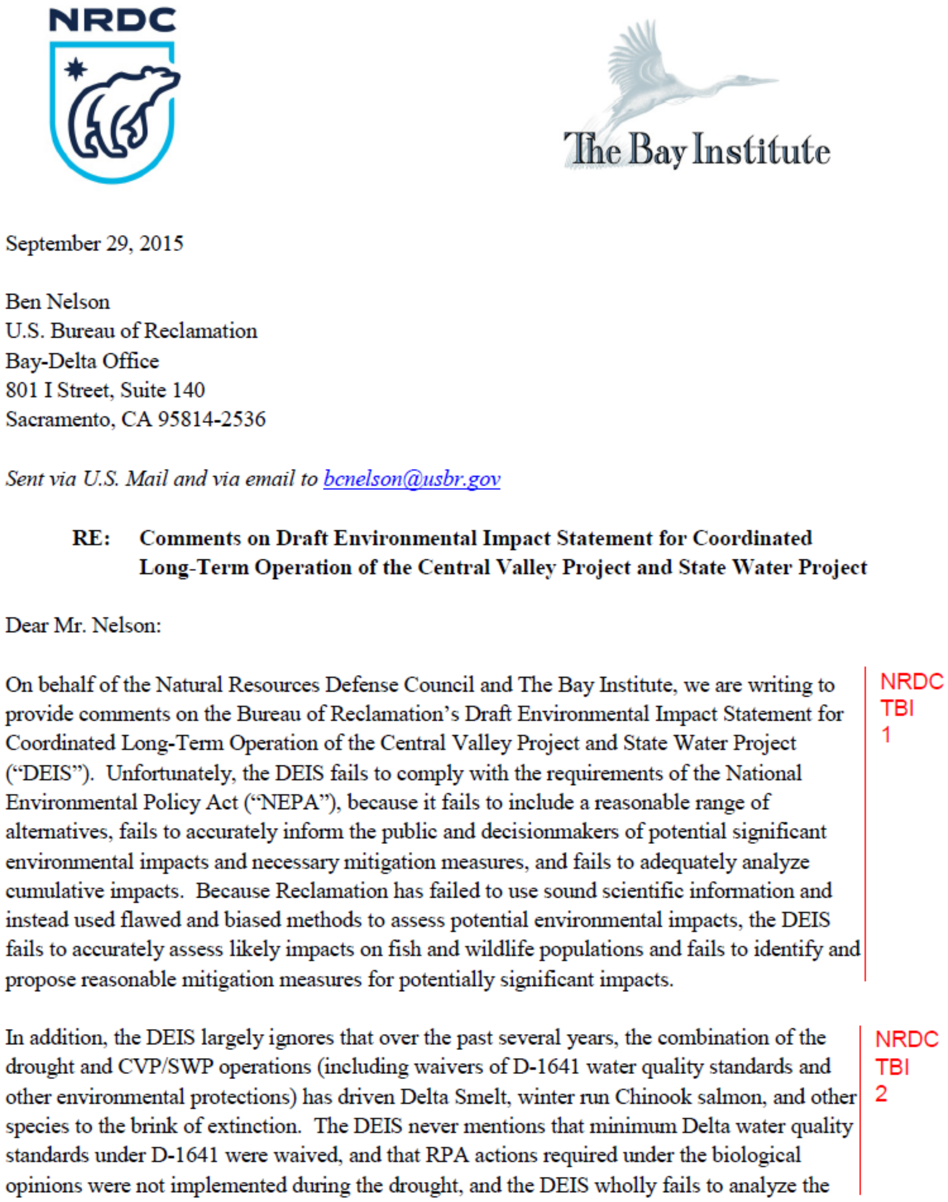
While the two-year study observed a variable and negative relationship between flow and survival past the Head of Old River barrier, there remained uncertainty due to the actual barrier structural configuration and how they would affect predator habitat in this reach. These studies did not speculated about overall survival rates or the biological significance of reach specific mortality around the Head of Old River barrier. Overall, the conclusions indicated that survival around the Head of Old River barrier would be structural design specific and highly variable; therefore certainty of the effect of the structures remains low.

GGSA PCFFA 25: The analysis in the Draft EIS did not rely on the 2012 Biological Opinion for analysis of effects. The latest (2014) Final Recovery Plan lists ocean harvest as a “very high” stressor on the winter-run Chinook Salmon population. Additional text has been added to Chapter 15, Recreation Resources, and Chapter 19, Socioeconomics, related to the effects of the harvest restrictions in Alternatives 3 and 4. The harvest rules specified in Alternatives 3, and especially Alternative 4, may be less protective for winter-run Chinook Salmon because this run is not allowed to be captured in either sport or commercial ocean salmon fishing. Additional text has been added to Section 9.4.3.5.2 on consistency of these alternatives with NMFS fisheries management framework for reducing the impact of ocean salmon fishery on winter-run Chinook Salmon.

GGSA PCFFA 26: Please see response to Comment GGSA PCFFA 17.

GGSA PCFFA 27: Reclamation has modified the Final EIS in response to comments from GGSA PCFFA and other commenters; and will use the Final EIS in the development of the Record of Decision.

1D.1.11 Natural Resources Defense Council and The Bay Institute



NRDC

The Bay Institute

September 29, 2015

Ben Nelson
U.S. Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536

Sent via U.S. Mail and via email to bcnelson@usbr.gov

RE: Comments on Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Dear Mr. Nelson:

On behalf of the Natural Resources Defense Council and The Bay Institute, we are writing to provide comments on the Bureau of Reclamation's Draft Environmental Impact Statement for Coordinated Long-Term Operation of the Central Valley Project and State Water Project ("DEIS"). Unfortunately, the DEIS fails to comply with the requirements of the National Environmental Policy Act ("NEPA"), because it fails to include a reasonable range of alternatives, fails to accurately inform the public and decisionmakers of potential significant environmental impacts and necessary mitigation measures, and fails to adequately analyze cumulative impacts. Because Reclamation has failed to use sound scientific information and instead used flawed and biased methods to assess potential environmental impacts, the DEIS fails to accurately assess likely impacts on fish and wildlife populations and fails to identify and propose reasonable mitigation measures for potentially significant impacts.

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In addition, the DEIS largely ignores that over the past several years, the combination of the drought and CVP/SWP operations (including waivers of D-1641 water quality standards and other environmental protections) has driven Delta Smelt, winter run Chinook salmon, and other species to the brink of extinction. The DEIS never mentions that minimum Delta water quality standards under D-1641 were waived, and that RPA actions required under the biological opinions were not implemented during the drought, and the DEIS wholly fails to analyze the

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impact of the reasonably foreseeable waiver of water quality standards in future droughts. Yet the DEIS only acknowledges under the No Action Alternative that abundance levels for delta smelt and other fisheries "are difficult to predict" and that "Currently low levels of relative abundance do not bode well for the Delta Smelt or other fish species in the Delta." DEIS at 9-139.[1] Under the Second Basis of Comparison, the DEIS concludes that,

> As described above for the No Action Alternative, abundance levels for Delta Smelt, Longfin Smelt, Striped Bass, Threadfin Shad, and American Shad are currently very low, and abundance and habitat conditions for fish in the Delta in future years are difficult to predict. It is not likely that operations of the CVP and SWP under the Second Basis of Comparison would result in improvement of habitat conditions in the Delta or increases in populations for these fish by 2030, and the recent trajectory of loss would likely continue.

DEIS at 9-150.[2] Despite these acknowledgements that current operations may very well lead to extinction of the species, the DEIS proposes no mitigation measures and does not even conclude that the alternatives result in significant impacts to Delta Smelt. Similarly, for longfin smelt, the DEIS ignores that current operations have resulted in the U.S. Fish and Wildlife Service concluding that listing longfin smelt under the Endangered Species Act is warranted, and continuation of existing spring outflow conditions is likely to result in adverse effects on the species. As a result, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations on Delta Smelt and longfin smelt.

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With respect to salmonids, the DEIS acknowledges that climate change will make it more difficult to achieve water temperature requirements with current upstream reservoir operations, impacting salmon and steelhead. *See, e.g.*, DEIS at 9-126 to 9-127. Yet the DEIS fails to conclude that these temperance exceedances constitute a significant environmental impacts and fails to consider any mitigation measures.[3] During the current drought, the failure to meet minimum upstream water temperatures resulted in greater than 95% mortality of the 2014 brood year winter run Chinook salmon cohort, and may result in similar mortality for the 2015 brood year. Increased frequency, duration and intensity of upstream temperature exceedances as a

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[1] In part, this conclusion is based on inaccurate assessment of entrainment impacts of the alternatives on Delta Smelt, as discussed below.

[2] Many of the flaws identified in the Second Basis of Comparison (which is the same as Alternative 1) also affect the analyses of Alternatives 3 and 4, and our comments are intended to address the similar flaws in the analyses of those alternatives as well.

[3] In contrast, Reclamation's revised draft environmental impact statement for the California WaterFix concludes that under the No Action Alternative, upstream reservoir operations will result in significant adverse environmental impacts to winter run Chinook salmon and green sturgeon spawning and egg incubation. *See, e.g.,* USBR, CA WaterFix RDEIS/SDEIR at ES-48.

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result of climate change in combination with CVP/SWP operations are likely to cause significant environmental impacts. The DEIS also fails to demonstrate whether operations of Shasta Dam under the No Action Alternative are consistent with requirements of the 2009 NOAA biological opinion, which includes performance measures and other requirements to maintain adequate cold water pool for winter run Chinook salmon below the dam. As a result, the DEIS must be revised to analyze compliance with the biological opinion and to consider changes in reservoir operations to mitigate upstream temperature impacts, including reductions in upstream water diversions and deliveries to CVP contractors, including senior contractors. NRDC TBI 4

Despite these short term and long term impacts, the DEIS asserts that with respect to several salmon and steelhead runs, the effects of CVP/SWP operations under Alternative 1 are similar to those under the No Action Alternative and Alternative 2. *See, e.g.,* DEIS at ES-30 to ES-31, 9-397 to 9-398.[4] However, the federal courts have twice held that operations under Alternative 1 would jeopardize the continued existence and recovery of listed salmonids and steelhead, in violation of the Endangered Species Act. The DEIS therefore suggests that operations under the No Action Alternative and under Alternative 2 would also jeopardize these listed salmonid species (primarily because of upstream water temperature impacts). Yet the DEIS does not identify a significant environmental impact from these effects, and it proposes no clearly defined mitigation measures to address these impacts (except for programs for upstream fish passage at major dams, which are already required under the No Action Alternative). NRDC TBI 5

The DEIS is fundamentally flawed, and Reclamation must revise the DEIS to analyze a broader range of alternatives using a credible methodology for assessing environmental impacts, including cumulative impacts.[5] NRDC TBI 6

I. The DEIS Fails to Accurately Assess Environmental Impacts to Fish and Wildlife: In general, Chapter 9 of the DEIS fails to utilize recent scientific information and utilizes outdated and inaccurate models to assess potential impacts to fish and wildlife populations. As a result, the DEIS fails to accurately assess the likely environmental impacts of the alternatives on fish and wildlife and significantly understates the environmental impacts of some alternatives. NRDC TBI 7

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[4] This is at least in part because of Reclamation's flawed methodology for assessing impacts, particularly with respect to operations in the Delta, as discussed elsewhere in this letter.

[5] In addition, Reclamation and DWR have not complied with CEQA, and compliance with CEQA is required before the Department of Water Resources could propose any changes to State Water Project operations. Numerous additional permits and approvals would be required before authorizing any changes to operations, including requirements under the federal Endangered Species Act, California Endangered Species Act, and other state and federal laws.

A. The DEIS Fails to Accurately Assess Impacts to Delta Smelt:

The DEIS substantially understates the environmental impacts of the alternatives on Delta Smelt because it ignores numerous recent scientific publications regarding the impact of water project operations on Delta Smelt, including: Rose et al 2013a, Rose et al 2013b, USGS 2015 (MAST report), and MacNally et al 2010. For instance, the only citation of Rose et al 2013a and 2013b in the DEIS occurs on page 9-115, in a discussion of delta smelt habitat, where it states that the DEIS chose not to use the life cycle model developed in these papers to assess impacts (the DEIS arbitrarily fails to provide any justification for choosing not to use this peer reviewed life cycle model to assess impacts). The DEIS' analysis of entrainment impacts on delta smelt wholly fails to discuss the conclusions of Rose et al 2013a and 2013b, which found that entrainment by the CVP and SWP was an important factor in the decline of delta smelt. *See* DEIS at 9-78 to 9-79. Similarly, the species description in the DEIS understates the role of entrainment as a stressor on the population and does not even mention the population level effects of entrainment. DEIS at 9-63 to 9-66. As a result of the failure to use sound scientific information, the DEIS misleads the reader on the impacts of entrainment by CVP/SWP operations on delta smelt. NRDC TBI 7 continued

In addition to failing to use the life cycle model prepared by Rose et al 2013 to assess impacts, the methodology used in the ADEIS to assess entrainment impacts is flawed and fails to adequately assess impacts under the alternatives. NRDC TBI 8

First, the DEIS uses average OMR values to calculate entrainment. DEIS at 9-114. As a result, the DEIS does not account for changes in operations within the OMR ranges specified under the biological opinion under the No Action Alternative, Alternative 2, and Alternative 5. Because the DEIS does not account for reductions in OMR to avoid significant entrainment events and to manage entrainment throughout the season, and the estimates of smelt entrainment are therefore unreasonably high under these alternatives. This substantially biases the comparison of entrainment impacts in the DEIS under these alternatives as compared to other alternatives. NRDC TBI 9

Second, the DEIS fails to adequately analyze entrainment impacts because it fails to assess whether entrainment under the alternatives would exceed the incidental take statement in the biological opinion, which is estimated to be 5% of the adult population based on the Fall Midwater Trawl Survey. *See* 2008 Delta Smelt biological opinion at 387. Modeling information in the DEIS indicates that entrainment would exceed the incidental take limit under several of the alternatives, as discussed below. Exceeding the incidental take limit would cause significant impacts. NRDC TBI 10

Third, the DEIS also fails to adequately assess entrainment impacts by using a 5% threshold, such that alternatives with entrainment estimates within 5% are considered to have similar effects. DEIS at 9-114. This is unreasonable and understates the environmental impacts of NRDC TBI 11 entrainment because it could result in a doubling of entrainment (5% versus 10%), and as noted above could result in substantially exceeding the incidental take limit. Kimmerer 2011 demonstrated that entrainment losses averaging 10% per year can be "…simultaneously nearly undetectable in regression analysis, and devastating to the population."

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The estimated entrainment under the Second Basis of Comparison approaches that 10% threshold for adults and greatly exceeds it for juveniles, *see* DEIS at 9-194, and Reclamation's estimated entrainment under this alternative and several others would likely exceed the take limit in many years. This would cause significant adverse effects that are not reported in the DEIS.

As a result of these substantial flaws, the DEIS fails to adequately analyze Delta Smelt entrainment impacts under the alternatives. The DEIS must be revised to analyze whether entrainment would exceed the incidental take limit (5% of the population), revise estimates of entrainment under the No Action Alternative, Alternative 2, and Alternative 5 to account for changes in operations under Actions 1-3 of the Delta Smelt biological opinion, and to eliminate use of the 5% threshold of significance.

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With respect to the effect of changes in X2 on Delta Smelt, the DEIS wholly fails to analyze the effects of changes in spring X2 on Delta Smelt. *See* Mast Report 2015. The DEIS also fails to analyze the effects on Delta Smelt of waiving spring X2 requirements in recent years during the drought, as the population has declined to record low levels. With respect to changes in Fall X2, the document also largely ignores all of the comments of the Fish and Wildlife Service in the Bay Delta Conservation Plan process, and it ignores the additional biological analysis of BDCP impacts on delta smelt by Kimmerer et al prepared for the Nature Conservancy in 2013. These analyses demonstrate the significant role of CVP/SWP operations on delta smelt. Instead, the DEIS provides misleading information about other stressors. For instance, the DEIS repeatedly hypothesizes that discharge of agricultural runoff from the Colusa Drain led to measureable improvements in zooplankton abundance in 2011 and 2012, but it fails to inform the reader that Delta Smelt populations declined substantially in 2012. *See* DEIS at 9-65 and 9-66. In addition, on the same page the DEIS misstates the conclusions of the MAST report regarding the importance of implementation of the fall outflow RPA in 2011 (rather than agricultural runoff) on subsequent delta smelt abundance.

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In addition, the DEIS fails to analyze the effects of CVP/SWP operations on Delta food webs, including phytoplankton and zooplankton that support delta smelt populations. Existing scientific information documents how changes in exports, residence time, and flows can affect these populations. *See, e.g.,* Jassby et al. 1995; Kimmerer 2002; Winder et al. 2011; Cloern and Jassby 2012. We raised this issue in our 2012 scoping comments, yet the DEIS wholly fails to analyze this impact. More recent studies document how changes in delta outflow can affect corbula populations and thus affect delta food webs. *See, e.g.,* Brown et al. 2012; Thompson et

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al. 2012; Teh 2012; Baxter and Slater 2012. And while the DEIS mentions the effect of introduced species on the food web, see DEIS at 9-65, it ignores peer reviewed research that hydrologic modifications, including diversions by the CVP and SWP, have facilitated invasions of the estuary. *See* Winder et al 2011. The DEIS must be revised to analyze these effects of CVP/SWP operations on delta food webs.

NRDC TBI 15

Finally, although the DEIS discusses the effects of predation on Delta Smelt, it fails to consider the role of CVP/SWP operations in facilitating the abundance of invasive predators and worsening water quality. For instance, DWR and Reclamation have concluded that waiver of D-1641 outflow requirements during the drought have resulted in increased microcystis blooms, other water quality impairments, and increased populations of black bass and other nonnative predators that impact Delta Smelt. *See* USBR/DWR March 30, 2015 Temporary Urgency Change Petition, Attachment A, at 69-70. However, the DEIS wholly fails to analyze these indirect impacts of operations on water quality and fisheries, including analysis of changes in residence time as a result of operations, even though Reclamation's NEPA analysis of the California WaterFix includes modeling of changes in residence time and how that affects microcystis and other harmful algal blooms. The DEIS must be revised to analyze these effects of CVP/SWP operations on water quality, microcystis, and other harmful algal blooms.

NRDC TBI 16

The DEIS fails to use sound scientific information for the assessment of environmental impacts of the alternatives on delta smelt and it wholly fails to analyze important direct and indirect effects of CVP/SWP operations on Delta Smelt (such as spring X2, effects on food webs, effects on predator populations). As a result, the DEIS understates the impacts of Alternatives 1, 3, 4, and the Second Basis of Comparison, and it overstates the impacts of the No Action Alternative, Alternative 2, and Alternative 5.

B. *The DEIS Fails to Accurately Assess Impacts to Longfin Smelt*[6]

NRDC TBI 17

As with Delta Smelt, the DEIS fails to reference recent scientific information regarding longfin smelt, resulting in the document inaccurately assessing environmental impacts on the species. For instance, the DEIS fails to reference numerous recent scientific studies documenting winter / spring delta outflow as the primary driver of subsequent longfin smelt abundance, including MacNally et al 2010 and recent analysis by the Fish and Wildlife Service and California Department of Fish and Wildlife regarding flow and longfin smelt during the BDCP process (including Rosenfield and Nobriga in press). For instance, in 2013 the Fish and Wildlife Service noted that, "More than forty years of science has clearly established that Delta outflow is a

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[6] We also note that the Bureau of Reclamation is also subject to the requirements of the California Endangered Species Act with respect to longfin smelt, which is listed as a threatened species under state law, consistent with section 3406(b) of the Central Valley Project Improvement Act of 1992 and Section 8 of the Reclamation Act of 1902.

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primary driver of longfin smelt abundance (e.g. Thomson et al. 2010). " In contrast, page 9-67 includes a single sentence about the effect of delta outflow being the largest factor affecting longfin smelt abundance. In addition, as discussed above, the DEIS fails to analyze the effects of CVP/SWP operations on delta food webs and indirect effects on longfin smelt.

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The DEIS uses an equation from Kimmerer 2009 to calculate average longfin smelt abundance by water year type, but because this analysis looks at each year in isolation, it understates the environmental impacts of multiple years of low outflow. In addition, because the DEIS ignores more recent scientific studies on flow thresholds for longfin smelt population growth prepared by the U.S. Fish and Wildlife Service in the BDCP process, the DEIS fails to assess whether spring outflows are likely to result in population growth. As a result, the DEIS likely understates the environmental impacts of the alternatives. We agree with the DEIS that the Second Basis of Comparison would result in far more adverse effects on longfin smelt that the No Action Alternative, DEIS at 9-196, but the DEIS fails to analyze whether the No Action Alternative results in adverse effects on longfin smelt.

The DEIS' conclusion that the Second Basis of Comparison would "maintain the recent trajectory of loss" for longfin smelt (page 9-152) is understated; it is likely that the Second Basis of Comparison and Alternatives 1, 3 and 4 will jeopardize the continued existence and recovery of longfin smelt, consistent with the U.S. Fish and Wildlife Service's recent conclusion that listing of longfin smelt under the Endangered Species Act is warranted but precluded. *See* 77 Fed. Reg. 19775 (April 2, 2012). In addition, the DEIS fails to demonstrate that implementation of the No Action Alternative would not result in significant impacts to the species, consistent with the finding that ESA listing is warranted and the ongoing population declines observed in numerous surveys. In fact, language in the DEIS admits that the No Action Alternative would result in "less adverse" effects than the Second Basis of Comparison, *see* DEIS at 9-156, but the DEIS fails to clearly state that the No Action Alternative results in adverse impacts on longfin smelt or to propose any mitigation measures to address that impact.

C. *The DEIS Fails to Accurately Assess Impacts on Salmonids*

As with the pelagic species discussed above, the DEIS fails to accurately assess the environmental impacts of CVP/SWP operations on salmonid survival and abundance. The DEIS omits references to important scientific studies, and instead relies on contradictory modeling information that does not accurately assess impacts. As a result, the DEIS fails to accurately assess environmental impacts and propose necessary mitigation measures.

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1. *The DEIS Fails to Accurately Assess Impacts to Migrating Salmonids in the Delta*

NRDC TBI 18 concluded

The DEIS fails to accurately assess impacts of CVP/SWP export pumping operations in the Delta on migrating salmonids, significantly understating the environmental impacts of increased pumping during migration seasons. For instance, recent life cycle models for fall run Chinook salmon and spring run Chinook salmon have been submitted to the Delta Science Program, which conclude that CVP/SWP delta exports significantly reduce spring and fall run salmon survival and abundance. *See* Cunningham et al 2015. The DEIS mentions this study briefly, but it fails to utilize this life cycle model to assess impacts. Similarly, Michel et al 2015 was recently published in the Canadian Journal of Fisheries and Aquatic Sciences, which reviews five years of acoustic tag data and demonstrates that increased flows dramatically increase survival of migrating salmon through the Sacramento River and Delta. Both of these studies contradict many of the methods and models utilized by Reclamation in the DEIS to assess impacts, such as the Delta Passage model (which predicts very minimal changes in survival and abundance despite significant changes in exports and Old and Middle Reverse Flows).

For example, Cunningham et al 2015 estimates that increasing exports by 30% above the 1967-2010 average would result in a 16-28% lower median survival rate from egg to adulthood for wild fall run Chinook salmon and a 39-59% reduction in median survival for spring run Chinook salmon, concluding that, "[a] 30% increase in exports decreased spring and fall stock survival to the point where they would all decline regardless of the climate scenario." In contrast, the Delta Passage Model predicts "very similar estimates of survival" for spring and fall run Chinook salmon under the No Action Alternative compared to the Second Basis of Comparison, despite the substantial increase in exports under the Second Basis of Comparison. *See* DEIS at 9-169, 9-178.

NRDC TBI 19

In addition, the Delta Passage Model only attempts to estimate survival of salmon smolts, *see* DEIS Appendix 9J at 9J-1, and cannot assess impacts to salmon fry or parr. Yet fry and parr life stages are often the majority of salmon migrating through the Delta, and the DEIS wholly ignores the impacts of CVP/SWP operations on these salmonid life histories.

NRDC TBI 20

Similarly, the DEIS fails to explain the contradictory information from use of the OBAN life cycle model and the Delta Passage Model on salmon survival through the Delta. On page 9-162, the DEIS states that the Delta Passage Model results in similar winter run Chinook salmon survival through the Delta under the No Action Alternative and the Second Basis of Comparison, and on the same page it states that the OBAN life cycle model predicts that median survival through the Delta would be 12 percent higher under the No Action Alternative compared to the Second Basis of Comparison. The DEIS provides no justification for its statement that the OBAN model's survival estimates "suggest a high probability of no difference between these

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two bases of comparison." DEIS at 9-162. In fact, the model demonstrates a very substantial difference in survival between the two alternatives, and Reclamation's conclusory statement is arbitrary and capricious.

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As a result, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations in the Delta on migrating salmonids, and the conclusions drawn in the DEIS are arbitrary and capricious.

2. *The DEIS Fails to Accurately Assess Upstream Water Temperature Impacts to Salmonids*

The DEIS' analysis of upstream temperature impacts on salmonids is flawed and understates the adverse impacts of CVP/SWP operations on salmonids (particularly in combination with climate change), and the DEIS fails to explicitly acknowledge that CVP/SWP operations cause significant adverse impacts and to propose mitigation measures to address these impacts in the short term. Reclamation's conclusions in the DEIS are arbitrary and capricious.

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Even using flawed methodology, the DEIS demonstrates that there will be significant adverse effects on salmon from high water temperatures as a result of climate change and CVP/SWP operations, including under the No Action Alternative:

> Under the No Action Alternative, the ability to control water temperatures depends on a number of factors and management flexibility usually ends in October when the cold water pool in Shasta Lake is depleted. With climate change, cold water storage at the end of May in Shasta Lake is expected to be reduced under the No Action Alternative for all water year types. This would further reduce the already limited cold water pool in late summer. **With the anticipated increase in demands for water by 2030 and less water being diverted from the Trinity River, it is expected that it would become increasingly difficult to meet water temperature targets at the various temperature compliance points. It is likely that severe temperature-related effects will be unavoidable in some years under the No Action Alternative. Due to these unavoidable adverse effects,** RPA Action Suite I.2 also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek (see below) which may support a second population of winter-run Chinook Salmon, and a fish passage program at Keswick and Shasta dams to partially restore winter-run Chinook Salmon to their historical cold water habitat.

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DEIS at 9-127 to 9-128 (emphasis added).[7] The DEIS also uses Reclamation's salmon mortality model to estimate temperature impacts on salmon production and mortality, concluding that the impacts from the No Action Alternative and the Second Basis of Comparison are similar, *see* DEIS at 9-160, that winter run Chinook salmon mortality is 31.4% in critically dry years under the No Action Alternative, *see* DEIS at Appendix 9C-8, and that Sacramento River spring run Chinook salmon mortality is 21.9% on average and 84.8% in critically dry years under the No Action Alternative, *see* DEIS at Appendix 9C-7. Similarly, the SALMOD model results in the DEIS estimate that in approximately 10% of years, there would be zero production of spring run Chinook salmon below Shasta Dam. *See* DEIS at Figure B-3-1. And the DEIS estimates that under both the No Action Alternative and the Second Basis of Comparison, Reclamation will frequently violate temperature standards at Shasta Dam, *see* DEIS at 9-159 to 9-160, and at other reservoirs, *see* DEIS at 9-166 to 9-168. Yet the DEIS fails to explicitly identify upstream temperature mortality as a significant adverse impact, and the only mitigation measure identified in the DEIS (fish passage program) is a long term potential measure that is already required under the No Action Alternative and is therefore part of the baseline. That mitigation measure does not address the ongoing significant adverse impact in the near term, nor does it propose anything that is not already required.

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Moreover, the DEIS relies on flawed methodologies to assess temperature impacts on salmonids, many of which provide contradictory results, and which mislead the public as to the effects of CVP/SWP operations. For instance, the DEIS uses the SALMOD model to calculate juvenile production and the extent of temperature related upstream mortality to eggs and fry, and concludes that the No Action Alternative results in similar impacts to the Second Basis of Comparison. DEIS at 9-162. Yet SALMOD's estimates of mortality and production are wildly inaccurate compared to recent data. For instance, Figure B-4-1 estimates that winter run Chinook salmon production would never drop below 500,000, yet in 2014 there was a total year class failure with over 95% mortality due to water temperatures. Figure B-4-1 also shows that according to the SALMOD model, in approximately 95% of years winter run Chinook salmon production does not vary by more than a few hundred thousand fish. Yet empirical data shows that winter run Chinook salmon egg to fry survival at Red Bluff Diversion Dam from 2002 to 2012 varied substantially, from a low of 15.4% to a high of 48.6%, with a mean of 26.4%. *See* U.S. Fish and Wildlife Service 2015 at Table 6c. Estimates for other salmon runs are similarly inaccurate compared to recent Sacramento River data from the U.S. Fish and Wildlife Service.

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[7] However, as noted above, the DEIS also fails to demonstrate whether operations of Shasta Dam under the No Action Alternative are consistent with requirements of the 2009 NOAA biological opinion, which includes performance measures and other requirements to maintain adequate cold water pool for winter run Chinook salmon below the dam. *See* DEIS at 9-125 (describing RPA requirements). To the extent that the modeled operations under the No Action Alternative fail to meet the RPA requirements, Reclamation must revise operations to be consistent with those RPA requirements.

And this recent data also contradicts the information presented in Reclamation's salmon mortality model, which significantly underestimates mortality compared to the recent data. NRDC TBI 22 continued

In addition, the analysis of water temperature impacts looks only at monthly average temperatures. DEIS at 9-109. As the DEIS notes briefly, "the effects of daily (or hourly) temperature swings are likely masked by the averaging process." DEIS at 9-110. This is clearly correct, and may help explain why the modeled results do not show the level of mortality seen from recent empirical data. Yet the DEIS fails to carry forward this caveat elsewhere in the discussion, when it presents the results of modeling. Similarly, the DEIS restricts its use of the IOS model to median escapement estimates and only uses a subset of the years from CALSIM, DEIS at 116, which excludes the highest mortality years in the driest years and therefore does not accurately assess impacts. NRDC TBI 23

Finally, the DEIS' analysis of weighted usable area for rearing habitat fails to account for more recent scientific research demonstrating the strong effect of increased flow on downstream salmonid survival in the Sacramento River. *See* DEIS at 9-107 to 9-109. The methodology used in the DEIS does not account for the significant reduction in survival of migrating salmon under lower flow conditions in the Sacramento River. *See* Michel et al 2015. As a result, the DEIS fails to accurately assess the impact of reduced flow on salmon survival in the Sacramento River using this methodology. NRDC TBI 24

The DEIS demonstrates that current CVP/SWP operations, including water deliveries to Sacramento River Settlement Contractors and other senior water rights holders, in combination with climate change, will result in significant adverse effects on salmon caused by violations of water temperature requirements. The DEIS predicts that these impacts will become more severe as a result of climate change and increased demands for water. As a result, the DEIS must consider alternatives and/or mitigation measures that reduce upstream water deliveries, including deliveries to Sacramento River Settlement Contractors and other water rights holders. NRDC TBI 25

3. *The DEIS Fails to Accurately Assess Impacts to Salmonids in the San Joaquin Basin*

The DEIS fails to accurately assess environmental impacts to salmonids in the San Joaquin Basin because it fails to assess impacts to spring run Chinook salmon and because it fails to assess the impacts from changes in river flows. NRDC TBI 26

First, the DEIS fails to acknowledge that small populations of spring run Chinook salmon have been established in recent years in the Stanislaus and other rivers. NMFS has acknowledged these populations exist, but the DEIS only analyzes impacts to fall run Chinook salmon and mistakenly concludes that spring run have been extirpated. DEIS at 9-87, 9-92. The DEIS

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wholly fails to analyze impacts to spring run Chinook salmon in the Stanislaus River and other San Joaquin River tributaries.

NRDC TBI 27

Second, the DEIS acknowledges some of the studies documenting that salmon survival in the Stanislaus River and other San Joaquin tributaries is driven by river flow conditions. For instance, the DEIS cites Zeug et al 2014 to show that higher flow generally results in higher salmon survival and subsequent abundance. DEIS at 9-92. Yet the DEIS ignores other scientific studies which conclude that flows drive salmonid survival and abundance, including Sturrock et al 2015, Buchanan et al 2015, State Water Resources Control Board 2010, 2012.[8] The DEIS also fails to emphasize that inadequate flow is the dominant factor limiting salmon survival and abundance, instead relying on outdated research from 1982 to assert that survival through the Stockton Deepwater Ship Channel is one of the most limiting factors. DEIS at 9-92.[9]

However, the DEIS fails to utilize this scientific information on the importance of river flow in assessing environmental impacts. While the DEIS analyzes impacts from changes in operations on water temperatures, it wholly fails to assess the impacts from changes in flows on the Stanislaus River. *See, e.g.,* DEIS at 2-202 to 2-209 (analyzing impacts to fall run Chinook salmon and steelhead).[10] The available scientific evidence demonstrates that a reduction in flows below the minimum requirements of the biological opinion would result in very significant adverse effects on steelhead, fall run Chinook salmon, and spring run Chinook salmon. *See, e.g.*, Sturrock et al 2015; Zeug et al 2014; Buchanan et al 2015; State Water Resources Control Board 2010, 2012. And the State Water Resources Control Board, National Marine Fisheries Service, U.S. Fish and Wildlife Service, California Department of Fish and Wildlife, and many others have demonstrated that current flow levels on the Stanislaus River and other San Joaquin River tributaries are causing significant impacts to salmon and steelhead, demonstrating a need to substantially increase flows to sustain salmon.

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[8] The DEIS also cites to 2001 research by Mesick on the effect of fall flows and exports on straying, but ignores Marston et al 2012, which concluded that fall pulse flows and export rates are correlated with higher rates of straying.

[9] The DEIS also incorrectly asserts that flows must exceed 5,000 cfs to mobilize gravel in the Stanislaus River. DEIS at 9-95. That is incorrect; Kondolf 2001 concluded that flows below 5,000 cfs could mobilize the riverbed, particularly in certain reaches of the river.

[10] Elsewhere, the DEIS asserts that under the No Action Alternative, Reclamation will not fully implement the biological opinion requirements regarding Stanislaus River and Lower San Joaquin River flows, in order to make water available to contractors, yet asserts with no justification that the impacts would be "similar or reduced relative to recent conditions." DEIS at 9-133. The DEIS reaches a similarly flawed conclusion with respect to the Second Basis of Comparison, concluding that the failure to implement the biological opinion requirements on the Stanislaus River would not improve. DEIS at 9-149.

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This is particularly problematic for Alternative 3, which proposes to substantially reduce Stanislaus River flows. The DEIS wholly fails to analyze the impact of reduced flows, and based solely on temperature modeling concludes that Alternative 3 would have slightly beneficial effects on fall run Chinook salmon. DEIS at 9-316. Because the DEIS fails to assess the environmental impacts of reduced flows, which is the dominant factor affecting salmon and steelhead on the Stanislaus, Lower San Joaquin River, and other tributaries, the DEIS fails to accurately assess the environmental impacts of CVP/SWP operations on salmonids in the San Joaquin Basin. Reclamation's conclusions in the DEIS are arbitrary and capricious. NRDC TBI 28

In addition, the DEIS fails to credibly analyze the impacts of the proposed trapping and barging of San Joaquin basin salmonids through the Delta under Alternative 3 and 4. The document makes unsubstantiated conclusions that this action would benefit salmonids without providing any analysis in the document. DEIS at 9-315 to 9-316. As a result, Reclamation's conclusion in the DEIS is arbitrary and capricious. There are substantial uncertainties regarding the effectiveness of capture operations (the stated goal is capturing 10-20% of the population) and potential adverse impacts. Moreover, coded wire tag data from the California Department of Fish and Wildlife show that salmon from the Merced Hatchery have successfully migrated through the Delta in recent years. *See* Kormos et al 2012; Palmer-Zwahlen and Kormos 2013. And in their comments on the ADEIS, NMFS raised substantial concerns that a trap and haul program would cause substantial adverse impacts on salmonids. NRDC TBI 29 The DEIS also fails to assess whether such a program is consistent with Reclamation's obligation to double natural production of salmon populations under the Central Valley Project Improvement Act.[11] NRDC TBI 30 Reclamation must substantially revise this section of the DEIS to provide a basis for its conclusion and to respond to the concerns raised by NMFS and others. NRDC TBI 31

4. *The DEIS Concludes that the Effects of Predator Control Program are Highly Uncertain and Could Cause Significant Adverse Environmental Impacts:*

As compared to the administrative draft, the DEIS' analysis of the impacts of predator control programs is substantially improved. For instance, the DEIS cites repeatedly to the Delta Science Program's independent peer review report (Grossman et al 2013) regarding the effects of predation on salmonids and the caveats that predator control programs will work as intended. *See* DEIS at 9-274 to 9-275. It also cites work by Peter Moyle suggesting that predator control programs could harm Delta Smelt, and acknowledges that predator control programs at the Columbia River have not demonstrated population level effects. DEIS at 9-274 to 9-276. As a result, the DEIS concludes that, NRDC TBI 32

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[11] More broadly, the DEIS fails to assess whether any of the alternatives meet Reclamation's obligations under section 3406(b).

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> the program may be difficult to implement, may not be effective, and may cause unintended harm to other native Delta fish species. Consequently, the outcome of the predator management program is highly uncertain. Compared to the No Action Alternative, which does not include a predator reduction program, Alternative 3 may or may not provide a benefit to salmonids and may result in an adverse effect on Delta smelt.

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DEIS at 9-276.

However, the DEIS fails to acknowledge that USBR's own studies regarding the Head of Old River Barrier on the San Joaquin River have shown that increased flows reduce predation on salmonids and reduced flows increase predation and reduce survival. *See* Bowen et al 20019 and 2010 (USBR Technical Memorandum 86-68290-10-07 and 86-68290-11). And the DEIS also inconsistently addresses the impact of CVP/SWP operations in contributing to predation by nonnative species, particularly by providing habitat conditions in the Delta and other rivers that favor non-native species. For instance, on page 9-354, the DEIS concludes that Alternative 5 may adversely affect striped bass, but the DEIS does not analyze whether or how that impact to striped bass may subsequently affect salmonids or other species.

5. *The DEIS Fails to Accurately Assess Impacts of Fishing Mortality and Greater Restrictions on Salmon Fishing Proposed in Some Alternatives:*

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The DEIS incorrectly assesses the impact of greater restrictions on salmon fishing under Alternatives 3 and 4. For instance, the DEIS downplays the effectiveness of the recent restrictions on salmon fishing as a result of the 2012 winter run Chinook salmon biological opinion, and it does not mention that NMFS' recovery plan for winter run Chinook salmon lists the ocean fishery as a low stressor on the population. *See* DEIS at 9-118, 9-277 to 9-278. The DEIS must be revised to account for this information in assessing impacts. Moreover, mark select fisheries are likely to substantially reduce fishing opportunities and may not improve conditions for wild salmon because of bycatch mortality, and the DEIS fails to analyze these potential adverse impacts of mark select fisheries.[12] In addition, as NMFS noted in its comments on the ADEIS, the harvest rule specified in Alternatives 3 and 4 may be less protective of winter run Chinook salmon than the existing biological opinion, given the restrictions on fishing at low levels of abundance. As noted in our prior comments, we strongly recommend that Reclamation work with the Pacific Fishery Management Council regarding these conclusions.

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[12] In addition, the DEIS fails to analyze the socioeconomic effects of reducing salmon fishing as proposed under Alternatives 3 and 4. *See, e.g.,* DEIS at 19-77.

6. The DEIS Fails to Accurately Assess Impacts of Climate Change on Salmon and Propose Mitigation Measures to Address those Impacts:

We appreciate that the DEIS includes the potential effects of climate change on precipitation and temperature, in order to assess how climate change may affect CVP/SWP operations. The DEIS assumes that climate change will reduce reservoir storage and cause increased temperature impacts on salmonids. *See, e.g.,* DEIS at 9-120, 9-123, 9-126 to 9-127, 9-130, 9-132 to 9-133, 9-146. However, the document wholly fails to propose any short term measures to mitigate the effects of CVP/SWP operations in combination with climate change in order to avoid violations of downstream water temperature standards that imperil salmon. As a result, the DEIS predicts more significant impacts on salmonids from increased upstream temperature, without proposing any changes or modifications to operations in order for Reclamation to meet its existing obligations under state and federal law to avoid violating water temperature requirements. The DEIS must be revised to analyze mitigation measures and alternatives that reduce or avoid water temperature violations below dams, including reduced upstream diversions and deliveries to senior water contractors. NRDC TBI 34

II. The DEIS Fails to Include a Reasonable Range of Alternatives:

NEPA requires consideration of a reasonable range of alternative actions that might achieve similar goals with less environmental impact. *See, e.g.,* 40 C.F.R. §1502.14. However, the DEIS fails to include any alternatives that substantially improve conditions for fish and wildlife species, or that incorporate increased water supply from other sources like water use efficiency or wastewater recycling. Reclamation has violated NEPA by failing to include any alternatives that reduce impacts on fish and wildlife populations and/or that meaningfully reduce reliance on the Delta, as required by the Delta Reform Act of 2009 (Cal. Water Code § 85021). NRDC TBI 35

In our scoping comments, we requested that Reclamation analyze an alternative in the DEIS that substantially increases Delta outflow in the winter-spring period to protect longfin smelt and other fish and wildlife species, and includes increased water use efficiency, water recycling, and other regional water supply programs to increase water supply reliability even if Delta exports decrease. *See* attachment 1 (scoping comments). However, Alternative 5 wholly fails to include any increase in regional and local water supplies, and Alternative 5 also fails to meaningfully increase Delta outflow.

Appendix 19A of the DEIS makes assumptions regarding investments in regional and local water supplies by SWP and CVP contractors, demonstrating that changes in local and regional water supplies are a reasonable alternative to consider. Yet Reclamation has failed to include an alternative that includes increased investments in these regional supplies, despite our scoping comments.

Similarly, none of the alternatives meaningfully increase Delta outflow in the winter and spring months, despite the significant adverse impacts on longfin smelt and other species affected by current outflow levels. Alternative 5 provides extremely limited increases in delta outflow. The model runs for Alternative 5 appear to be constrained by several assumptions, including assumptions concerning the amount of deliveries in any year to upstream contractors such as the Sacramento River Settlement Contractors, and export levels. Those assumptions can and should be modified to reflect alternative water supplies available to contractors and the need to reduce CVP/SWP diversions and deliveries to comply with environmental requirements. Modifying those assumptions would allow significant changes in the model output to improve reservoir levels and outflows. As noted above, the DEIS assumes that increased outflow necessarily results in reduced reservoir storage and increased water temperatures at upstream reservoirs, but that depends on assumptions regarding water diversions and exports. We understand that Phase 2 of the State Water Resources Control Board's update of the Bay Delta Water Quality Control Plan includes operational changes so that substantially increased delta outflow does not impact water temperature control at upstream reservoirs, and that the same is true for Alternative 8 in the BDCP / California WaterFix EIS. Reclamation must review this work to modify Alternative 5 so that it results in substantial increases in spring outflow and does not impair upstream water temperature compliance, even if that results in reduced exports and diversions upstream.

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Finally, the DEIS also fails to include any alternatives that address the impacts of upstream operations and climate change. As noted above, the DEIS asserts that the effects of climate change and CVP/SWP operations (including water deliveries to senior contractors) will make it difficult to meet temperature compliance standards. DEIS at 9-126 to 9-127. However, the DEIS fails to include any alternative that would avoid this impact and meet temperature compliance obligations, including reductions in water deliveries to senior contractors.

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Overall, the DEIS fails to analyze a reasonable range of alternatives that would eliminate or reduce the environmental impacts of ongoing CVP/SWP operations, as required by NEPA.

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III. Alternatives are Not Consistent with Reclamation's Water Rights and the Purpose and Need Statement

In addition, Alternative 3 is not consistent with the stated purpose and need in the DEIS, because the New Melones Operations Criteria in Alternative 3 would cause Reclamation to violate the terms and conditions of its existing water rights and the State Water Resources Control Board's Water Rights Decision 1641 ("D-1641"). *See, e.g.*, DEIS at 3-36. It appears that other alternatives, except for Alternative 5, likewise would result in violations of Reclamation's water rights permits with respect to Vernalis pulse flow obligations under D-1641. *See* DEIS at 3-42. Reclamation is obligated to meet Vernalis pulse flow requirements under D-1641, as the State

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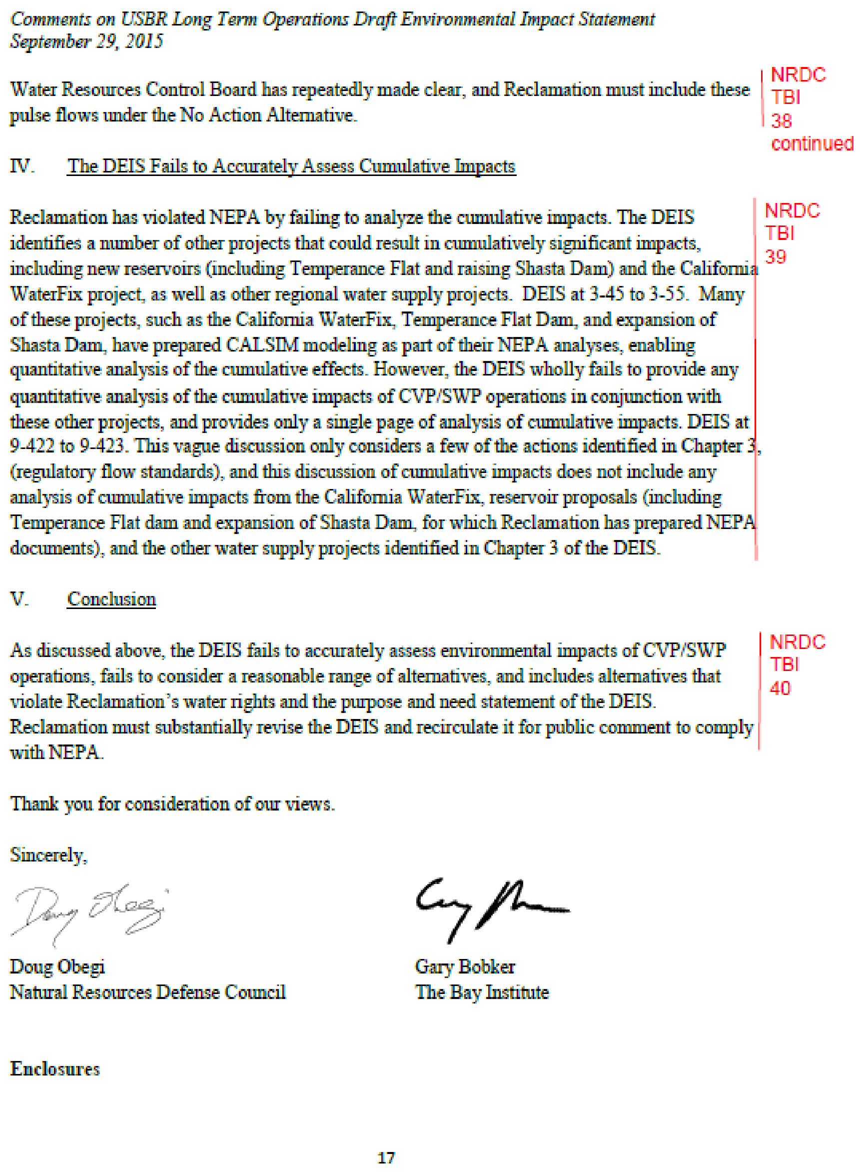

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September 29, 2015

Water Resources Control Board has repeatedly made clear, and Reclamation must include these pulse flows under the No Action Alternative.

NRDC TBI 38 continued

IV. The DEIS Fails to Accurately Assess Cumulative Impacts

Reclamation has violated NEPA by failing to analyze the cumulative impacts. The DEIS identifies a number of other projects that could result in cumulatively significant impacts, including new reservoirs (including Temperance Flat and raising Shasta Dam) and the California WaterFix project, as well as other regional water supply projects. DEIS at 3-45 to 3-55. Many of these projects, such as the California WaterFix, Temperance Flat Dam, and expansion of Shasta Dam, have prepared CALSIM modeling as part of their NEPA analyses, enabling quantitative analysis of the cumulative effects. However, the DEIS wholly fails to provide any quantitative analysis of the cumulative impacts of CVP/SWP operations in conjunction with these other projects, and provides only a single page of analysis of cumulative impacts. DEIS at 9-422 to 9-423. This vague discussion only considers a few of the actions identified in Chapter 3, (regulatory flow standards), and this discussion of cumulative impacts does not include any analysis of cumulative impacts from the California WaterFix, reservoir proposals (including Temperance Flat dam and expansion of Shasta Dam, for which Reclamation has prepared NEPA documents), and the other water supply projects identified in Chapter 3 of the DEIS.

NRDC TBI 39

V. Conclusion

As discussed above, the DEIS fails to accurately assess environmental impacts of CVP/SWP operations, fails to consider a reasonable range of alternatives, and includes alternatives that violate Reclamation's water rights and the purpose and need statement of the DEIS. Reclamation must substantially revise the DEIS and recirculate it for public comment to comply with NEPA.

NRDC TBI 40

Thank you for consideration of our views.

Sincerely,

Doug Obegi
Natural Resources Defense Council

Gary Bobker
The Bay Institute

Enclosures

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1D.1.11.1 Attachments to Comments from Natural Resources Defense Council and The Bay Institute

Attachments to the Natural Resources Defense Council and The Bay Institute Comment letter are included in Attachment 1D.3 located at the end of Appendix 1D.

1D.1.11.2 Responses to Comments from Natural Resources Defense Council and The Bay Institute

NRDC TBI 1: Comment Noted. Please see responses to Comments NRDC TBI 2 through NRDC TBI 40.

NRDC TBI 2: Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, and Section 9.3.8 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions and changes in fisheries resources.

Conditions that have led to consideration of the federal listing of Longfin Smelt are discussed on page 9-67 of the Draft EIS.

NRDC TBI 3: The population of winter-run Chinook salmon is at extreme risk. NMFS recently named Sacramento River winter-run Chinook salmon as one of the eight species most at-risk of extinction in the near future. Last year (2014), due to a lack of ability to regulate water temperatures in the Sacramento River in September and October, water temperature rose to greater than 60°F. This reduced early life stage survival (eggs and fry) from Keswick to Red Bluff from a recent average of approximately 27 percent (egg-to-fry survival estimates averaged 26.4 percent for winter-run Chinook salmon in 2002-2012) down to 5 percent in 2014. Consequently, 95 percent of the year class of wild winter-run Chinook was lost last year. Additional information regarding key components of the 2015 Shasta Temperature Management Plan is provided at: http://www.usbr.gov/mp/drought/docs/shasta-temp-mgmt-plan-key-components-06-18-15.pdf.

The 2014 spawning run of spring-run Chinook salmon returning to the upper Sacramento River system also experienced significant impacts due to drought conditions as well as elevated temperatures on the Sacramento River and other tributaries. Similar to winter-run, spring-run eggs in the Sacramento River experienced significant and potentially complete mortality due to high water temperatures downstream of Keswick Dam starting in early September 2014 when water temperatures exceeded 56° F. Few juvenile spring-run Chinook Salmon were observed this year migrating downstream of the Sacramento River during high winter flows, when spring-run originating from the upper Sacramento River, Clear Creek, and other northern tributaries are typically observed, indicating that the population was significantly impacted. Similar concerns for spring-run exist this year as for winter-run. While spring-run have greater distribution and inhabit locations in addition to the Sacramento River, conditions on those streams are also expected to be poor due to the drought. The conservation of storage expected as a result of the changes requested in the Temporary Urgency Change (TUC) Permit submitted by Reclamation and DWR in response to drought conditions are expected to also benefit spring-run this year. Additional information regarding CVP and SWP operations under a TUC Order issued on July 3, 2015, by the State Water Resources Control Board is provided at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/tucp_order070315.pdf.

The discussion in Chapter 9, Fish and Aquatic Resources, does find that increased air temperatures and reduced snowfall would result in water temperatures that would result in substantial adverse impacts to salmonids and sturgeon in the rivers downstream of the CVP reservoirs under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 (see subsections “Changes in Exceedance of Water Temperature Thresholds” in Section 9.4.3 of Chapter 9). The EIS analysis compares conditions in 2030 under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. The EIS analysis has been prepared in accordance with NEPA and does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions (as is presented in CEQA documents, such as the Bay Delta Conservation Plan Environmental Impact Report/Environmental Impact Statement). The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. This No Action Alternative represents the current management direction and level of management intensity consistent with the explanation of the No Action Alternative included in Council of Environmental Quality’s Forty Most Asked Questions (Question 3). NEPA does not require agencies to mitigate impacts, nor does it require agencies to identify mitigation associated with the No Action Alternative.

NRDC TBI 4: More details have been included in Section 9.4.3 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to qualitatively responses to RPA actions not included in the CalSim II model in the No Action Alternative and Alternatives 2 and 5. Please also see response to Comment NRDC TBI 4.

NRDC TBI 5: The EIS analysis is based upon the comparison of conditions in 2030 under different alternatives. The results of those comparisons related to water temperatures show relatively minimal changes under the Alternatives 1 through 5 to the No Action Alternative; and under the No Action Alternative and Alternatives 1 through 5 to the Second Basis of Comparison. However, as described in the response to Comment NRDC TBI 3, the water temperatures in the rivers downstream of the CVP reservoirs would result in substantial adverse impacts to salmonids and sturgeon under Alternatives 1, 2, 3, and 4 and the Second Basis of Comparison without the addition of fish passage methods that are included in the No Action Alternative and Alternative 5.

The CVP and SWP reservoirs are operated in accordance with regulatory limitations, including applicable state and federal laws, regulations, and water rights first prior to deliver of water to CVP and SWP water contractors. The CVP and SWP cannot choose to meet only portions of the applicable state and federal laws, regulations, and water rights; and, it is not possible to fully meet the temperature thresholds downstream of the CVP and SWP reservoirs in 2030 with climate change. Therefore, fish passage around the CVP and SWP reservoirs is the only measure available to provide habitat with appropriate water temperatures for early lifestages.

NRDC TBI 6: Because compliance with the California Environmental Quality Act (CEQA) would be under DWR's purview, Reclamation consulted with DWR on this comment. On October 5, 2015, DWR provided the following response: "The District Court required Reclamation to comply with NEPA on the provisional acceptance of the RPA actions. There is no action for the State of California requiring California Environmental Quality Act (CEQA) review."

NRDC TBI 7: The reference to Rose et al. (2013 a, b) and Baxter et al. (2010) has been included in the Final EIS on page 9-62 of the Draft EIS. The MAST report is referenced and described on pages 9-65 and 9-66 of the Draft EIS. A summary of conclusions in Rose et al.,(2013), MacNally et al. (2010) and Thomson (2010) was added to page 9-62 of the Draft EIS.

NRDC TBI 8: The life cycle model developed by Rose et al. (2013a, b) was not included in this analysis because it uses a wide array of daily data, many of the assumptions and parameter values were based on judgment.

NRDC TBI 9: Implementation of OMR flow requirements under the No Action Alternative, Alternative 2, and Alternative 5 are consistent with the approach explained in Appendix 5A, Section B (5A.8.1) and takes into account day-weighted monthly averages of trigger and off-ramp conditions. Implementation of 2008 USFWS BO RPA actions in CalSim II model were developed in 2009 through discussions with several agencies, as described in Section 9.4.1.3.3. Not all aspects of the 2008 USFWS BO and 2009 NMFS BO can be simulated in the CalSim II model which is a monthly time-step model.

In Alternative 3, OMR requirements are implemented in a similar fashion. It is acknowledged in Chapter 9, Fish and Aquatic Resources, that both Alternative 1 and Alternative 3 would have increased adverse effects compared to the No Action Alternative (See Table 9.4). Therefore, although the benefits of the OMR action are not fully captured in model output, the impact analysis in Chapter 9 includes a discussion of the quantitative results from the models and a qualitative analysis of other aspects in Alternative 3, including the benefits from the OMR criteria.

NRDC TBI 10: The analysis in the EIS compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for a broad range of physical, environmental, and human resources.

The analytical tools used in the impact assessment of fisheries resources described in Chapter 9, Fish and Aquatic Resources, evaluate differences in conditions related to different lifestages of different species in the Delta watershed. However, there are no available analytical tools to quantitatively predict the total population differences for all species considered in this EIS which consider all portions of the life histories of the fish (by species and run), including ocean harvest conditions for anadromous fish. Results from life cycle models for winter-run Chinook Salmon, as presented in Chapter 9, predict life stage survival and adult escapement, but not total populations. At this time, accepted population models do not exist to analyze the effects of the alternatives for the fisheries species and runs considered in this EIS. Therefore, the NEPA analysis does not determine if the alternatives would cause violations of existing biological opinion take limits. Rather, the NEPA analysis presents incremental differences between the alternatives, No Action Alternative, and Second Basis of Comparison.

NRDC TBI 11: The statement in this comment regarding Kimmerer (2011) is misconstrued and inaccurate. Kimmerer was reporting on an analysis designed to determine what level of impact could be detected by correlative methods. His regression analysis was between a simulated stock-recruitment index and OMR flows (assumed 0 if OMR is greater than 0 [northward]) to determine how large the maximum percentage loss (Pmax) would be before losses become detectable in the regression analysis. His results showed that the losses were not generally detectable in the regression until Pmax reached about 60 to 80 percent and maximum losses less than 20 percent were generally undetectable. Repeating the simulation 10,000 times with Pmax equal to 20 percent, the upper 95 and 90 percent confidence limits of the regression slope excluded zero (i.e., was statistically detectable) in 5 and 9 percent of the cases, respectively. This led to the conclusion that "a loss to export pumping on the order reported by Kimmerer (2008) can be simultaneously nearly undetectable in regression analysis, and devastating to the population." He also noted that "This also illustrates how inappropriate statistical significance is in deciding whether an effect is biologically relevant." Which was the sole reason for this exercise. Kimmerer (2011) did not imply there was a threshold of 10 percent mortality that would lead to devastating impacts on the population.

The determination of similar results based upon an incremental difference of 5 percent or less is indicative of a level of uncertainty in the model results. The EIS impact analysis starts with use of the monthly CalSim II model to project CVP and SWP water deliveries. Because this regional model uses monthly time steps to simulate requirements that change weekly or change through observations, it was determined that changes in the model of 5 percent or less were related to the uncertainties in the model processing. Therefore, reductions of 5 percent or less in this comparative analysis are considered to be not substantially different, or “similar.” The definition of the similar results has been added to the text in several locations in Chapter 9, Fish and Aquatic Resources, and to the appendices of Chapter 9 in the Final EIS.

NRDC TBI 12: Please refer to responses to Comments NRDC TBI 10 and NRDC TBI 11.

NRDC TBI 13: As noted in the Appendix 5A, the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 include and meet the SWRCB D-1641 requirements to the extent allowed by the hydrology. The modeling for the EIS simulates the operations results are intended to be a reasonable representation of long-term operational trends. The Draft EIS also included an analysis of larval/juvenile delta smelt entrainment, based on Kimmerer (2008) regression estimating percentage entrainment as a function of X2 and OMR. The specific actions undertaken under recent droughts were not included in the EIS modeling efforts because the analysis considers the coordinated long-term operation of the CVP and SWP. The analysis is based upon an 82-year hydrology which includes conditions that occur in a wide range of hydrology, including droughts. However, specific responses to the droughts and floods would be developed on individual basis and are not considered in the long-term analysis. The Draft EIS included an analysis of the fall X2 requirements as discussed in Appendix 9G based on the Feyrer et al. (2011).

The Draft EIS, at two locations in the document, suggested that food resources for Delta Smelt may have been supplemented in 2011 and 2012 when the release of Colusa Basin Drain water through the Yolo Bypass resulted in increases in nutrients and phytoplankton that led to measurable increases in zooplankton in the Yolo Bypass, Cache Slough, and the Sacramento River near Rio Vista. This was based on information contained in Frantzich (2014). The trends in Delta Smelt abundance, including the index value for 2012, are indicated in Table 9.1 on page 9-63 of the Draft EIS.

It is unclear how the Draft EIS, as suggested in the comment, “misstates the conclusions of the MAST report regarding the importance of implementation of the fall outflow RPA in 2011 (rather than agricultural runoff) on subsequent delta smelt abundance.” The conclusions from the MAST Report reported on page 9-66 of the DEIS are nearly verbatim. The paragraph following the MAST Report conclusions in the DEIS suggests that agricultural runoff through the Yolo Bypass may have contributed to an increase of food resources. This paragraph was deleted in the Final EIS because it repeats information stated previously.

NRDC TBI 14: Existing conceptual models were considered in the preparation of the aquatic resources analysis in the EIS. Predicting and analyzing the differential effects of alternative project operations on the abundance and composition of phytoplankton, zooplankton and benthic organisms would require a coupled hydrodynamic-food web model of the Delta. Such a model is currently not available. However, additional text was added to Section 9.4.1.3.2 of the Draft EIS to better capture the current literature on this subject.

NRDC TBI 15: The analysis of changes in hydrology resulting from operations contained was based on CalSim II modeling, which relies on a long-term period of record. As mentioned in Section 5A.A.3.5, “In CalSim II, operational decisions are made on a monthly basis, based on a set of predefined rules that represent the assumed regulations. The model has no capability to adjust these rules based on a sequence of hydrologic events such as a prolonged drought, or based on statistical performance criteria such as meeting a storage target in an assumed percentage of years..” Nonetheless, text has been added to Chapter 9 to acknowledge the current drought and its effects on aquatic resources, including algal blooms and invasive species.

As indicated in the comment, the BDCP/WaterFix environmental documents included an analysis of residence time to evaluate changes in microcystis and invasive species. For that study, residence time was strongly influenced by shifting diversion to the north Delta (and by increased habitat restoration areas in early stages of the project under BDCP/WaterFix). Under the Draft EIS alternatives, all diversions would be conducted at the current export facilities and all alternatives would include the same acreage of restoration. The operations in summer months would not vary significantly to affect temperature (mostly affected by ambient conditions) and residence time. Thus, incremental changes between alternatives regarding microcystis and invasive species would be indiscernible.

NRDC TBI 16: Please refer to response to Comments NRDC TBI 14 and NRDC TBI 15.

NRDC TBI 17: The analysis in the EIS analysis compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for Longfin Smelt. The NEPA analysis does not determine if the alternatives would change the findings of the biological opinions in the determination of the likelihood of the alternatives to cause jeopardy to the continued existence of the species, or destroy or adversely affect their critical habitat.

NRDC TBI 18: The results described in Cunningham et al. (2015) was added on page 9-78 (of the Draft EIS) to quantify the effects of exports on salmonid survival. Differences, such as those described by Cunningham in relation to exports are not exhibited in a comparison of the No Action Alternative with Alternatives 1 through 5 since the impact analyses results for all of the alternatives comparisons do not result in the distinct export regimes (+1 standard deviations of the mean) modeled by Cunningham et al. (2015). Results of the SALMOD model for late fall-run Chinook Salmon in the Sacramento River (Table B-2-5 of Appendix 9D) show comparable results for pre-smolt and smolt mortality due to habitat (flow) as Michel et al. (2015) in that mortality is increased in drier years as compared to wetter years.

NRDC TBI 19: Please see Appendix 9M, Salmonid Salvage Analysis, which describes the methods for addressing the effects of export facilities on juvenile salmonids. This analysis, based on coded wire tagged fish, covers a broader range of size classes than does the DPM analysis.

NRDC TBI 20: Although the median survival predicted by the OBAN model was 12 percent higher under the No Action Alternative than under the Second Basis of Comparison, the probability intervals indicated that no difference between scenarios was a likely outcome (i.e. the dashed line of no difference lies within the dark gray central 0.50 probability interval in Figure 9I-14). The text on page 9-162 (of the Draft EIS) has been modified for clarity; however, specific degrees of certainty cannot be determined with the existing analytical tools.

NRDC TBI 21: Please see response to NRDC TBI 5.

NRDC TBI 22: SALMOD is not used as a predictive model, it is used as a comparative tool for analyzing differences between alternatives that would occur over a range of hydrologic conditions represented by output from the 82-year CalSim II model (see Appendix 9D, SALMOD Model Documentation). As used, SALMOD output represents the mean values for production and mortality each year with the same initial conditions for population parameters and varying operations simulated by CalSim II. It is not a life-cycle model and does not provide a time trajectory of production. There is no expectation that SALMOD output will mirror recent (or historical) data on production or mortality. However, the comparison of mean values for production and mortality are a valid and appropriate method of comparing possible outcomes among the various alternatives. Similarly, the Reclamation Salmon Mortality Model utilizes CalSim II output through the temperature models and is not expected to mirror recent or historical estimates of mortality (see Appendix 9C, Reclamation's Salmon Mortality Model Analysis Documentation). It too is used as a comparative tool to distinguish potential effects among the alternatives. The results of the impact analysis is to understand the differences in the outcomes of the alternatives as compared to the No Action Alternative and the Second Basis of Comparison.

NRDC TBI 23: As described and presented in Appendix 9H of the Draft EIS, the IOS model uses the full 82-year CalSim II simulation period. The impact analysis used in the EIS evaluates the differences between alternatives based on changes in the median annual escapement and the range of escapement values encompassed in the first and third quartiles (25 to 75 percent of years) over the 82-year CalSim II simulation period (see page 9-116 of the Draft EIS). As described in the response to Comment NRDC TBI 22, SALMOD is not used as a predictive model to mirror past data, it is used as a comparative tool for analyzing differences between alternatives that would occur over a range of hydrologic conditions represented by output from the 82-year CalSim II model. As used, SALMOD output represents the mean values for production and mortality each year with the same initial conditions for population parameters and varying operations simulated by CalSim II. It is not a life-cycle model and does not provide a time trajectory of production. However, the comparison of mean values for production and mortality are a valid and appropriate method of comparing possible outcomes among the various alternatives under a NEPA analysis. Similarly, the Reclamation Salmon Mortality Model is used as a comparative tool to distinguish potential effects among the alternatives.

While likely effects from water temperature on early life stages occur at a shorter temporal scale than these models, comparative analyses are useful for long-term analyses, as in the EIS, because there is moderate certainty for long-term conditions.

NRDC TBI 24: The analysis of weighted usable area (WUA) in the Draft EIS is not intended to describe salmonid survival. The WUA methodology is used as a metric for evaluating changes in physical habitat related to flow as described in Appendix 9E, Weighted Useable Area Analysis, and on page 9-108 of the Draft EIS. The results of the SALMOD model are used to evaluate changes in salmonid survival in the Sacramento River (see Appendix 9D). Results of the SALMOD model for late fall-run Chinook Salmon in the Sacramento River (Table B-2-5 of Appendix 9D) show that mortality for pre-smolts and smolts is increased in drier years as compared to wetter years; this is consistent with Michel et al. (2015).

NRDC TBI 25: The EIS alternatives include consistent climate change conditions without consideration of potential regulatory or operational changes due to climate conditions in the future. Potential climate-related operational changes are currently unknown and it would be speculative to develop such assumptions for a NEPA analysis. This comparative approach eliminates the effects of climate change from the incremental changes between the alternatives, No Action Alternative, and Second Basis of Comparison.

The EIS analysis has been prepared in accordance with NEPA and does not compare the conditions under the alternatives, No Action Alternative, and Second Basis of Comparison to the existing conditions (as is presented in CEQA documents). The No Action Alternative represents operations consistent with implementation of the 2008 and 2009 Biological Opinions. This No Action Alternative represents the current management direction and level of management intensity consistent with the explanation of the No Action Alternative included in Council of Environmental Quality's Forty Most Asked Questions (Question 3). NEPA does not require agencies to mitigate impacts, nor does it require agencies to identify mitigation associated with the No Action Alternative.

NRDC TBI 26: "Spring-running" fish were not analyzed due to uncertainty whether they are genotypically spring-run, and if so, whether they are strays or a distinct population; and their exemption from take related to diverting or receiving water in accordance with the San Joaquin River reintroduction program. In the most recent Recovery Plan (NMFS 2014), it is stated that native spring-run Chinook salmon have been extirpated from all tributaries in the San Joaquin River Basin.

NRDC TBI 27: The references included in the comment provide additional information that is consistent with citations already included in the Draft EIS. Many of these reports also indicate that there still remains uncertainty in the flow-survival relationship. Sturrock et al. (2015) did not conclude that flows drive salmonid survival and abundance but did provide evidence that salmon populations fluctuate considerably with river flows experienced during juvenile rearing. The text on page 9-92 of the Draft EIS has been modified to include the reference in the comment, and to indicate that mortality in the Stockton Deep Water Ship Channel is one of the limiting factors.

Footnote 9 in the comment regarding Kondolf is not correct. Despite one site having a lower value (i.e., TMI 280 cfs) than 5,000 cfs, Kondolf used a combination of sites to identify that mobility overall occurs beginning at about 5,000 cfs. On page 36 of Kondolf, it states "Results of the bed mobility analysis for five (TMl, RI, RS, R28A, and R78) of nine sites studied suggest that flows around 5,000 to 8,000 cfs are necessary to mobilize the D50 of the channel bed material (Table 7.1 and Appendix C)." There was one site (TMI 1) where flows less than 5,000 cfs (280 cfs) would mobilize gravel, but as Kondolf explains "The mobility of the gravel at TMI probably reflects the smaller diameter of the augmented gravel, rather than the mobility of the gravels that would naturally occur in this steeper reach."

Text has been modified on the page 9-149 of the Draft EIS has been modified in the Final EIS to provide more clarity on the statement referenced in Footnote 9 of this comment.

NRDC TBI 28: Long-term average flows are not substantially reduced under Alternative 3 as compared to the No Action Alternative or the Second Basis of Comparison for the Stanislaus River below Goodwin Dam (see Figures 5-68, 5-69, and 5-70 in Chapter 5, Surface Water Resources and Water Supplies). There are anticipated flow reductions generally from March through June and particularly in October under Alternative 3, but flows are anticipated to be increased under Alternative 3 relative to the No Action Alternative and comparable to flows under the Second Basis of Comparison in many months. As described on pages 9-313 through 9-315 of the Draft EIS, water temperatures under Alternative 3 are anticipated to be similar to the No Action Alternative or slightly lower in most months and lead to a slight reduction in egg mortality for fall-run Chinook salmon. The text on page 9-316 of the Draft EIS has been modified to improve the readability

NRDC TBI 29: The description of the trap and haul program assumptions and methodologies presented in Chapter 9 of the Draft EIS were not extensive. Additional information has been included on the text from page 9-316 of the Draft EIS, and additional information has been provided in Appendix 9O of the Final EIS.

NRDC TBI 30: Reclamation's proposed action in the 2008 Biological Assessment included actions developed to contribute to Section 3406(b)(1) of the Central Valley Project Improvement Act (CVPIA) and other requirements of CVPIA. These actions were analyzed as part of the proposed action in the 2008 USFWS BO and 2009 NMFS BO. These actions are therefore also incorporated in the No Action Alternative and Alternative 5. Alternatives 1 through 4 and the Second Basis of Comparison due not fully contribute to the goals of Section 3406(b)(1).

NRDC TBI 31: Please see responses to comments from National Marine Fisheries Service in Appendix 1.A.1.

NRDC TBI 32: Text has been added to Section 9.4.3.4 of the FEIS to include the studies by Bowen et al. (2009, 2010) regarding predation on salmonids around a Head of Old River barrier.

While the two-year study observed a variable and negative relationship between flow and survival past the Head of Old River barrier, there remained uncertainty due to the actual barrier structural configuration and how they would affect predator habitat in this reach. These studies did not speculated about overall survival rates or the biological significance of reach specific mortality around the Head of Old River barrier. Overall, the conclusions indicated that survival around the Head of Old River barrier would be structural design specific and highly variable; therefore certainty of the effect of the structures remains low.

NRDC TBI 33: The analysis in the Draft EIS did not rely on the 2012 Biological Opinion for analysis of effects. The latest (2014) Final Recovery Plan lists ocean harvest as a "very high" stressor on the winter-run Chinook Salmon population. Additional text has been added to Chapter 15, Recreation Resources, and Chapter 19, Socioeconomics, related to the effects of the harvest restrictions in Alternatives 3 and 4. The harvest rules specified in Alternatives 3, and especially Alternative 4, may be less protective for winter-run Chinook Salmon because this run is not allowed to be captured in either sport or commercial ocean salmon fishing. Additional text has been added to Section 9.4.3.5.2 on consistency of these alternatives with NMFS fisheries management framework for reducing the impact of ocean salmon fishery on winter-run Chinook Salmon.

NRDC TBI 34: Please see response to Comment NRDC TBI 25.

NRDC TBI 35: The CVP and SWP reservoirs are operated in accordance with regulatory limitations, including applicable state and federal laws, regulations, and water rights first prior to deliver of water to CVP and SWP water contractors. Under the current regulatory scenario, it is not possible to fully meet the temperature thresholds downstream of the CVP and SWP reservoirs in 2030 with climate change. Additional reservoir releases to increase Delta outflow would result in further temperature issues in the rivers downstream of the CVP and SWP reservoirs. Reclamation cannot modify the state water rights requirements or SWRCB water quality criteria.

The EIS analysis indicates in that alternative water supplies would be required under Alternatives 1 through 5, the No Action Alternative, and the Second Basis of Comparison because CVP and SWP water deliveries are anticipated to be less than under existing conditions and full water contract amounts are only delivered in extremely wet years, as described in Chapter 5, Surface Water Resources and Water Supplies, and Chapter 19, Socioeconomics. Many of the municipalities are considering the alternative water supplies as part of their urban water management plans, as described in Appendix 5D, Municipal and Industrial Water Demands and Supplies.

As described in Section 1.6 of Chapter 1, Introduction, of the Draft EIS, it is anticipated that substantial changes could occur to CVP and SWP operations as future projects are implemented. It is anticipated that most of these future projects have been identified in Section 3.5 of Chapter 3, Description of Alternatives, including the Bay Delta Water Quality Control Plan Update. Many of these future projects have not been fully defined and are not anticipated to be operational until the late 2020s. If any of these future projects would substantially change CVP operations, Reclamation would evaluate the need to request initiation of consultation under ESA with the USFWS and NMFS.

The future projects are being developed for different project objectives than the purpose and need in this EIS for the coordinated long-term operation of the CVP and SWP. Because the future operations under future projects have not been finalized at this time; and because projects that would substantially change CVP operations would require future consultations with USFWS and NMFS, it would be pre-decisional to include these projects in the alternatives evaluated in this EIS. Therefore, the alternatives under these future projects are considered in the cumulative effects analysis in this EIS.

NRDC TBI 36: Please refer to response to Comment NRDC TBI 34.

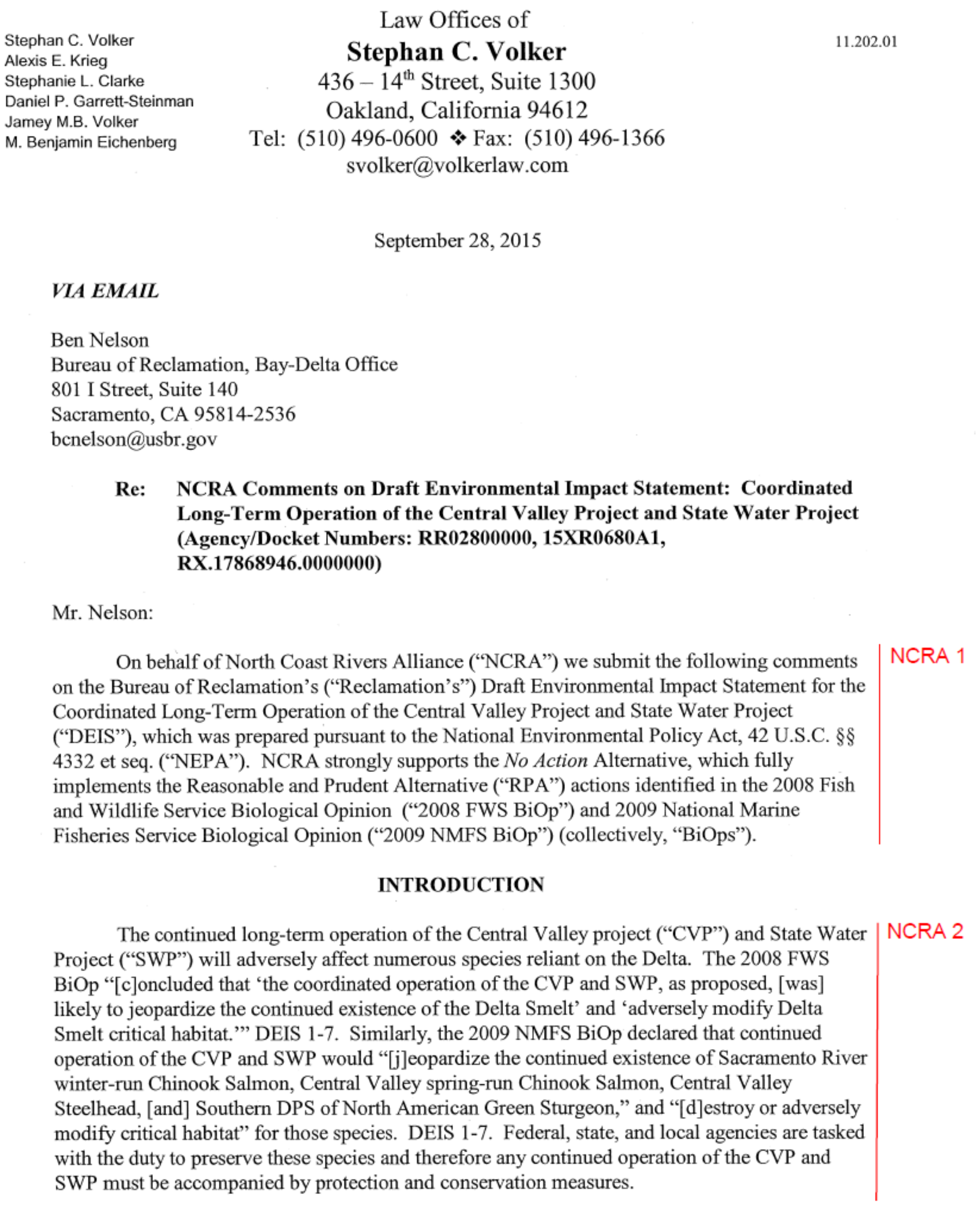
NRDC TBI 37: The EIS analysis compares conditions under a range of alternatives (Alternatives 1 through 5) with the No Action Alternative to identify beneficial and adverse impacts for a broad range of physical, environmental, and human resources. A reasonable range of alternatives includes technically and economically feasible alternatives to address the purpose and need for the action (40 CFR 1502.14). However, the range of alternatives can be limited if the alternatives analyzed address the full spectrum of alternatives (Question 1b of CEQ Forty Most Asked Questions). The range of alternative concepts were evaluated with respect to screening criteria defined in the purpose of the action (see Chapter 2, Purpose and Need), a determination if the concept addressed one or more significant issues, and if the concept was included in one or more alternatives (Table 3.1 in Chapter 3, Description of Alternatives).

NRDC TBI 38: The Council on Environmental Quality guidance describes that a "potential conflict with local or federal law does not necessarily render an alternative unreasonable, although such conflicts must be considered." Therefore, the range of alternatives considered in this EIS does include actions that are not necessarily consistent with existing federal and state requirements for the existing long-term operation of the CVP and SWP. The selection of the range of alternatives considered in the EIS was informed by several factors, including scoping comments, as described in Section 3.4 of Chapter 3, Description of Alternatives, in the EIS. Alternative 3 was developed through consideration of scoping comments from the Coalition for a Sustainable Delta, Oakdale Irrigation District, and South San Joaquin Irrigation District, as described in Section 3.4.5.

NRDC TBI 39: The discussion of cumulative impacts in Chapter 9, Fish and Aquatic Resources, has been expanded in the Final EIS.

NRDC TBI 40: Reclamation has modified the Final EIS in response to comments from NRDC, TBI, and other commenters; and will use the Final EIS in the development of the Record of Decision.

1D.1.12 North Coast Rivers Alliance



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September 28, 2015

VIA EMAIL

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Re: NCRA Comments on Draft Environmental Impact Statement: Coordinated Long-Term Operation of the Central Valley Project and State Water Project (Agency/Docket Numbers: RR02800000, 15XR0680A1, RX.17868946.0000000)

Mr. Nelson:

NCRA 1

On behalf of North Coast Rivers Alliance ("NCRA") we submit the following comments on the Bureau of Reclamation's ("Reclamation's") Draft Environmental Impact Statement for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project ("DEIS"), which was prepared pursuant to the National Environmental Policy Act, 42 U.S.C. §§ 4332 et seq. ("NEPA"). NCRA strongly supports the *No Action* Alternative, which fully implements the Reasonable and Prudent Alternative ("RPA") actions identified in the 2008 Fish and Wildlife Service Biological Opinion ("2008 FWS BiOp") and 2009 National Marine Fisheries Service Biological Opinion ("2009 NMFS BiOp") (collectively, "BiOps").

INTRODUCTION

NCRA 2

The continued long-term operation of the Central Valley project ("CVP") and State Water Project ("SWP") will adversely affect numerous species reliant on the Delta. The 2008 FWS BiOp "[c]oncluded that 'the coordinated operation of the CVP and SWP, as proposed, [was] likely to jeopardize the continued existence of the Delta Smelt' and 'adversely modify Delta Smelt critical habitat.'" DEIS 1-7. Similarly, the 2009 NMFS BiOp declared that continued operation of the CVP and SWP would "[j]eopardize the continued existence of Sacramento River winter-run Chinook Salmon, Central Valley spring-run Chinook Salmon, Central Valley Steelhead, [and] Southern DPS of North American Green Sturgeon," and "[d]estroy or adversely modify critical habitat" for those species. DEIS 1-7. Federal, state, and local agencies are tasked with the duty to preserve these species and therefore any continued operation of the CVP and SWP must be accompanied by protection and conservation measures.

NCRA 2 continued

As the situation in the Delta becomes more dire and fish populations continue their precipitous decline, the impacts of the continued long-term operation of the CVP and SWP become more severe.[1] For example, fishing yields for Chinook salmon have seen a steep decline in recent years.[2] Indeed, the 2014 commercial catch shrunk to 151,367 Chinook from 285,592 in the previous year. *Id.* At the tail end of the 2015 commercial season, preliminary yield numbers were only 96,878 Chinook. *Id.* Recreational yields for Chinook have likewise fallen, from 112,022 Chinook in 2013 to 65,936 in 2014. *Id.* As of August 31, 2015, this year's yield so far was only 25,541 Chinook. *Id.* Protection of the Delta is paramount to the survival of these species. The RPAs identified in the BiOps help protect the Delta's many imperiled fish species *before* their populations are extirpated. The ongoing drought plaguing the state will only exacerbate these potential impacts, further highlighting the importance of implementing the No Action Alternative and subsequently *all* of the RPAs. If we fail to protect these species now, we may not have a chance in the future.

A. The Bureau Must Not Implement *Any* of the Action Alternatives Presented in the DEIS

NCRA 3

None of the action alternatives considered in the DEIS can be approved. DEIS ES-7 to ES-14, 3-30 to 3-42. Three out of five action alternatives – Alternatives 1, 3, and 4 – fail to implement *any* of the RPAs identified in the BiOps and Alternative 2 only incorporates some of the RPAs. DEIS ES-11to ES-13, 3-31 to 3-40. Failing to fully implement the RPAs would not only risk entire populations of fish species, but it would also violate the Endangered Species Act, 16 U.S.C. §§ 1531 et seq. ("ESA"). Furthermore, the one action alternative that does implement all of the RPAs – Alternative 5 – is poisoned by the DEIS' attempt to sneak in an additional 32,000 acre-feet/year ("afy") water diversion. DEIS ES-14, 3-41 to 3-42. Since none of the action alternatives implement *all* of the RPAs while maintaining or lessening water diversions, Reclamation should approve the No Action Alternative.

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[1] Phillip Reese and Ryan Sabalow, *Feds scramble to avoid another mass salmon die-off in the Sacramento River,* SACRAMENTO BEE (Sept. 5, 2015) (detailing some of the most recent challenges facing Chinook salmon), attached as Exhibit 1and also available at: http://www.sacbee.com/news/state/california/water-and-drought/article34197762.html#storylink=cpy

[2] Pacific Fisheries Council, Status Report for the 2015 Ocean Salmon Fisheries off Washington, Oregon and California, Supplemental Informational Report 13 (Sept. 2015), attached as Exhibit 2 and also available at: http://www.pcouncil.org/wp-content/uploads/2015/09/SUP_IR13_Salmon_Catch_Update_SEPT2015BB.pdf

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1. Failing to Fully Implement the RPAs Would Violate the ESA

NCRA 4

As noted above, approval of Alternatives 1 through 4 would violate the Endangered Species Act, 16 U.S.C. §§ 1531 et seq. ("ESA"). The main goals of the ESA are "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, [and] to provide a program for the conservation of such . . . species." 16 U.S.C. § 1531(b); *See also* 50 C.F.R. § 402.01. The ESA also declares that all "Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance" of these purposes. 16 U.S.C. § 1531(c). Thus Reclamation must "seek to conserve" the species that continue to be decimated by the major water diversions associated with the coordinated long-term operation of the CVP and SWP. *Id.*; 50 C.F.R. §§ 402.02; 402.14, 402.15.

The United States courts have ardently reaffirmed the importance of the ESA. The Supreme Court held in *Tennessee Valley Authority v. Hill*, 437 U.S. 153, 180 (1978) ("*TVA*"), that the ESA "represented the most comprehensive legislation for the preservation of endangered species ever enacted by any nation," and "that Congress intended endangered species to be afforded the highest of priorities." *Id.* at 174. Indeed, the court noted that endangered species should be given "*priority over* the 'primary missions' of federal agencies." *TVA*, 437 U.S. at 185, emphasis added. If, like here, a proposed action presents a possibility of jeopardy to an endangered or threatened species or its habitat, the agency *must* consult with FWS and NMFS to create biological opinions that include RPAs to mitigate that jeopardy. 16 U.S.C. § 1536(b)(3)(A); 50 C.F.R. § 402.14(h).

Indeed, the ESA "affirmatively command[s] all federal agencies 'to insure that actions *authorized*, *funded*, or *carried out* by them do not jeopardize the continued existence' of an endangered species or '*result* in the destruction or modification of habitat of such species . . . .'" *TVA*, 437 U.S. at 173, *quoting* 16 U.S.C. § 1536, emphasis in original. This includes the affirmative requirement to adopt RPAs where necessary. 16 U.S.C. § 1536(b)(3)(A); 50 C.F.R. § 402.14(h). Agencies cannot ignore reliable information provided by FWS and NMFS in the BiOps. "Although the agency is technically not bound by findings of the . . . biological opinion[s], courts give great deference to the expertise of the FWS [and NMFS] on these issues, and an agency that attempts to proceed with an action in the face of a critical . . . biological opinion will almost certainly be found to have acted arbitrarily and capriciously and contrary to law." *Lone Rock Timber Company v. U.S. Department of the Interior*, 842 F.Supp. 433, 440 (D.Or. 1994), *citing Sierra Club v. Marsh*, 816 F.2d 1376, 1386 (9th Cir.1987) *and TVA*, 437 U.S. 153, internal citations omitted. A decision to continue long-term operation of the CVP and SWP without implementing all of the RPAs "in the face of reliable information that [it] will adversely impact protected species" violates the ESA. *Id.*

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The Ninth Circuit Court of Appeals has "recognize[d] that the preparation of an EIS will not alter Reclamation's obligations under the ESA." *San Luis & Delta-Mendota Water Authority v. Jewell*, 747 F.3d 581, 653 (2014). Here, the DEIS and both BiOps state that the continued operation of the CVP and SWP *is likely to* adversely affect protected species and their habitat, and jeopardize their continued existence. DEIS 1-7. This admission alone is more than enough to trigger these agencies' duty to insure that their actions in operating the CVP and SWP do not "jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species." 16 U.S.C. § 1536(a)(2), (b)(3)(A); 50 C.F.R. § 402.14(h). In order to insure that no such jeopardy is likely, the No Action Alternative should be approved and all of the RPAs identified in the BiOps should be implemented. NCRA 5

2. Alternative 5, the *Only* Action Alternative that Fully Implements the RPAs, Cannot Stand

Like the No Action Alternative, Alternative 5 would fully implement the RPAs. However, Alternative 5 also includes water contracts for the El Dorado County Water Agency ("EDCWA") and the El Dorado Irrigation District ("EID"). One of the contracts would allow EID to store up to 17,000 afy of non-CVP water in Folsom Dam; the other would provide up to 15,000 afy of CVP water to EDCWA from Folsom Dam. These contracts would result in reduced outflow from Folsom Dam rather than the greater flows needed for imperiled fish as noted above and discussed below. Neither the project's purpose and need, nor the RPAs, provide any specific justification for including these water contracts in any of the Action Alternatives. NCRA questions the decision to include these contracts in Alternative 5. NCRA 6

When compared with the No-Action Alternative, Alternative 5 would increase egg mortality for fall-run Chinook Salmon within the Sacramento and Feather River Systems during critically dry and below normal years, respectively. DEIS 9-347. The DEIS acknowledges that these effects would be more adverse than the No-Action Alternative. Therefore the No-Action Alternative must be selected.

There is an additional reason why Alternative 5 must be rejected. Its impacts are worse than those revealed in the DEIS. The DEIS should be revised to fully account for the likely increase in below normal rainfall years due to climate change. Although the DEIS does assume that climate change will increase short-duration, high-rainfall events that reduce snow-pack, and increase water temperature, it does not mention intensified drought conditions. Yet emerging research confirms that impacts associated with drought conditions – such as an increase in below NCRA 7

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normal rainfall years – are likely to increase with California's average temperature.[3] An increase in so-called below normal and critically dry years will amplify Alternative 5's detrimental effects on fall-run Chinook Salmon. For this additional reason, Alternative 5 must not be approved.

NCRA 7 continued

CONCLUSION

NCRA 8

For the reasons stated above, NCRA strongly urges adoption of the No-Action Alternative as the best hope to prevent extirpation of California's native fish.

Respectfully submitted,

Stephan C. Volker
Attorney for North Coast Rivers Alliance

SCV:taf

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[3] *See* Williams, A. P., R. Seager, J. T. Abatzoglou, B. I. Cook, J. E. Smerdon, and E. R. Cook, (2015), Contribution of anthropogenic warming to California drought during 2012–2014, Geophys. Res. Lett., 42, 6819–6828, doi:10.1002/2015GL064924, attached as Exhibit 3(finding that human caused warming intensified drought impacts). While Appendix 5A states that CalSim II modeling examined climate change effects, the DEIS does not state that CalSim II modeling included any consideration of rising temperature's impact on drought intensity. Instead, CalSim II applies historic trends forward.

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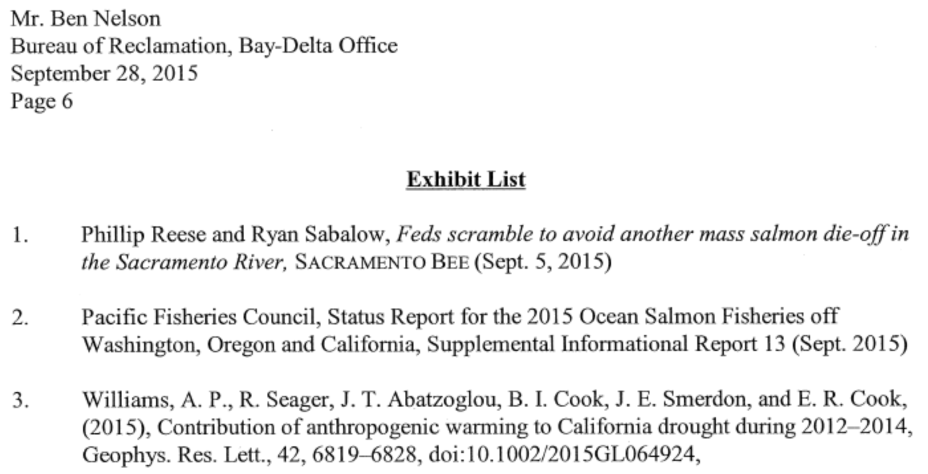


Mr. Ben Nelson
Bureau of Reclamation, Bay-Delta Office
September 28, 2015
Page 6

Exhibit List

1. Phillip Reese and Ryan Sabalow, *Feds scramble to avoid another mass salmon die-off in the Sacramento River,* SACRAMENTO BEE (Sept. 5, 2015)
2. Pacific Fisheries Council, Status Report for the 2015 Ocean Salmon Fisheries off Washington, Oregon and California, Supplemental Informational Report 13 (Sept. 2015)
3. Williams, A. P., R. Seager, J. T. Abatzoglou, B. I. Cook, J. E. Smerdon, and E. R. Cook, (2015), Contribution of anthropogenic warming to California drought during 2012–2014, Geophys. Res. Lett., 42, 6819–6828, doi:10.1002/2015GL064924,

1D.1.12.1 Attachments to Comments from North Coast Rivers Alliance

Attachments to the North Coast Rivers Alliance Comment letter are included in Attachment 1D.4 located at the end of Appendix 1D.

1D.1.12.2 Responses to Comments from North Coast Rivers Alliance

NCRA 1: Comment noted.

NCRA 2: The conclusions of the 2008 USFWS BO and 2009 NMFS BO cited in this comment discussed conditions that would likely jeopardize the continued existence of listed species prior to implementation of the RPA actions included in each BO. The existing conditions and the future conditions under the No Action Alternative, as described in the EIS, include implementation of the RPA actions for the coordinated long-term operation of the CVP and SWP. The RPAs contained in the BOs provide actions to modify the operations in order to avoid jeopardy of listed species or adverse modifications or destruction of critical habitat.

NCRA 3: The commenter's support of the No Action Alternative is acknowledged.

The EIS analysis compares conditions under Alternatives 1 through 5 with the No Action Alternative to identify beneficial and adverse impacts for a broad range of physical, environmental, and human resources. The NEPA analysis does not determine if the alternatives would change the findings of the biological opinions in the determination of the likelihood of the alternatives to cause jeopardy to the continued existence of the species, or destroy or adversely affect their critical habitat.

NCRA 4: The commenter's opposition of Alternatives 1 through 4 is acknowledged. As discussed in the response to Comment NCRA 3, the EIS does not determine if the alternatives would be likely to cause jeopardy to the continued existence of the species, or destroy or adversely affect their critical habitat.

NCRA 5: The comment related to the text on page 1-7 of the Draft EIS is a citation and a summary of information presented in the 2008 USFWS BO and 2009 NMFS BO. This information presented on page 1-7 of the Draft EIS is not a conclusion of the EIS.

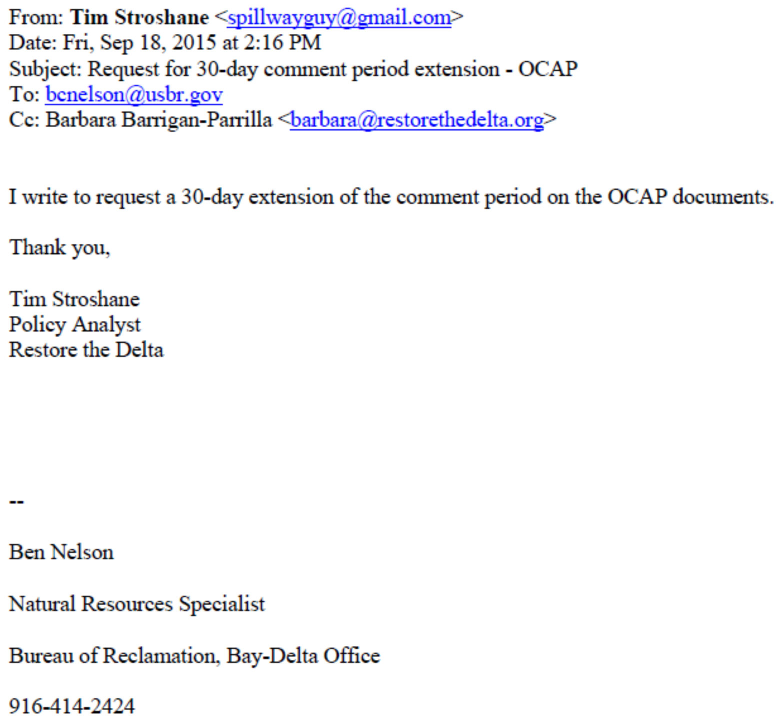
NCRA 6: Alternative 5 was developed as part of the range of alternatives to be considered in the EIS. The commenter's opposition to Alternative 5 and support of the No Action Alternative are acknowledged.

NCRA 7: The analysis in the EIS includes a range of hydrologic conditions projected to occur with a projected 2030 level of demand and regulatory requirements (including implementation of the 2008 USFWS BO and 2009 NMFS BO. As described in Appendix 5A, Section A, CalSim II and DSM2 Modeling, of the EIS, the range of hydrologic conditions analyzed in the EIS includes severe droughts and flood periods that have occurred in a 82-year hydrology with changes for projected climate change and sea level rise. The climate change assumptions are incorporated with historical hydrologic patterns to develop projected conditions in the Year 2030 for all alternatives considered in the EIS. As indicated in the comment, the projected pattern and frequency of water year types in the Year 2030 analysis in the EIS is different than under existing conditions.

The commenter's opposition to Alternative 5 is acknowledged.

NCRA 8: The commenter's support of the No Action Alternative is acknowledged.

1D.1.13 Restore the Delta



From: **Tim Stroshane** <spillwayguy@gmail.com>
Date: Fri, Sep 18, 2015 at 2:16 PM
Subject: Request for 30-day comment period extension - OCAP
To: bcnelson@usbr.gov
Cc: Barbara Barrigan-Parrilla <barbara@restorethedelta.org>

Restore the Delta 1

I write to request a 30-day extension of the comment period on the OCAP documents.

Thank you,

Tim Stroshane
Policy Analyst
Restore the Delta

--

Ben Nelson

Natural Resources Specialist

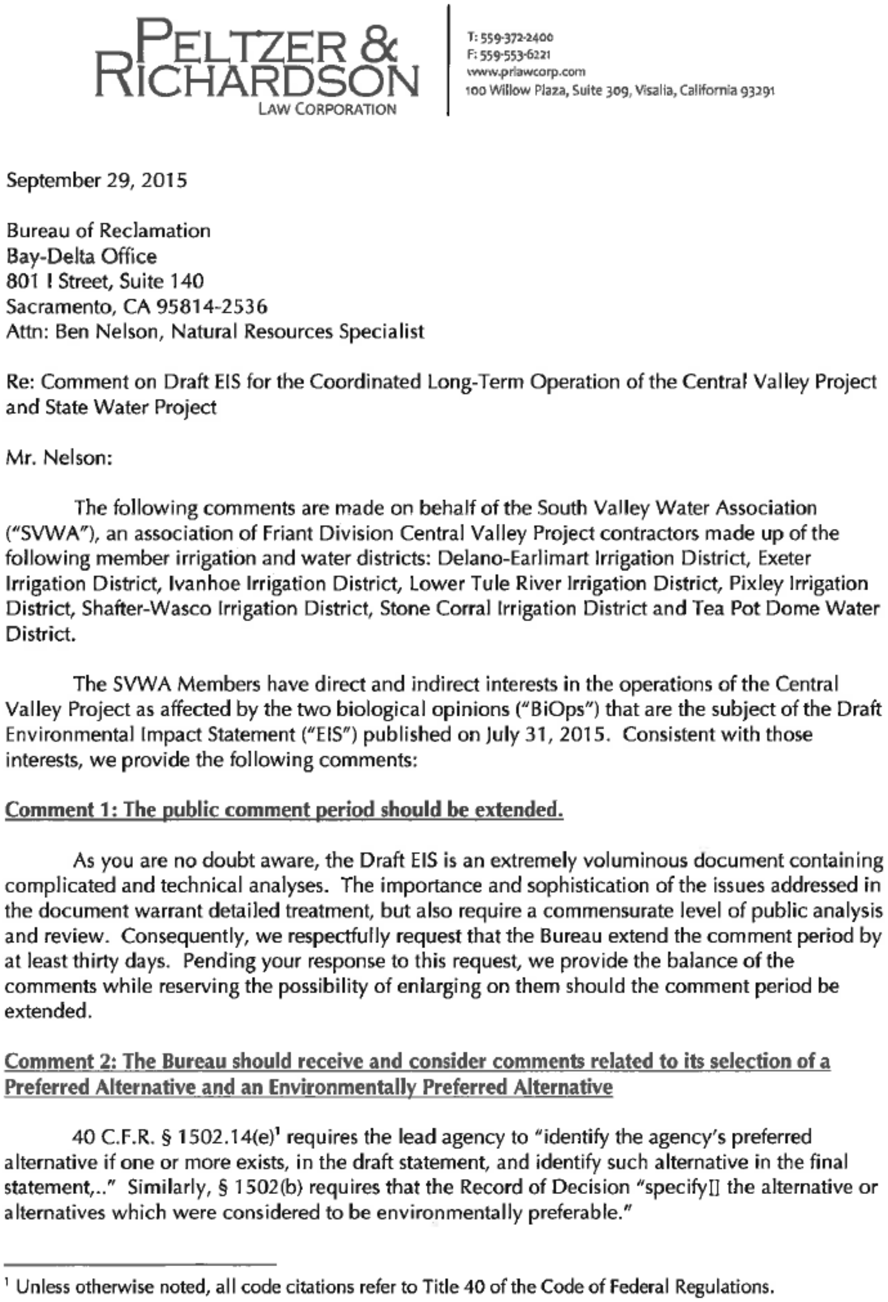
Bureau of Reclamation, Bay-Delta Office

916-414-2424

1D.1.13.1 Responses to Comments from Restore the Delta

Restore the Delta 1: At the time the request for extension of the public review period was submitted, the Amended Judgement dated September 30, 2014 issued by the United States District Court for the Eastern District of California (District Court) in the *Consolidated Delta Smelt Cases* required Reclamation to issue a Record of Decision by no later than December 1, 2015. Due to this requirement, Reclamation did not have sufficient time to extend the public review period. On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to extend the public review period.

1D.1.14 South Valley Water Association



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September 29, 2015

Bureau of Reclamation
Bay-Delta Office
801 I Street, Suite 140
Sacramento, CA 95814-2536
Attn: Ben Nelson, Natural Resources Specialist

Re: Comment on Draft EIS for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project

Mr. Nelson:

SVWA 1

The following comments are made on behalf of the South Valley Water Association ("SVWA"), an association of Friant Division Central Valley Project contractors made up of the following member irrigation and water districts: Delano-Earlimart Irrigation District, Exeter Irrigation District, Ivanhoe Irrigation District, Lower Tule River Irrigation District, Pixley Irrigation District, Shafter-Wasco Irrigation District, Stone Corral Irrigation District and Tea Pot Dome Water District.

The SVWA Members have direct and indirect interests in the operations of the Central Valley Project as affected by the two biological opinions ("BiOps") that are the subject of the Draft Environmental Impact Statement ("EIS") published on July 31, 2015. Consistent with those interests, we provide the following comments:

Comment 1: The public comment period should be extended.

SVWA 2

As you are no doubt aware, the Draft EIS is an extremely voluminous document containing complicated and technical analyses. The importance and sophistication of the issues addressed in the document warrant detailed treatment, but also require a commensurate level of public analysis and review. Consequently, we respectfully request that the Bureau extend the comment period by at least thirty days. Pending your response to this request, we provide the balance of the comments while reserving the possibility of enlarging on them should the comment period be extended.

Comment 2: The Bureau should receive and consider comments related to its selection of a Preferred Alternative and an Environmentally Preferred Alternative

SVWA 3

40 C.F.R. § 1502.14(e)[1] requires the lead agency to "identify the agency's preferred alternative if one or more exists, in the draft statement, and identify such alternative in the final statement,.." Similarly, § 1502(b) requires that the Record of Decision "specify[] the alternative or alternatives which were considered to be environmentally preferable."

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[1] Unless otherwise noted, all code citations refer to Title 40 of the Code of Federal Regulations.

SVWA 3 continued

The Bureau should, as soon as reasonably practicable, announce which Alternatives it intends to select as the Preferred Alternative and the Environmentally Preferable Alternative and why it believes those Alternatives to be superior to the others for their respective categories. Pursuant to its authority under § 1503.1(b),[2] the Bureau should then solicit comments on its tentative selections to ensure the public has an opportunity to participate in these crucial decisions. In this way, the Bureau will allow for greater public scrutiny and input, improve the quality of the ultimate decision, and provide greater transparency into the decision-making process.[3]

In any event, the Final EIS must include in the Executive Summary a clear and concise explanation regarding the Bureau's selection of a Preferred Alternative and the evidence used to arrive at that conclusion.[4] Further, because an EIS must "serve as the means of assessing the environmental impact of proposed agency actions, rather than justifying decisions already made,"[5] such explanation should include a discussion of the Alternatives *not* selected as the Preferred Alternative, and an explanation as to why the Bureau declined to select those Alternatives as the Preferred Alternative.

Comment 3: The Draft EIS fails to address significant and reasonably foreseeable effects on CVP contractors resulting from water deliveries to the San Joaquin River Exchange Contractors from the San Joaquin River

SVWA 4

The Final EIS must include a discussion of the effects of the agency action and the significance of those effects.[6] Effects can be "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative."[7] "Effects may also include those resulting from actions which may have both beneficial and detrimental effects, even if on balance the agency believes that the effect will be beneficial."[8]

Chapter 5 of the Draft EIS shows the changes in CVP water deliveries under the Alternatives as compared to the No Action Alternative and the Second Basis of Comparison according to CalSim II modeling results. For each comparison, the San Joaquin River Exchange

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[2] § 1503.1(b) provides that "[a]n agency may request comments on a final environmental impact statement before the decision is finally made." Because the Bureau has not yet announced its selection of a Preferred Alternative, that decision will be part of the final environmental impact statement. Accordingly, this provision authorizes the Bureau to request comments on that decision before it is finally made.

[3] See § 1500.2 ("Federal agencies shall to the fullest extent possible ... encourage and facilitate public involvement in decisions which affect the quality of the human environment."); Westlands Water Dist. v. U.S. Dep't of Interior, 376 F.3d 853, 868 (9th Cir. 2004) ("The touchstone for [judicial] inquiry [into the adequacy of an EIS] is whether an EIS's selection and discussion of alternatives fosters informed decision-making and informed public participation.").

[4] See § 1502.14(e); § 1502.1 ("Statements shall be concise, clear, and to the point, and shall be supported by evidence...").

[5] § 1502.2(g).

[6] § 1502.16(a)-(b).

[7] § 1508.8.

[8] Id.

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SVWA 4 continued

Contractors, which are described as a "South of Delta" contractor, are shown to experience no change in CVP water deliveries.[9]

The Exchange Contractors ordinarily receive water from the Delta but can, under certain circumstances, receive water from the San Joaquin River. Indeed, for the past two years, the Exchange Contractors have received less than 75% of their allotment from the Delta, with the remaining portion being diverted from the San Joaquin River. However, the model underlying the Draft EIS assumes that *all* water received by the Exchange Contractors, under all alternatives and in all water year types, will be satisfied exclusively from the Delta. This assumption simply does not comport with the reality.

When the Bureau delivers to the Exchange Contractors water from the San Joaquin River, that water is no longer available for CVP contractors who ordinarily receive their water from that source—namely the members of the SVWA, among others. As a result, these CVP contractors receive less water than they would have if the Exchange Contractors' water had been diverted exclusively from the Delta. However, because the Draft EIS assumes that all water received by the Exchange Contractors is derived exclusively from the Delta, it does not, and indeed cannot, account for the effects on the Friant Division CVP contractors when this does not occur, as it has in the past two years.

The impacts of this shortfall are significant.[10] By way of example, last year Friant Division contractors, including the SVWA members, received a zero percent contract allocation. Prior to the announcement that the Exchange Contractors would be receiving water from the San Joaquin River, the anticipated delivery to these contractors as a group was approximately a 15-20 percent Class 1 supply. Thus, as a direct result of the Exchange Contractors' receipt of water from the San Joaquin River, rather than the Delta, the Friant Division contractors experienced an extreme impact as compared to a scenario in which all of the Exchange Contractor entitlement is received from sources in the Delta. Because this shortage affects the entire Friant Division service area, constituting millions of acres of productive farm land, it is a cumulatively significant impact.[11] Moreover, in light of disputes regarding the nature of rights held by the Exchange Contractors, these impacts are highly controversial. Further, by failing to address these impacts, the Bureau may establish a precedent that they need not be considered in an EIS.[12]

The failure to first acknowledge and then analyze the impacts of the inability to satisfy all Exchange Contractor demands from Delta sources constitutes a major failing of the Draft EIS. As noted in the Bureau's own material announcing the availability of the Draft EIS for public comment, a major purpose of the current EIS process is to satisfy a directive from a federal court that it consider impacts to the human environment associated with the BiOps' implementation. As

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[9] See Draft EIS, Ch. 5, Tables 5.26 (at 5-93), 5.43 (at 5-122), 5.60 (at 5-150), 5.77 (at 5-176), 5.94 (at 5-203), 5.111 (at 5-231).

[10] See § 1508.27 (reciting factors relevant to determination of significance).

[11] See § 1508.27(7)("Significance exists if it is reasonable to anticipate a cumulatively significant impact on the environment. Significance cannot be avoided by ... breaking it down into small component parts.")

[12] See § 1508.27(4)("The degree to which the effects on the quality of the human environment are likely to be highly controversial."); § 1508.27(6)("The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration.").

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SVWA 4 continued

discussed above, the Draft EIS omits an entire area of severe impacts to the human environment that do not require any speculation or modeling because they are *actually occurring and readily quantifiable*. This renders the Draft EIS inadequate on its face.

The reduction in water deliveries to south-of-delta contractors due to the Exchange Contractors receipt of water from the San Joaquin River is a significant effect or impact within the meaning of NEPA. Additionally, because this effect has actually occurred in each of the two preceding water years, it is a reasonably foreseeable consequence of the continued operation of the CVP. Therefore, consistent within its obligations pursuant to NEPA, the Bureau must include in the Final EIS an analysis and discussion of these effects, including a discussion of possible mitigation measures.[13]

Comment 4: Including two baselines of comparison (the No Action Alternative and the Second Basis of Comparison) undermines the EIS's fundamental purpose. The Second Basis of Comparison should be rebranded as the No Action Alternative and all discussion of the current No Action Alternative should be relocated to an appendix or removed entirely.

SVWA 5

NEPA's purpose is to "foster excellent action ... [by] help[ing] public officials make decisions that are based on understanding of environmental consequences."[14] Because "scientific analysis, expert agency comments, and public scrutiny are essential to implementing NEPA,"[15] EISs must be "concise, clear, and to the point,"[16] "must concentrate on the issues that are truly significant to the action in question" and must not "amass[] needless detail."[17] Accordingly, agencies preparing an EIS are instructed to generate a document that is "*no longer than absolutely necessary* to comply with NEPA and [its] regulations."[18] Further, the document must be analytic rather than encyclopedic, written in plain language, follow a clear format, and emphasize the portions of the EIS that are useful to decision makers and the public.[19]

In response to comments received during the scoping process, the Bureau decided to include two bases of comparison in the Draft EIS: the No Action Alternative and the Second Basis of Comparison. While the Bureau's motives in making this decision were perhaps laudable—namely to appease critics on both sides regarding what the appropriate baseline for comparison should be—in practice, the inclusion of two baselines fundamentally impairs the Draft EIS's utility because it distracts from the core issues, effectively doubles the amount of analysis necessary to understand and comment upon the Draft EIS, and confuses the public as to what information will be considered in reaching a final decision about the continued operation of the CVP and SWP.

The inclusion of two baselines of comparison is a distraction because it forces the reader to focus on issues that are not truly significant to the environmental consequences of continued

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[13] See § 1502.16(h)("[The EIS] shall include discussions of ... means to mitigate adverse environmental impacts.").
[14] § 1500.1(c).
[15] § 1500.1(b).
[16] § 1500.2(b).
[17] § 1500.1(b).
[18] § 1502.2(c) (emphasis added).
[19] See § 1500.4.

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SVWA 5 continued

CVP/SWP operations, such as what the two baselines are designed to represent, how to effectively interpret the results of both comparisons, and to what extent each will be relied upon in reaching an ultimate decision. The Draft EIS' failure to adequately emphasize the purposes for which each baseline is useful only exacerbates this problem.

Furthermore, including two baselines for comparison effectively doubles the amount of analysis and review necessary to understand and comment upon the document. The impacts of continued CVP/SWP operations are wide-ranging and varied. However, it is precisely for this reason that the Final EIS must be streamlined to enable that the decisionmaker to concentrate on the issues that are truly significant and not be distracted by extraneous information.

To interpret the data in the Draft EIS, the reader must compare the baseline with five alternatives across seventeen different impact categories, many of which are subdivided based on the impacts to different locations or species. The Surface Water Resources and Water Supplies category, for instance, contains eighteen different subdivisions. Further, within this category, each subdivision is divided yet again according to the six different water-year types. And, in many cases, the impacts within each water-year type are then discreetly analyzed for each month of the year where results differ. Thus, to interpret the data related to the Surface Water Resources and Water supply category, the reader must analyze nearly 6,500 data points.[20] If a second baseline for comparison is factored in, that number is doubled to nearly 13,000—and this is for only one of seventeen impact categories. Of course, these figures do not account for the fact that often times numerous data points can be addressed and considered simultaneously; however, they do illustrate to some degree the extent of the demand placed on the reader to understand and interpret the results of the Draft EIS.

The net effect of analyzing two separate bases of comparison in the substantive portions of the Draft EIS is to mask the gravity of impacts to the human environment. It does not facilitate understanding; it overwhelms the reader with an unmanageable jumble of analysis that obfuscates the issues surrounding continued CVP/SWP operations.

SVWA 6

As the Bureau has acknowledged, it is obligated pursuant to the District Court's instruction on remand to include a "basis of comparison" similar to conditions prior to the RPAs' implementation.[21] That directive, combined with NEPA's requirements regarding the form and contents of an EIS—particularly, that it "be no longer than absolutely necessary to comply with NEPA"—mandate that the Second Basis of Comparison be rebranded as the No Action Alternative and that all discussion of the current No Action Alternative be relocated to an appendix or removed entirely.

Comment 5: The Preferred Alternative and the Environmentally Preferable Alternative should not be based on the 2008 BiOps.

SVWA 7

Alternatives 2 and 5 should not be selected as the Preferred Alternative or the Environmentally Preferable Alternative because they rely on the fundamentally flawed 2008 BiOps

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[20] 5 (alternatives) x 18 (impact category subdivisions) x 6 (water-year types) x 12 (months per year) = 6,480.

[21] See Draft EIS, at ES-8 ("The [District Court's] comments indicated that the EIS should include a 'basis of comparison' for the alternatives that was similar to conditions prior to implementation of the RPAs.").

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SVWA 7 continued

and would cause serious environmental and socioeconomic harm in exchange for minimal environmental benefits.

The 2008 BiOps are fundamentally flawed

The continued operation of CVP and SWP facilities must be based on the best available science. However, Alternatives 2 and 5 are based on scientific conclusions that we now know to be fundamentally flawed.

Rather than reiterate comments that have already been made on several occasions, we would join in comments from San Luis & Delta-Mendota Water Authority, Westlands Water District, and the Center for Environmental Science, Accuracy & Reliability as they pertain to scientific flaws and inadequacies in the 2008 BiOps, including:

- the excessive focus on X2 location as a indicator of smelt abundance;
- the insufficient focus on food availability is a driver of smelt abundance;
- the importance of considering turbidity triggers and normalized salvage in OMR flow application to reduce entrainment;
- the importance of temperature control for salmonids;
- the effects of recreational and commercial fishing on salmonids;
- the effects of ocean conditions on salmonids;
- the effects of competition from and control of hatchery fish on salmonids;
- the importance of using delta smelt life cycle models; and
- the detrimental effects of ammonia deposition on delta smelt food supply.[22]

Relative to other Alternatives, Alternatives based on the 2008 BiOps would cause serious environmental and socioeconomic harm by reducing groundwater levels and increasing groundwater extraction

SVWA 8

Groundwater is a vital resource for California. The negative consequences associated with excessive groundwater use are well-known and numerous. Excessive groundwater extraction can cause failed wells, deteriorated water quality, environmental damage, and irreversible land subsidence that damages infrastructure and diminishes the capacity of aquifers to store water for the future.[24] In Judge Wanger's words, "[t]he potential environmental impact of groundwater overdraft is beyond reasonable dispute."[25]

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[22] See San Luis & Delta-Mendota Water Authority, Westlands Water District, State Water Contractors, Inc., Comment re Notice of Intent and Scoping under the National Environmental Policy Act on Remanded Biological Opinions on the Coordinated Long-term Operation of the Central Valley Project and the State Water Project, June 28, 2012, p. 17-23; Central for Environmental Science, Accuracy & Reliability, Comments in response to the U.S. Bureau of Reclamation Federal Register notice of March 28, 2012, requesting suggestions and information on the alternatives and topics to be addressed and any other important issues related to the EIS on the continued long-term operation of the CVP, in a coordinated manner with the SWP, June 28, 2012, p. 14-15; Center for Environmental Science, Accuracy & Reliability, Letter re inadequacies of 2008 Biological Assessments, June 17, 2008.

[24] See also San Luis & Delta-Mendota Water Authority, Westlands Water District, State Water Contractors, Inc., Comment re Notice of Intent and Scoping under the National Environmental Policy Act

SVWA 8 continued

The enactment by the State of California in 2014 of the Sustainable Groundwater Management Act, which mandates actions to achieve sustainable groundwater management by 2034 testifies to the fundamental importance of groundwater in California and to the state's commitment to protecting this priceless resource. In enacting this historic legislation, the California Legislature declared that "[i]t is the policy of the state that groundwater resources be managed sustainably for long-term reliability and multiple economic, social, and environmental benefits for current and future beneficial uses."[26]

Based on the results described in the Draft EIS, Alternatives 2 and 5 would not only jeopardize this vital resource in direct contravention of the express policy of the state of California,[27] they would fail to realize any countervailing benefits capable of justifying the damage that would be caused to the state's groundwater resources.

Implementation of Alternative 2 would increase groundwater extraction and reduce groundwater levels

According to the Draft EIS, the No Action Alternative and Alternative 2 would lead to identical outcomes with respect to groundwater resources.[28] Referring to the No Action Alternative, the EIS explains that "CVP and SWP water deliveries would be less in 2030 than under recent historical conditions" and "these reductions … would result in a greater reliance on groundwater, especially during dry and critical dry years."[29] Further, according to the Bureau, "it does not appear to be reasonable and foreseeable that sustainable groundwater management would be achieved by 2030."[30] Consequently, the increased reliance on groundwater anticipated under Alternative 2 would likely lead to overdraft. Even worse, compared with the Second Basis of Comparison, Alternative 2 would increase groundwater pumping in the San Joaquin Valley by approximately 8 percent and would reduce July groundwater levels in all water-year types, ranging from up to 10 feet in central and southern San Joaquin Valley to up 200 feet in the Westside subbasin.[31] As the Draft EIS acknowledges, this reduction in groundwater levels could cause additional land subsidence.

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on Remanded Biological Opinions on the Coordinated Long-term Operation of the Central Valley Project and the State Water Project, June 28, 2012, Exhibit D Environmental Impacts.

[25] San Luis & Delta-Mendota Water Auth. v. Salazar, 686 F. Supp. 2d 1026, 1050 (E.D. Cal. 2009).

[26] Cal. Water Code § 113.

[27] See Draft EIS, Ch. 7, at 7-117 ("Under the No Action Alternative, it is anticipated that increased groundwater withdrawals due to reductions in CVP and SWP water supplies and reduced groundwater recharge due to climate change could result in increased irreversible land subsidence…"); Table ES.1, Comparison of Alternatives 1 through 5 to the No Action Alternative, at ES-xiii (showing that under Alternative 5 groundwater levels in all water year types would decline approximately 2 to 10 feet in most of the central and southern San Joaquin Valley and 25 to 50 feet in the Westside subbasin); ES.9 Impact Analysis, at ES-15 (indicating no changes between No Action Alternative and Alternative 2).

[28] See Draft EIS, Executive Summary, at ES-15.

[29] See Draft EIS, Ch. 7, at 7-120.

[30] Id.

[31] See Draft EIS, Executive Summary, at ESxlii-xliii.

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SVWA 8 continued

These results are unacceptable. By increasing reliance on groundwater, Alternative 2 would undermine the implementation of the Sustainable Groundwater Management Act and jeopardize California's ability to manage its most important natural resource in accordance with its stated policy.[32]

Implementation of Alternative 5 would increase groundwater extraction and reduce groundwater levels

SVWA 9

The Draft EIS found that, as compared with the No Action Alternative, which, as noted above, would increase groundwater reliance, Alternative 5 would *reduce groundwater levels in all water-year types*, ranging from as much as 10 feet in the Central and Southern San Joaquin Valley to as much as 50 feet in the Westside Subbasin.[33] Here too, the results are even worse when compared against the Second Basis of Comparison. Similar to the comparison with Alternative 2, under Alternative 5 groundwater pumping would increase by approximately 8 percent in the San Joaquin Valley. Further, July groundwater levels would decline in all water-year types, ranging from up to 10 feet in central and southern San Joaquin Valley to up to *500 feet* in the Westside Subbasin.

This cannot be allowed. At a time when the state's aquifers are at historic lows, any action that would have the effect of lowering the water table—thereby exacerbating a host of negative environmental, social, and economic consequences—should be endorsed, if at all, only with an extraordinary level of justification. However, as discussed below, to the extent any benefits would result from the implementation of Alternative 2 or 5, they would be insufficient to justify the immense collateral damage to the state's groundwater resources.

Implementation of Alternatives 1, 3, and 4 would reduce groundwater pumping and increase groundwater levels[34]

SVWA 10

Unlike Alternatives 2 and 5, Alternatives 1, 3, and 4, all resulted in meaningful benefits to the state's groundwater resources. While the data suggests similar groundwater levels and pumping under Alternatives 1 and 4 in the Sacramento Valley, both Alternatives resulted in an 8% reduction in groundwater pumping in the San Joaquin Valley.[35] Further, July groundwater levels were predicted to increase in all water-year types by as much as 10 feet in Central and Southern San Joaquin Valley, up to 50 feet in the Delta-Mendota, Tulare Lake, and Kern County subbasins, and by as much as 500 feet in the Westside subbasin, where some of the most severe overdraft anywhere in the state is occurring.

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[32] To the extent that the Draft EIS fails to address this conflict, the Final EIS must remedy that deficiency. The discussion of environmental consequences must include discussions of, inter alia, "possible conflicts between the proposed action and the objectives of .... State... policies ... for the area concerned." See § 1502.16(c); see also § 1506.2(d)("To better integrate environmental impact statements into State or local planning processes, statements shall discuss any inconsistency of a proposed action with any approved State or local plan and laws (whether or not federal sanctioned). Where an inconsistency exists, the statement should describe the extent to which eh agency would reconcile its proposed action with the plan or law.).

[33] See Draft EIS, Table ES.1 Comparison of Alternatives 1 through 5 to the No Action Alternative, at ES-xiii

[34] Unless otherwise noted, all comparisons in this section are to the No Action Alternative.

[35] See Draft EIS, Table ES.1 Comparison of Alternatives 1 through 5 to the No Action Alternative, at ES-xiii

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SVWA 10 continued

Similarly, Alternative 3, while expected to produce similar results in the Sacramento Valley, would cause a 6% reduction in groundwater pumping in the San Joaquin Valley, with July groundwater levels in all water year types expected to increase in step with the increases under Alternatives 1 and 4 (up to 10 feet in the Central and Southern San Joaquin Valley, up to 50 feet in the Delta-Mendota, and up to 500 feet in the Westside subbasin).

On balance, Alternatives based on the 2008 BiOps would fail to produce any meaningful benefits to fish and aquatic resources.

SVWA 11

According to the Draft EIS, Alternative 2 would not result in any reduction of adverse effects to the species considered. In fact, the effects may become more adverse for the Steelhead and Chinook Salmon in the Sacramento River System and the Stanislaus River/Lower San Joaquin River.[37] All other effects would be similar to those under the No Action Alternative.[38] Similarly, as compared with the Second Basis of Comparison, the Draft EIS predicts that implementation of Alternative 2 would result in adverse effects for the Chinook Salmon and Steelhead and similar effects for most other species considered.[39] Only the Delta Smelt and the Longfin Smelt are predicted to experience a reduction in adverse effects within this comparison.

Because the only reduction in adverse effects predicted under Alternative 2 is to the Delta and Longfin Smelt, and because Alternative 2 would also increase the adverse effects to Chinook Salmon and Steelhead, there is, on balance, no meaningful benefit in terms of fish and aquatic resources. Any benefit to the Delta and Longfin Smelt is effectively negated by the increased adverse effects on Chinook Salmon and Steelhead.

SVWA 12

Likewise, the Draft EIS predicts that implementation of Alternative 5 would not result in any reduction of adverse effects to any of the species considered, as compared with the No Action Alternative.[40] On the contrary, the only change predicted by the Draft EIS would be an increase in adverse effects for Lamprey, Hardhead, and Striped Bass in the Stanislaus and San Joaquin rivers. On the other hand, when compared against the Second Basis of Comparison, the effects of implementing Alternative 5 are largely mixed. Although potentially beneficial for some species, the effects are highly uncertain in some cases and would be accompanied by increased adverse effects for many other species. In total, the Draft EIS predicts six instances of increased adverse effects and six instances of reduced adverse effects, with the balance of effects classified as similar or uncertain.[41] Thus, as with Alternative 2, Alternative 5 would fail to produce any meaningful benefit to fish and aquatic resources.

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[37] See id., at ES-xviii.
[38] See Draft EIS, Table ES.2 Comparison of Alternatives 1 through 5 to the Second Basis of Comparison, at ES-xlvii.
[39] See id., at ES-xliv.
[40] See Draft EIS, Table ES.1 Comparison of Alternatives 1 through 5 to the No Action Alternative, at ES-xxiii.
[41] See Draft EIS, Table ES.2 Comparison of Alternatives 1 through 5 to the Second Basis of Comparison, at ES-lii-lv (summary below).

- Trinity River Region:
  - Similar results for all species
- Sacramento River System:
  - Uncertain effects for Chinook Salmon species

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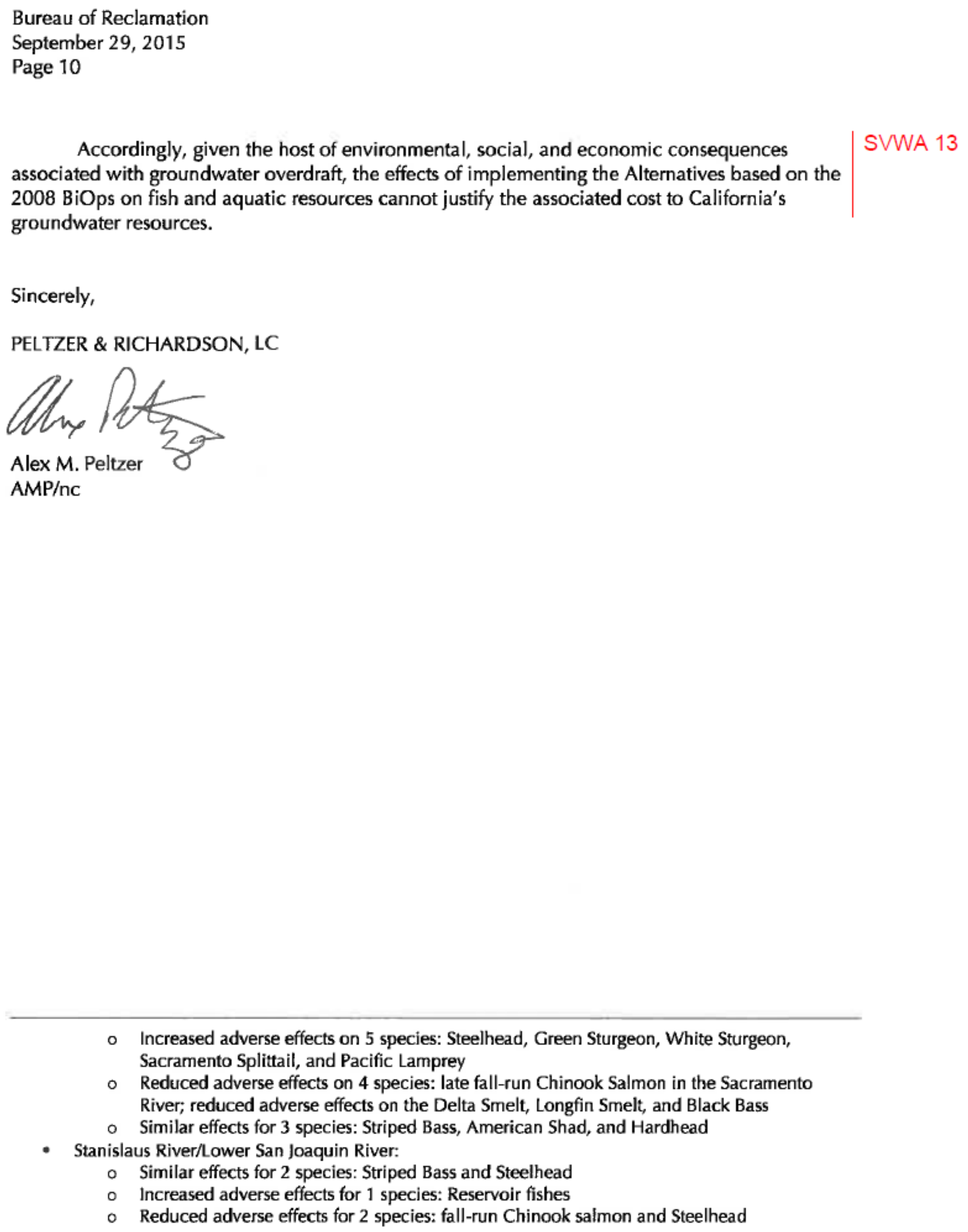

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Page 10

Accordingly, given the host of environmental, social, and economic consequences associated with groundwater overdraft, the effects of implementing the Alternatives based on the 2008 BiOps on fish and aquatic resources cannot justify the associated cost to California's groundwater resources.

SVWA 13

Sincerely,

PELTZER & RICHARDSON, LC

Alex M. Peltzer
AMP/nc

  - Increased adverse effects on 5 species: Steelhead, Green Sturgeon, White Sturgeon, Sacramento Splittail, and Pacific Lamprey
  - Reduced adverse effects on 4 species: late fall-run Chinook Salmon in the Sacramento River; reduced adverse effects on the Delta Smelt, Longfin Smelt, and Black Bass
  - Similar effects for 3 species: Striped Bass, American Shad, and Hardhead
- Stanislaus River/Lower San Joaquin River:
  - Similar effects for 2 species: Striped Bass and Steelhead
  - Increased adverse effects for 1 species: Reservoir fishes
  - Reduced adverse effects for 2 species: fall-run Chinook salmon and Steelhead

1D.1.14.1 Responses to Comments from South Valley Water Association

SVWA 1: Comment noted.

SVWA 2: At the time the request for extension of the public review period was submitted, the Amended Judgement dated September 30, 2014 issued by the United States District Court for the Eastern District of California (District Court) in the *Consolidated Delta Smelt Cases* required Reclamation to issue a Record of Decision by no later than December 1, 2015. Due to this requirement, Reclamation did not have sufficient time to extend the public review period. On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to extend the public review period.

SVWA 3: The Preferred Alternative is described in Section 1.5 of Chapter 1, Introduction, of the Final EIS. The Environmentally Preferred Alternative will be identified and discussed in the Record of Decision, as required by the CEQ regulations.

SVWA 4: The EIS analysis assumes all water deliveries to the San Joaquin River Exchange Contractors are conveyed through the Delta; and water deliveries from Millerton Lake would be similar under all alternatives and the Second Basis of Comparison in all water year types. However, it is recognized that during extreme droughts, water can be delivered to the San Joaquin River Exchange Contractors from Millerton Lake and CVP deliveries to users along the Friant and Madera canals can be reduced. Droughts have occurred throughout California's history, and are constantly shaping and innovating the ways in which Reclamation and DWR balance both public health standards and urban and agricultural water demands while protecting the Delta ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and the ongoing drought. More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, in the Final EIS to describe historical responses by CVP and SWP to these drought conditions, including recent deliveries of CVP water to the San Joaquin River Exchange Contractors.

SVWA 5: The comment is noted that inclusion of two basies of comparison does increase the number of alternative comparisons. The results of the impact assessment were presented separately for the alternatives as compared to the No Action Alternative and to the Second Basis of Comparison. The purposes of what the two basis of comparison represent are presented in Section 3.3 of Chapter 3, Description of Alternatives.

SVWA 6: As described in Section 3.3, Reclamation had provisionally accepted the provisions of the 2008 USFWS BO and 2009 NMFS BO, and was implementing the BOs at the time of publication of the Notice of Intent in March 2012. Under the definition of the No Action Alternative in the National Environmental Policy Act regulations (43 CFR 46.30), Reclamation's NEPA Handbook (Section 8.6), and Question 3 of the Council of Environmental Quality's Forty Most Asked Questions, the No Action Alternative could represent a future condition with "no change" from current management direction or level of management intensity, or a future "no action" conditions without implementation of the actions being evaluated in the EIS. The No Action Alternative in this EIS is consistent with the definition of "no change" from current management direction or level of management. Therefore, the RPAs were included in the No Action Alternative as Reclamation had been implementing the BOs and RPA actions, except where enjoined, as part of CVP operations for approximately three years at the time the Notice of Intent was issued (2008

USFWS BO implemented for three years and three months, 2009 NMFS BO implemented for two years and nine months).

As described in Section 3.3, Reclamation included the Second Basis of Comparison to identify changes that would occur due to actions that would not have been implemented without Reclamation's provisional acceptance of the BOs, as required by the District Court order. However, the Second Basis of Comparison is not consistent with the definition of the No Action Alternative used to develop the No Action Alternative for this EIS. Therefore, mitigation measures have not been considered for changes of alternatives as compared to the Second Basis of Comparison.

SVWA 7: The commenter's opposition to Alternatives 2 and 5 is acknowledged.

SVWA 8: The commenter's discussion of groundwater conditions under Alternative 2 as compared to the No Action Alternative and Second Basis of Comparison are consistent with the discussion of the impact analysis in Section 7.4.3.3 of Chapter Groundwater Resources and Groundwater Quality of the EIS. The commenter's opposition to Alternative 2 is acknowledged.

SVWA 9: The commenter's discussion of groundwater conditions under Alternative 5 as compared to the No Action Alternative and Second Basis of Comparison are consistent with the discussion of the impact analysis in Section 7.4.3.6 of Chapter Groundwater Resources and Groundwater Quality of the EIS. The commenter's opposition to Alternative 5 is acknowledged.

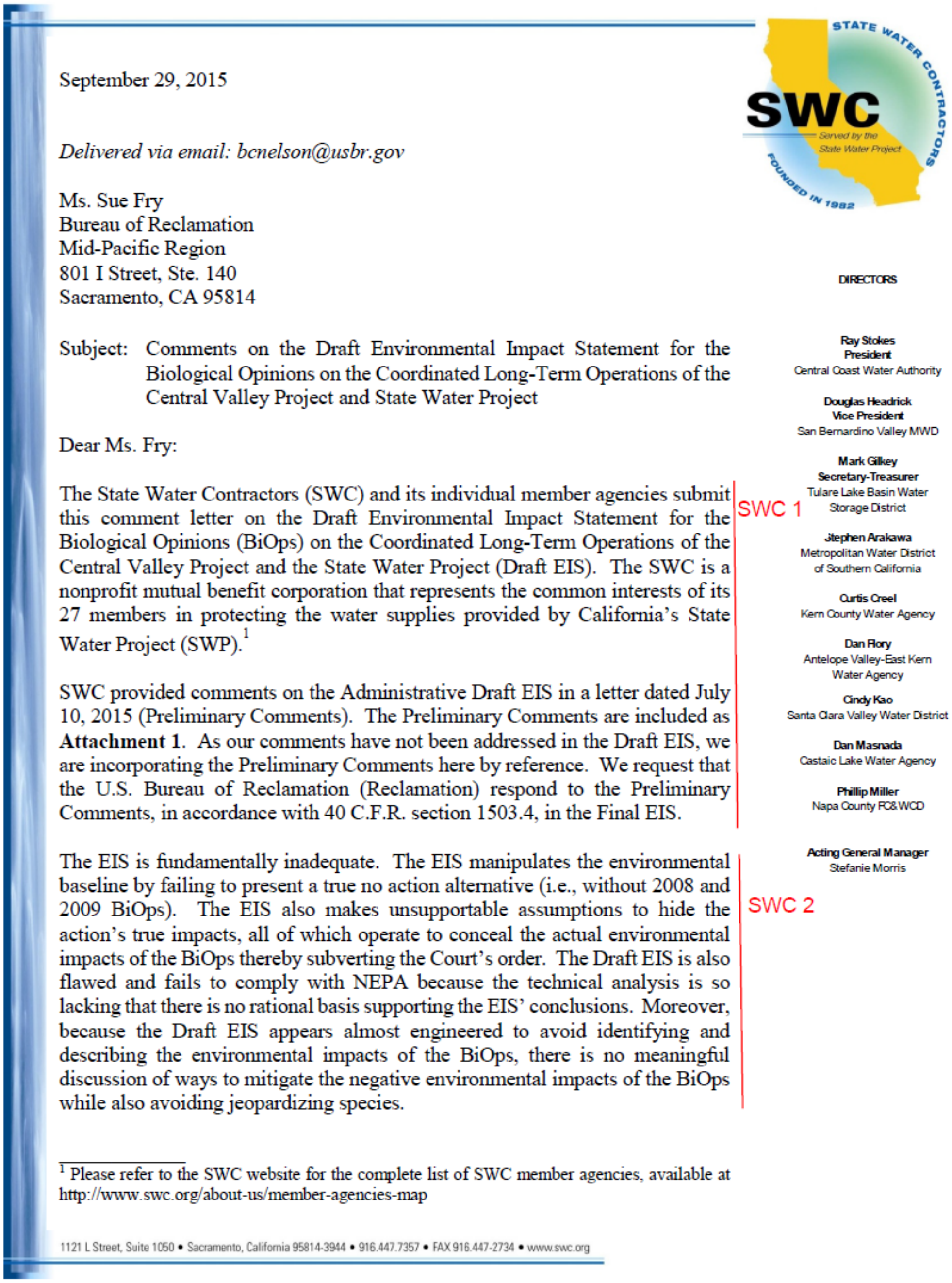
SVWA 10: The commenter's discussion of groundwater conditions under Alternatives 1, 3, and 4 as compared to the No Action Alternative and Second Basis of Comparison are consistent with the discussion of the impact analysis in Sections 7.4.3.2, 7.4.3.4, and 7.4.3.5 of Chapter Groundwater Resources and Groundwater Quality of the EIS. The commenter's support of Alternatives 1, 3, and 4 is acknowledged.

SVWA 11: The commenter's opposition of Alternative 2 is acknowledged.

SVWA 12: The commenter's opposition of Alternative 5 is acknowledged.

SVWA 13: The commenter's opposition to the No Action Alternative and Alternatives 2 and 5 is acknowledged.

1D.1.15 State Water Contractors



STATE WATER CONTRACTORS
SWC
Served by the State Water Project
FOUNDED IN 1982

September 29, 2015

Delivered via email: bcnelson@usbr.gov

Ms. Sue Fry
Bureau of Reclamation
Mid-Pacific Region
801 I Street, Ste. 140
Sacramento, CA 95814

Subject: Comments on the Draft Environmental Impact Statement for the Biological Opinions on the Coordinated Long-Term Operations of the Central Valley Project and State Water Project

Dear Ms. Fry:

The State Water Contractors (SWC) and its individual member agencies submit this comment letter on the Draft Environmental Impact Statement for the Biological Opinions (BiOps) on the Coordinated Long-Term Operations of the Central Valley Project and the State Water Project (Draft EIS). The SWC is a nonprofit mutual benefit corporation that represents the common interests of its 27 members in protecting the water supplies provided by California's State Water Project (SWP).[1]

SWC provided comments on the Administrative Draft EIS in a letter dated July 10, 2015 (Preliminary Comments). The Preliminary Comments are included as **Attachment 1**. As our comments have not been addressed in the Draft EIS, we are incorporating the Preliminary Comments here by reference. We request that the U.S. Bureau of Reclamation (Reclamation) respond to the Preliminary Comments, in accordance with 40 C.F.R. section 1503.4, in the Final EIS.

SWC 1

The EIS is fundamentally inadequate. The EIS manipulates the environmental baseline by failing to present a true no action alternative (i.e., without 2008 and 2009 BiOps). The EIS also makes unsupportable assumptions to hide the action's true impacts, all of which operate to conceal the actual environmental impacts of the BiOps thereby subverting the Court's order. The Draft EIS is also flawed and fails to comply with NEPA because the technical analysis is so lacking that there is no rational basis supporting the EIS' conclusions. Moreover, because the Draft EIS appears almost engineered to avoid identifying and describing the environmental impacts of the BiOps, there is no meaningful discussion of ways to mitigate the negative environmental impacts of the BiOps while also avoiding jeopardizing species.

SWC 2

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[1] Please refer to the SWC website for the complete list of SWC member agencies, available at http://www.swc.org/about-us/member-agencies-map

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The SWC would like to work with Reclamation to resolve these issues, as compliance with the National Environmental Policy Act (NEPA) and the Endangered Species Act are not mutually exclusive. There are feasible alternatives that can cause less impacts to water supply and agricultural resources while also avoiding jeopardy. The SWC have included as **Attachment 2** a suite of proposed actions that are a cohesive, standalone alternative to the RPAs and should have been analyzed as a separate alternative, or alternatively as mitigation measures. Some of the actions are already being implemented to some extent. SWC 3

I. THE EIS FAILS TO EVALUATE A "WITHOUT RPA" ALTERNATIVE AND/OR A "WITHOUT PROJECT" NO ACTION ALTERNATIVE AND IS THEREFORE FLAWED.

SWC 4

The Draft EIS is contrary to the Court's order and NEPA. The United States District Court for the Eastern District of California stated: "Reclamation's implementation of the BiOp [Biological Opinions] is a major federal action because it ***substantially alters the status quo*** in the Project's operations." Memorandum Decision Re Cross Motions for Summary Judgment of NEPA Issues, Doc. 339, at pp. 42-43, E.D. Cal. Case No. 09-407 (Nov. 13, 2009) (OCAP NEPA Decision), emphasis added. Specifically, the Court explained that the potential adverse effects including, but not limited to, loss of jobs, increased groundwater pumping, fallowing land, land subsidence, air pollution resulting from heavier reliance on groundwater pumping and a decrease in surface irrigation were in and of themselves the kind of "serious questions" about whether a project may cause significant degradation of the human environment. The Court ordered Reclamation to comply with NEPA. Order Granting and Denying Cross-Motions for Summary Judgment on NEPA Issues, at p. E.D. Cal. Case No. 09-407, at p. 2 (Dec. 2, 2009).

The Draft EIS unlawfully circumvents the Court's order by incorporating the Reasonable and Prudent Alternatives (RPAs) that the Court ordered Reclamation to analyze relative to a no-action (no RPA) alternative under NEPA into the baseline (i.e., the no action alternative). This masks the effects of the RPAs. An EIS that is developed to cure a past violation may not rationalize or justify a decision already made by assuming that the action being validly undertaken is part of the status quo and, thus, constitutes a no-action alternative. *Pit River Tribe v. United States Forest Serv.* 469 F.3d 768, 786 (9th Cir. 2006). While the CEQ's regulations and guidance note that the No Action alternative is typically the maintenance of the status quo, the CEQ has also explained that "no action" typically means that the proposed activity would not take place. *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations,* Question 3, 46 Fed Reg. 18026 (Mar. 23, 1981). The regulations "require the analysis of the no action alternative even if the agency is under a court order or legislative command to act" and including the alternative of no action "is necessary to inform the Congress, the public, and the President as intended by NEPA." *Id*

Reclamation cannot place the RPAs in the environmental baseline and characterize these as the "no action" alternative and fulfill its Court-ordered obligation to analyze the effects of accepting the RPAs as compared to the no RPA, no-action alternative.

The use of a Second Basis of Comparison as an alternative no action baseline fails to satisfy the Court's order, in part, because the EIS does not treat the Second Basis of Comparison as a true No Action Alternative. For example, when the No Action Alternative (existing biological opinions

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baseline) is compared to the Second Basis of Comparison (no biological opinions), there is no discussion of mitigation of the effects of the biological opinions as the comparative analysis was "just for discussion purposes." (*see*, *e.g.* EIS at pp. ES-14 and 15.) SWC 4 continued

Reclamation also failed to evaluate the RPAs' effects because neither the Second Basis of Comparison nor Alternative 1 exclude all of the regulatory requirements contained in the biological opinions. All of the RPA Actions described in section 3.3.1.2, "Actions included in the 2008 USFWS BO and 2009 NMFS BO that Would Have Occurred without Implementation of the Biological Opinions," should have been excluded from the Second Basis of Comparison and Alternative 1. There is no basis for concluding that if Reclamation and the Department of Water Resources ("DWR") were not required to implement these RPAs, Reclamation and DWR would nevertheless have the funding and the manpower to undertake the RPAs. Furthermore, evidence of progress toward implementation of the RPAs does not suggest that these actions would have been implemented if the biological opinions did not exist, rather it merely suggests that DWR and Reclamation have been working diligently to satisfy their existing regulatory obligations. Finally, because the fishery agencies felt compelled to include all of these actions as RPAs suggests that the fishery agencies did not have confidence that these actions would occur if they were not included as requirements in the biological opinions. The EIS violates the Court's order because it failed to exclude the RPAs from the without biological opinion baseline/alternative. SWC 5

The EIS states that near-term impacts (prior to year 2030) are not addressed. (Draft EIS at p. 4-3 ["As described above, this EIS only addresses long-term operational impacts."] and p. 4-1 ["This EIS does not address interim changes that would occur between now and 2030."].) The document analyzes future conditions projected to the year 2030, based on a recognition that coordinated long-term operation of the CVP and SWP will continue to at least 2030 (p. ES-7). The analysis, however, should be focused on the impacts of implementing the RPAs and the RPA changes in the CVP and SWP operations, an action that has already started and will occur between now and 2030. The study period approach that focuses on impacts expected to occur in 2030, combined with an analysis that centers on the assumption that the no action/status quo alternative is the implementation of the RPAs, leads to flaws in the impacts analysis. The cumulative impacts analysis, for example, assumes that several projects not currently in existence will happen and will lessen or alter the impacts of implementing the RPAs. This assumption is made even though the RPAs' impacts will be felt immediately and the listed projects may not be undertaken for many years. Furthermore, many of the projects were meant to create additional supplies not to replace dwindling baseline supplies. The analysis should recognize that the RPAs, and their resulting reductions in water supplies will be occurring between now and 2030. If the short-term impacts of implementing the RPA actions were acknowledged, it would be clear that the RPA implementation will result in significant impacts. SWC 6

Reclamation should revise and recirculate the EIS so it will comply with the Court's order to analyze the environmental consequences of changing the status quo by adopting the RPAs, in accordance with NEPA. SWC 7

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II. THE DRAFT EIS FAILS TO ADEQUATELY ANALYZE DIRECT AND INDIRECT IMPACTS

The Draft EIS fails to adequately consider the effect of the RPAs on surface water resources, groundwater resources, agricultural resources and fishery resources.

SWC 8

The CEQ regulations require that an EIS contain a "full and fair discussion" of significant environmental impacts. 40 C.F.R. § 1502.1. "The agency shall make available to the public high quality information, including accurate scientific analysis and expert agency comments, before decisions are made and actions are taken." Daniel R. Mandelker, *NEPA Law and Litigation* § 10:18 (2013 Ed.), citing 40 C.F.R. § 1500.1 (b). "To satisfy NEPA, the federal agency should consider every significant aspect of the environmental impact of a proposed action and inform the public that it has indeed considered environmental concerns in its decisionmaking process." *Earth Island Inst. v. U.S. Forest Serv.*, 442 F.3d 1147, 1153-54 (9th Cir. 2006) (internal quotation marks and citation omitted).

As such, NEPA requires a searching and transparent investigation of the environmental consequences of federal actions. The "agency must either obtain information that is essential to a reasoned choice among alternatives, or explain why such information was too costly or difficult to obtain." *Native Village of Point Hope v. Jewell*, 2014 U.S. App. LEXIS 1150, at p. *6 (9th Cir. Jan. 22, 2014), citing 40 C.F.R. § 1502.22. If essential information is unavailable, the EIS must state that the information provided is incomplete or unavailable and the relevance of the incomplete or unavailable information to evaluating reasonably foreseeable significant adverse impacts, summarize the existing credible evidence that is relevant, and document that the agency's evaluation is based on generally accepted methodology. 40 C.F.R. § 1502.22.

The above standards ensure that an EIS meets its primary purpose as an "action-forcing device." *See* 40 C.F.R. § 1502.1. The purpose of an EIS is to "foster both informed decision-making and informed public participation." *See State of Cal. v. Block*, 690 F.2d 753 (9th Cir. 1982). "An environmental impact statement is more than a disclosure document." 40 C.F.R. § 1502.1. "It shall be used by Federal officials in conjunction with other relevant material to plan actions and make decisions." *Ibid.*; *see also*, *League of Wilderness Defenders/Blue Mountains Biodiversity Project v. Kent Connaughton*,763 F.3d 755, 762-63 (9th Cir. 2014) ("Federal agencies must undertake a "full and fair" analysis of the environmental impacts of their activities. This is a crucial cornerstone of NEPA.").

When reviewing the adequacy of an EIS, courts demand a well-reasoned discussion. As the U.S. Supreme Court has stated, "[t]he agency must examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made." *Motor Vehicle Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983). "In order for an agency decision to pass muster under the APA's [Administrative Procedure Act's] arbitrary and capricious test the reviewing court must determine that the decision makes sense. Only by carefully reviewing the record and satisfying [itself] that the agency has made a reasoned decision can the court ensure that agency decisions are founded on a reasoned evaluation of the relevant factors." *Dubois v. U.S. Dept. of Agriculture*, 102 F.3d 1273, 1285 (1st Cir. 1996), internal quotations omitted. The Draft EIS fails to meet NEPA's requirements.

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"Whether there may be a significant effect on the environment requires consideration of two broad factors: context and intensity. Context simply delimits the scope of the agency's action, including the interests affected. Intensity relates to the degree to which the agency action affects the locale and interests identified in the context part of the inquiry." *Native Village of Chickaloon v. Nat'l. Marine Fisheries Serv.*, 947 F.Supp.2d 1031, 1069-70 (D. Ak. 2013), internal quotations omitted. Factors relevant to the intensity of an effect include whether the effects are likely to be highly controversial. 40 C.F.R. § 1508.27, subds. (b)(4) and (b)(8). SWC 8 continued

A. The EIS failed to properly analyze the effects of the RPAs on surface water supplies.

Specific issues in the analysis and its treatment of direct and indirect impacts from water supply reductions include the following:

1. The Draft EIS improperly assumes that water suppliers will be able to meet demands without adequately analyzing the impacts of the actions that may be undertaken to satisfy this assumption.

SWC 9

In Chapter 5, the Draft EIS explains that under the No Action Alternative and Second Basis of Comparison, it is assumed that, on a regional scale, water demands would be met on a long-term basis and in dry and critical dry years using a combination of conservation, CVP and SWP water supplies, other imported water supplies, groundwater, recycled water, infrastructure improvements, desalination water treatment, and water transfers and exchanges. The same assumptions apply for the comparison of the No Action Alternative and Alternative 1, but there is no adequate analysis of the impacts of utilizing other imported supplies, groundwater pumping, additional infrastructure projects, desalination, or other means of satisfying demands. There is no recognition of the impacts from using these alternative supplies, or the likelihood that they can adequately mitigate the impacts of CVP and SWP reductions.

2. The Draft EIS fails to properly analyze the impacts of the RPAs on the ability to transfer water.

SWC 10

The Draft EIS states that it is assumed that transfers will occur in a similar manner as have occurred for the past 10 years, while simultaneously acknowledging impacts to transfers from the limits on conveyance capacity during certain months under the RPA actions but providing no measures to mitigate this impact. There are numerous inconsistencies in the manner in which the Draft EIS discusses water transfers and the impacts of the RPA actions on the ability to undertake cross Delta water transfers.

On Page 5-64, and elsewhere throughout the document, the Draft EIS acknowledges that the 2008 USFWS BiOp and 2009 NMFS BiOp include export restrictions that limit the use of conveyance capacity for transfers in certain months. Table 5.42 purportedly includes these reductions in the comparison of Alternative 1 and the No Action Alternative.

Elsewhere, however, the document assumes that overall impacts to water supplies will be limited because of the availability of transfer water (*see, e.g.* p. 19-57). Table 5D.50 in Appendix 5D discussing MWD's water demand and supplies includes Yuba River Accord purchases, even

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SWC 10 continued

though the ability to receive these supplies has been limited in recent years. Similarly, on Page 19-79 (lines 23 – 25), in the discussion of socioeconomic impacts, the Draft EIS states that it is assumed that communities that do not have alternative water supplies would utilize water transfers. This assumption is included even though the document notes elsewhere that implementation of the RPAs will impact the ability to undertake water transfers.

While the Draft EIS includes a discussion of "effects related to cross Delta water transfers" (*e.g.*, EIS p. 5-125) and "effects related to water transfers" (*e.g.*, EIS p. 6-81) in several sections, these discussions do not analyze or disclose the impacts of limiting the ability of water suppliers to obtain alternative supplies through water transfers, particularly when these alternative supplies are necessary to mitigate the impacts on reductions in contract deliveries that are caused by the implementation of the RPAs. Instead, the discussion examines impacts to flow patterns and other factors from undertaking additional water transfers, evaluating, in cursory detail, the impacts from undertaking water transfers and citing to recent analyses in a separate NEPA document examining proposed water transfers. Reclamation should revise this analysis to focus on the impacts of limiting water transfer opportunities both as a result of restrictions on conveyance capacity and a reduction in Sacramento Valley supplies and include appropriate measures to mitigate the RPA's restrictions on water transfers.

3. The Draft EIS fails to adequately consider the cumulative water supply effect of potentially reduced CVP-SWP supplies as water supply needs develop upstream.

SWC 11

In section 5.4.2.1.2, Draft EIS p. 5-66, the analysis considers General Plan development in the Sacramento Valley, which estimates that upstream development will increase demand by 443,000 acre-feet by 2030. The reported predicted an increase in demand would include CVP contractors as well as non-water contractors. The assumption that this projected increase in demand would occur and that it would directly result in a corresponding decrease in water supply to the non-Sacramento Valley state and federal water contractors is speculative. The Draft EIS fails to evaluate whether the existing Sacramento Valley water rights includes almost a half million acre-feet of additional supply. If Sacramento Valley water use were to increase demand by nearly a half million acre-feet, without the development of additional surface storage, there would likely be an impact on other senior water rights in the Delta watershed that would need to be addressed. Conversely, if in-Delta watershed demand were to occur, then there could be a significant impact on SWP-CVP water supplies (surface and groundwater), and this impact should have been evaluated in the cumulative impact section as it would exacerbate 2030 water supply impacts resulting from the biological opinions.

4. The Draft EIS fails to mitigate significant water supply impacts.

SWC 12

In the Executive Summary and elsewhere (*see*, *e.g.* pp ES-14 and15), the Draft EIS states that mitigation measures are not included to address adverse impacts for the alternatives as compared to the Second Basis of Comparison, because this analysis was included for informational purposes only. Prior comments have pointed out the problem with this approach. Reclamation is required to propose mitigation measures: "The mitigation measures discussed in an EIS must cover the range of impacts of the proposal . . . Once the proposal itself is considered as a whole to have significant effects, all of its specific effects on the environment (whether or not 'significant') must

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SWC 12 continued

be considered, and mitigation measures must be developed where it is feasible to do so." CEQ, *Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations*, 46 Fed.Reg. 18026, Question 19 (March 23, 1981). With respect to water supply impacts, in the comparison of Alternative 1, which is identical to the Second Basis of Comparison, and the No Action Alternative, the analysis fails to fully identify the impacts of the No Action Alternative on water supply reductions relative to the Second Basis of Comparison, or to propose any mitigation for these impacts.

Draft EIS Tables 3.5 and 3.7 on pages 3-56 and 3-92, which compare the No Action Alternative and Second Basis of Comparison, disclose that long-term average annual exports would be 18 percent less under the No Action Alternative (i.e. implementation of the BiOps), and that deliveries without Article 21 water to SWP South of Delta water contractors would be reduced by 19 percent in dry years, and 22 percent in critical dry years, with deliveries of Article 21 water to SWP South of Delta contractors reduced by over 80 percent. However, the Draft EIS indicates that mitigation is not proposed for the No Action Alternative. The Draft EIS also concludes that mitigation is not necessary in Table, 3.6 (comparing Alternative 1 and the No Action Alternative) despite the same estimates of a reduction in deliveries to CVP and SWP contractors. These erroneous conclusions appear to be based on the assumption set forth in Section 5.4.2.1.3 that M&I contractors will make up for CVP and SWP supply reductions using imported water supplies, groundwater, recycled water, infrastructure improvements, desalination, and water transfers and exchanges, but simply setting forth this assumption does not satisfy the NEPA requirement to evaluate the significant effects to the human environment.

The discussion in Chapter 5 and the tables in Chapter 3 also minimize the impacts to water supplies and the related socioeconomic and other impacts by separately listing impacts in each region (*e.g.* up to 14.4 percent reductions in storage in Shasta Lake and up to 12.5 percent reduction in Lake Oroville) without discussing the cumulative or combined impact of the reductions in flows and storage levels. The overall impact of implementing the RPAs should be evaluated, with an examination of the direct and indirect impacts of implementing the RPAs and recommended mitigation to reduce the impacts.

B. The Draft EIS failed to properly analyze the effect of the RPAs on groundwater resources.

Specific issues in the analysis and its treatment of direct and indirect impacts to groundwater resources include the following:

1. The Draft EIS' position that groundwater pumping could fully mitigate reductions in surface water deliveries fails to account for existing, and the resulting future, water quality and overdraft conditions.

SWC 13

The Draft EIS acknowledges that groundwater quality and groundwater overdraft limit the agricultural sector's reliance on groundwater.[2] *See, e.g.,* Draft EIS, at pp. 12-5, 7-26, 7-34 and 7-

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[2] The groundwater modeling conducted for the Draft EIS focused on reasonably foreseeable changes in groundwater quality and levels as a result of the Action. *See* Draft EIS, Appendix 7A at p. 7A-3. The results of these projections

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SWC 13 continued

11. However, this admission is not reflected in the analysis as the Draft EIS fails to account for groundwater quality, subsidence and/or overdraft as limiting conditions on regional groundwater withdrawals for the agricultural sector. *See* Draft EIS at p. 12-24. The Draft EIS' conclusions are inadequately supported by the facts.

For example, the Draft EIS states that under the No Action Alternative, it is anticipated that increased groundwater withdrawals due to reductions in CVP and SWP water supplies and reduced groundwater recharge due to climate change could result in increased irreversible land subsidence and continue to degrade water quality in portions of the Central Valley that are already characterized by low quality groundwater. Draft EIS, at p. 7-117-118. Groundwater levels under the No Action Alternative, as compared to the Second Basis of Comparison, could decline by as much as 200 feet in some years in portions of the central and southern San Joaquin Valley. Draft EIS, at p. 7-121. July average groundwater levels decline 10 to 50 feet in the Delta-Mendota, Tulare Lake, and Kern County subbasins; and 100 to over 200 feet in the Westside subbasin in all water year types. *Ibid.* In critical dry years, groundwater levels decline by up to 200 feet in the Westside subbasin. *Ibid.* These declines significantly exceed historic groundwater declines for the referenced regions and suggest that groundwater resources are not a sustainable replacement source of water for the agricultural sector. *See* Draft EIS, Chapter 7, Section 7.3.

SWC 14

Secondly, the Draft EIS quantifies the incremental changes in groundwater quality and levels, and resulting regional subsidence, but fails to state whether these changes would foreclose certain regions from relying on groundwater resources to offset reduced CVP and SWP deliveries. *See, generally*, Draft EIS, Chapter 7, and Section 7.4. This information is clearly essential to the analysis of each of the Alternative's effects on agricultural resources because Reclamation assumes that groundwater resources can offset the Action's effects and should be included in the Draft EIS. *See Native Village of Point Hope v. Jewell*, *supra*, 2014 U.S. App. LEXIS 1150, at p. *6 (9th Cir. Jan. 22, 2014), citing 40 C.F.R. § 1502.22.

The Draft EIS appears to acknowledge that historically, groundwater resources have not effectively mitigated reductions in surface water supplies. The Draft EIS provides that "[i]n extreme dry periods, such as 2014 when there were no deliveries of CVP water to San Joaquin Valley water supply agencies with CVP water service contracts, permanent crops were removed because the plants would not survive the stress of no water or saline groundwater (Fresno Bee 2014)." Draft EIS, at p. 12-10. Elsewhere, the Draft EIS states that "[d]ue to the increased frequency of water supply reductions, especially in drier years . . . the amount of fallowed and non-harvested lands has increased as a percentage of total lands within Westlands Water District. *Id.* at 12-12. The Draft EIS also states that since 2000, farmers have increased the amount of fallowed and non-harvested acres to 10 to 34 percent of the total land in the [Westlands water] district. *Id.* at 12-15. These admissions undermine Reclamation's conclusion that implementing the RPAs would have a less than significant effect on agricultural resources.

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are used in the Statewide Agricultural Production model (SWAP) to estimate the Action's long-term effects on agricultural resources. Draft EIS, Appendix 12A at pp. 12A-3, 12A-22 ("Groundwater is an alternative source to augment local surface, SWP, and CVP water delivery in all SWAP regions. The cost and availability of groundwater therefore has an important effect on how SWAP responds to changes in delivery. However, SWAP is not a groundwater model and does not include any direct way to adjust pumping lifts and unit pumping cost in response to long-run changes in pumping quantities. Economic analysis using SWAP must rely on an accompanying groundwater analysis.").

Reclamation should revise and recirculate the Draft EIS with a discussion on whether changes in groundwater quality and levels due to increased pumping would limit the agricultural sector's reliance on groundwater as a replacement source. Alternatively, if Reclamation is unable to characterize these effects, it is required to supplement the EIS to state why the analysis cannot be feasibly conducted. SWC 14 continued

2. The Draft EIS failed to properly consider the impact of the Sustainable Groundwater Management Act.

SWC 15

Throughout Chapter 7, the Draft EIS makes incorrect assumptions regarding groundwater and the ability to pump groundwater as replacement water in the future. First, while the Draft EIS acknowledges the California Sustainable Groundwater Management Act (SGMA), it fails to adequately consider it. Specifically and repeatedly throughout this chapter, it assumes that there can be continued groundwater pumping. This has the effect of masking significant economic and environmental impacts.

The Draft EIS assumes that by 2030, groundwater sustainability plans (GSPs) will not be implemented. (See 7-109). This is incorrect. The GSPs must be completed by 2020 or 2022. These GSPs will identify a sustainable yield, which will require groundwater pumping to stay within the sustainable yield. One does not reach a sustainability goal in a year. Rather, it takes infrastructure projects and potential reductions in groundwater pumping to achieve sustainability over time. For this reason, groundwater use reduction measures will have to be implemented well in advance of 2030 to meet sustainable yield by 2042.

The Draft EIS incorrectly assumes that because full compliance must be achieved by 2042, reductions in pumping will not occur before 2042. That is a blatantly faulty conclusion and is inconsistent with the SGMA. The SGMA requires DWR to review plan implementation at least once every five years to ensure that the plan is meeting the sustainability goal. (Cal. Water Code, §10733.6 ["The department shall issue an assessment for each basin for which a plan or alternative has been submitted in accordance with this chapter, with an emphasis on assessing progress in achieving the sustainability goal within the basin. The assessment may include recommended corrective actions to address any deficiencies identified by the department."].) Thus, a local agency may not simply submit a GSP and then do nothing until 2042 as this EIS suggests. To the contrary, California law requires GSP implementation to occur before 2042 and if pumping exceeds the sustainable yield, pumping must be reduced or additional supplemental sources of water must be made available to meet the demand.

Additionally, SGMA allows the State, through the State Water Resources Control Board (SWRCB) to manage a basin through a probationary plan if the Department in consultation with the SWRCB determines that a groundwater sustainability plan is inadequate or that the groundwater sustainability program is not being implemented in a manner that will likely achieve the sustainability goal. (Water Code, § 10735.2.) The SWRCB through a probationary plan, and one year after the determination that certain conditions are not met, the plan can implement certain actions, including reductions in groundwater extractions. (Water Code, § 10735.8.) This can occur after 2020 for basins designated as critically overdrafted basins and after 2022 for all other basins subject to SGMA. (Water Code § 10735.2)

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SWC 15 continued

Furthermore, the Draft EIS identifies that the pumping caused by reductions in surface water supply (Alternatives 5) will cause large drops in groundwater levels which will cause increased subsidence. (Draft EIS, at p. 7-136-137.) The impacts to groundwater for other alternatives are essentially masked because the No Action Alternative includes the RPAs and thus the Draft EIS does not adequately analyze or disclose the impacts caused by each of the alternatives studied. Furthermore, in Alternative 5, which specifically shows drops of water levels as high as 200 feet per year, it assumes that SGMA would not apply. However, as indicated above, that is not correct. Since the definition of a sustainability goal includes operating within the sustainable yield, and sustainable yield is defined as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result," this requires that the basin not have undesirable results. (Water Code, § 10721 subd. (v).) Undesirable results include "chronic lowering of groundwater levels" and "significant and unreasonable land subsidence that interferes with surface land uses." (Water Code, § 10721 subd.(w).) Thus it is not acceptable to assume that with increased pumping, decreasing water levels and potential increased subsidence that pumping can continued unfettered after 2020 or 2022 depending on the basin.[3]

SWC 16

Reclamation's assumption in Draft EIS section 7.4 that groundwater pumping can continue unchecked is without basis. This faulty assumption renders the analysis of groundwater impacts in the Draft EIS inadequate. Reclamation is required to grapple with the realities of groundwater use and regulation in California. Notably, the list of groundwater basins that are in critical overdraft included in the Draft EIS is out of date. DWR, in accordance with the SGMA, recently updated the list of critically overdrafted basins in California. As such, we request that Reclamation include the updated list in the Final (and supplemental) EIS.

C. The Draft EIS failed to properly analyze the effect of the RPAs on socioeconomics resulting from diminished water supplies.

SWC 17

Specific issues in the analysis and its treatment of direct and indirect impacts to socioeconomics include the following:

1. The Draft EIS failed to properly analyze the effect of the RPAs on the cost and availability of urban water supplies.

Throughout the discussion of socioeconomic impacts, the analysis assumes that shortages in municipal and industrial supplies will be minimal, due to increased use of alternative supplies. By using the long-term study period time frame, the analysis fails to recognize the significant time period required to plan and construct many infrastructure improvements, as well as recycled water, desalination, and other projects. For the short-term, there is little support for the assumption that impacts from a reduction in supplies will be minimal. Recognizing that the impacts set forth in Draft EIS Tables 19.78 and 19.79 are likely greater than the assumptions, particularly over the short term, there is no support for the failure to recognize the need to mitigate impacts.

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[3] The key basins analyzed are all subject to SGMA because they are designated as high or medium priority under the California Statewide Groundwater Elevation Monitoring Program (CASGEM). (Water Code, § 10720.7.)

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In Draft EIS section 19.4.3.9.1, in the final section of the socioeconomic impact discussion, the analysis apparently assumes that the future water resource management projects included in the cumulative effects analysis, including the recycled water projects, desalination projects, and groundwater storage and recovery projects listed in Chapter 3, will reduce any adverse economic impacts associated with a reduction in supplies, even though some of these projects may not be producing water for several years and some of them produce supplies at significantly increased costs, and with associated impacts which are not accounted for in the analysis. Furthermore, many of these projects are meant to support future water demands and not to supplement the reduction of existing water supplies. SWC 17 continued

2. The Draft EIS fails to analyze the short-term impacts of reductions in water demands or the impacts of using alternative supplies.

Throughout the discussion of socioeconomic impacts, the analysis assumes that shortages in municipal and industrial supplies will be minimal, due to increased use of alternative supplies. By using the long-term study period time frame, the analysis fails to recognize the significant time period required to plan and construct many infrastructure improvements, such as as recycled water, desalination, and other projects and that many projects are planned for meeting future demands not to make up for dwindling water supplies. For the short-term, there is little support for the assumption that impacts from a reduction in supplies will be minimal. Recognizing that the impacts set forth in Tables 19.78 and 19.79 are likely greater than the assumptions, particularly over the short term, there is no support for the failure to recognize the need to mitigate impacts. SWC 18

In section 19.4.3.9.1, in the final section of the socioeconomic impact discussion, the analysis apparently assumes that the future water resource management projects included in the cumulative effects analysis, including the recycled water projects, desalination projects, and groundwater storage and recovery projects listed in Chapter 3, will reduce any adverse economic impacts associated with a reduction in supplies, even though some of these projects may not be producing water for several years and some of them produce supplies at significantly increased costs, and with associated impacts which are not accounted for in the analysis.

It should be noted that a number of the projects discussed in Section 3.5 of Chapter 3 are contingent on additional analysis and future actions, and in some cases, Congressional authorization, before they can be fully implemented. This is recognized in section 1.6, where the Draft EIS states that several projects discussed as part of the cumulative effects analysis will be incorporated into a change in operations after 2030, Thus, any assumptions that these projects will reduce the socioeconomic, water quality, public health or other impacts associated with a reduction in water supplies is inappropriate. Many of these projects were meant to support future water demands and not to mitigate the reduction of existing water supplies.

3. The Draft EIS fails to properly analyze the impacts that the RPAs would have on the cost and availability of agricultural water supplies.

Reclamation concludes in the Draft EIS that implementing the RPAs and alternative RPAs would have a less than significant effect on agricultural productivity in the long-term, and in dry and SWC 19

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SWC 19 continued

critical dry years. This conclusion rests entirely on Draft EIS' assumption that "[m]ost of the change in CVP and SWP irrigation supplies would be offset by changes in groundwater pumping, with only small changes in crop acreage in production." *See, e.g.*, Draft EIS at pp. 19-39,[4] 19-48, 19-53, 19-55, 19-56, 19-59, 19-64, 19-66, 19-67, 19-70, 19-77, 19-79, 19-81, 19-86, 19-88 and 19-90. The Draft EIS' conclusion is invalid because it is contradicted by the Draft EIS and is otherwise unsupported. *See* SWC Comments, *supra,* Section III (B)(1).

The Draft EIS fails to explain its conclusion that a one percent reduction in regional agricultural production from implementing the RPAs is less than significant. *See, e.g.*, Draft EIS at pp. 19-39, 12-27-59, 19-48, 19-53, 19-55, 19-56, 19-59, 19-64, 19-66, 19-67. Even less than a one percent reduction in agricultural production in the Central Valley may be significant. As is acknowledged in the Draft EIS in the introduction to socioeconomic impacts, certain locations are likely to experience severe economic impacts due to limited alternative water supplies. *See, e.g.,* Draft EIS at p. 19-39 ("Individual growers that rely on CVP and SWP supply and have no access to groundwater would have their irrigated acreage affected by larger amounts."). Nevertheless, the Draft EIS concluded that impacts were less than significant, not requiring mitigation.

D. The Draft EIS failed to properly analyze the effect of the RPAs on agricultural resources.

SWC 20

The Draft EIS' discussion of agricultural resources is based on the same modeling and assumptions used in the socioeconomic and water supply analyses, and most of the errors in those sections are repeated in the agricultural resources section. For example, the conclusions of "no effect" in the agricultural resources section is also based on the incorrect assumption that lost surface supplies will be replaced by groundwater, without consideration of the availability and quality of those supplies. (*See e.g.*, pp. 12-28, 12-30, 12-33, 12-43, 12-24 (SWAP model does not restrict groundwater withdrawals based on overdraft or water quality conditions).) The analysis of agricultural resources is further flawed because it fails to analyze short-term impacts to agricultural resources resulting from the implementation of the RPAs. (*See e.g.*, 12-24 (GSP discussion) and p. 12-25 (climate change would reduce available supply but effects not considered between 2008/2009 and 2030)). As a result of the Draft EIS' failure to identify impacts to agricultural resources, the Draft EIS also fails to identify potentially significant indirect effects caused by large scale land fallowing, particularly in dry years, including but not limited to impacts to air quality (dust).

E. The Draft EIS failed to properly analyze the effect of RPAs on fishery resources.

Specific issues in the analysis and treatment of direct and indirect impacts to fishery resources include the following:

1. The Draft EIS violates the Court's order and NEPA by using the existing BiOp RPAs as the metric for evaluating the effects of the project.

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[4] The Draft EIS contains significant analytical overlap between the socioeconomic and agricultural resources sections, with the socioeconomic chapter providing greater specificity as to how the analysis was conducted.

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SWC 21

The Draft EIS unlawfully circumvents the Court's order by using the same RPAs that the Court ordered Reclamation to analyze as the metric for measuring the environmental effects of the RPAs and alternatives. The RPAs cannot be used as the metrics for evaluating the effects of the RPAs. Examples include:

- Delta Smelt Fall Abiotic Index: The Draft EIS uses the Fall X2 RPA to measure the biological effects of the alternatives and Second Basis of Comparison. (Draft EIS, at p. 9G-2.) This undermines the Court's order as the EIS not only fails to consider the effects of the biological opinions, but it uses the biological opinion (in this case the Fall X2 RPA) as the measure of success or failure for each of the alternatives.

  See above regarding the Draft EIS' description of Feyrer *et al*. 2011.[5] The Draft EIS at p. 9G-2 (as well as other locations) mischaracterizes what Feyrer *et al*. concluded.

- Delta Smelt OMR: The EIS uses the biological opinion's equation for estimating Delta Smelt entrainment, which is the basis for the Delta Smelt OMR RPAs. (Draft EIS, at p. 9G-2.) As further evidence of keeping to the confines of the 2008 Delta Smelt biological opinion RPAs, the EIS fails to update the biological opinion's equation with the most recent (approximately) 10-years of data. Then, each of the alternatives were compared to the estimated entrainment in the biological opinion (No Action Alternative), and deviations from the biological opinion's estimated entrainment were used to identify potentially significant impacts.

2. The Draft EIS fails to identify a scientific rationale for determinations of significance.

SWC 22

In Section 9.4, significance criteria are inconsistently identified. For example, there is no presentation of the approach that will be used to assess differences among alternatives for the "Analysis of Fish Passage, Predator Control Programs, and Ocean Salmon Harvest Restrictions." This is inconsistent with other mechanisms such as "Changes in Fish Entrainment and Salmonid Production" where the models used for evaluating potential effects are presented. This approach is inadequate because an EIS "shall identify any methodologies used and shall make explicit reference by footnote to the scientific and other sources relied upon for conclusions in the statement." 40 C.F.R. § 1502.24.

SWC 23

A related, but separate, issue within the analysis of mechanisms of impact (Section 9.4), is the lack of development and application of significance criteria. (*See e.g.*, Draft EIS, at p. 9-108 [What is the logic behind the assumption that differences in monthly average flows of greater than 5% are biologically meaningful and how does that relate to the analysis of flooded habitat (Yolo Bypass)?]; *see id. at* p. 9-110 [What is the justification for assumption that differences in modeled monthly average temperatures greater than 0.5°F are biologically meaningful?]).

Several criteria are presented in the Affected Environment Section as being biologically meaningful (e.g., a change of 1% monthly average flow of less than 0.5°F (Draft EIS p. 9-153 to

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[5] Feyrer, F., Newman, K., Nobriga, M., Sommer, T. 2011. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. *Estuaries and Coasts*, published online. DOI 10.1007/s12237-010-9343-9.

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SWC 23 continued

9-154).) Yet, these criteria are not applied consistently in the alternatives analysis. (*See, e.g.*, Draft EIS at p. 9-221 [Draft EIS should not have found that differences less than 0.5°F are biologically meaningful according to stated significance criteria].) Moreover, the significance terminology is undefined and inconsistently applied. Sometimes temperature differences less than 0.5°F are considered "similar" and sometimes a "slight or minor increase/decrease."

The reliance on qualitative comparisons among alternatives rather than statistical analyses makes it difficult to evaluate biologically meaningful differences between alternatives. For example, in order to truly appreciate the potential effect of an absolute difference of 1°F, it is necessary to know confidence in that value, or in other words the variation around that metric, and the probability that the difference will actually occur. Accepted professional standards would suggest that a change of 1°F with a variance of 1°F or 80% confidence would not be different than no change at all. While meaningful statistical analyses should be used to detect real difference in alternatives effect, this may not always be appropriate, particularly for model outputs. In these cases, it would be appropriate to use sensitivity analysis to determine how sensitive the model is to variation in inputs. Statistical tools are invaluable in considering multiple effects as they quantify the potential for change, remove potential for subjectivity, and minimize interpretative bias.

Related to the above comment, the conclusions made for individual mechanisms of impact throughout the alternatives analysis are difficult to evaluate due to the use of subjective qualitative comparisons. As noted, the analysis is replete with characterization of numeric relationships as "similar," "slightly," "somewhat" and/or "moderately different" yet there is no attempt to define nor numerically justify these characterizations. This leads to subjective application where in one instance a temperature of less than 0.5 °F is considered a "relatively minor temperature change," (page 9-172) but in another instance the same temperature was stated to be "slightly higher" (page 9-171). Additional confusion arises from the use of terms such as "likely to have little effect." It is not clear if such a conclusion is intended to state a "no effect" or a "likely to adversely affect" conclusion. Although not preferable to statistical analyses, qualitative comparisons can be useful where statistics are unsuitable. However, it is important to define and apply standardized criteria consistently across all comparisons, so that the same change in the environment is always considered similarly.

SWC 24

Although the Draft EIS contains a series of tables at the end of Chapter 9 that serve to summarize the environmental consequences and highlight differences between the alternatives, the tables are entirely narrative and laden with qualitative assessments; e.g., "unlikely to be affected," "small likelihood," "slightly lower," "generally would be slightly less," etc. Again, the end result is that the reader can't track the logic behind the assessment calls made regarding potential impacts.

3. **The Draft EIS' conclusions are not well supported by the comparison of model outputs.**

SWC 25

Draft EIS Appendices 9J, 9L, and 9M include the results of entrainment, salvage, and passage models. These results for comparative purposes are visually depicted as box plots with no presentation of values for descriptive metrics (mean, median, standard deviation, interquartile range, etc.), nor any statistical analysis comparing the model results across alternatives. Since no analysis is provided, it is not possible to determine the usefulness of the model output to compare

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SWC 25 continued

alternatives. Distributional differences among alternatives that are described in the text are often not intuitively obvious from the box plots where median values are slightly offset and interquartile ranges show substantial overlap. *See, e.g.*, Draft EIS, at p. 9-170, Fig. 9M.1 [Unclear that any of the differences, particularly March and June are statistically different]; *id.* at p. 9-180 [Box plots in Appendix 9J (Fig. 9J) do not provide visually intuitive depictions of statistically different survival estimates]; *id.* at pp. 9-204 and Fig. 9K.5 and 9L.4, p. 9-208 and Fig, 9L.2; *id.* at p. 9-237; *id.* at Appendix 9J, Fig. 9J; *id.* at p. 9-256 and 9-285, Appendix 9L, Fig. 9L.10, Fig. 9L.1, and Fig. 9L.12; EIS p. 9-330, Appendix 9M, Fig. 9M-4.

This lack of analysis results in subjective interpretation of the data (graphs) that leads to apparent discrepancies across stocks. Examples of different interpretations from the same data/graph include hydrodynamic (pages 9-169 and 9-178; 9-178 and 9-223) and salvage (pages 9-324 and 9-327). Furthermore, it is possible that the large sample size, 81 water years, could result in statistically significant differences in predicted metrics that are not relevant to the fish population due to inherent variances, and/or model sensitivity. Therefore, some discussion of the biological significance of the predicted difference in survival at the population level is needed to adequately evaluate alternatives.

4. The Draft EIS fails to disclose scientific uncertainty and disagreements among experts.

SWC 26

The Draft EIS describes a body of science without acknowledging that there is significant uncertainty and disagreements between experts.

NEPA requires disclosure of uncertainty and scientific disagreements between experts. 40 C.F.R section 1502.9(b) states: "The agency shall discuss at appropriate points in the final statement any responsible opposing view which was not adequately discussed in the draft statement and shall indicate the agency's response to the issues raised." As explained in *Center for Biological Diversity v. United States Forest Service*, "The Service's failure to disclose and analyze opposing viewpoints violates NEPA and 40 C.F.R § 1502.9(b) of the implementing regulations." 349 F.3d. 1157, 1167 (9th Cir. 2003). Further, "…NEPA's requirement that responsible opposing viewpoints are included in the final impact statement 'reflects the paramount Congressional desire to internalize opposing viewpoints into the decision-making process to ensure that an agency is cognizant of all environmental trade-offs that are implicit to the decision'." (*Ibid.*, citing *Cal. v. Block*, 690 F. 2d. 753, 770-771 (9th Cir. 1982).

There are many examples of where the Draft EIS fails to acknowledge scientific uncertainty. This error raises significant questions regarding the validity of the Reclamation's conclusions. While the Draft EIS appropriately states at p. 9-119 that, "…the analysis attempts to identify the level of uncertainty and qualify effect conclusions where competing hypotheses may exist," the Draft EIS both fails to identify uncertainty and fails to identify the universe of scientific information that should have informed its "level of certainty" decisions. While the Draft EIS appropriately proposes a weight of evidence approach at p. 9-199, it only considers a small subset of the entire body of relevant scientific literature, thus it does not apply a weight of evidence approach.

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a) The Draft EIS fails to acknowledge the significant uncertainty associated with the factors affecting Delta Smelt distribution, particularly the role of salinity.

SWC 27

The Draft EIS fails to acknowledge the significant scientific uncertainty associated with the factors affecting Delta Smelt distribution. (*See e.g.*, Draft EIS, at pp. 9-64 to 9-65 and 9-115; Appendix 9B, pp. 125-126.) While Manly *et al.* (2014)[6] is mentioned, it is misconstrued. Manly *et al.* raises significant uncertainty as to whether Delta Smelt distribution is primarily influenced by salinity (position of the low salinity zone). Manly *et al.* re-evaluated Feyrer *et al.* (2011) and showed that since turbidity, salinity and geography are highly cross-correlated it is difficult to determine which, if any of these factors are most influential. Latour (2015)[7] also found that geographic location and salinity were collinear so the covariates are indistinguishable in effect. Kimmerer *et al.* (2013)[8] should also have been considered as they made a similar conclusion (p. 13):

> The lack of consistent parallels between the availability of salinity-based habitat and abundance could have had several causes. First, our use of salinity as the only variable that defines habitat is clearly inadequate. For example, turbidity is consistently important as a covariate in analyses of delta smelt distribution (Feyrer et al, 2007; Nobriga et al. 2008). Given the difficulty in determining the controls on the delta smelt population, it is not surprising that such a simple descriptor of habitat is inadequate for this species.

The Draft EIS should also have acknowledged the issues of survey inefficiency for Delta Smelt. Bennett and Burau (2014)[9] have shown that the tidal cycle significantly influences Delta Smelt catchability in the open water where the sampling occurs. Latour (2015) identified the influence of month, region, and turbidity in determining Delta Smelt catchability. If the survey data are biased by these inefficiencies and not adjusted accordingly, then Feyrer *et al.* (as well as all other studies relying on the survey data) may not be accurately describing Delta Smelt distribution irrespective of the highly cross-correlated nature of the covariates.

Relevance: These studies are highly relevant as they raise questions as to whether salinity can be used as the sole factor defining Delta Smelt habitat, as was done in the 2008 FWS biological opinion, and whether the abiotic habitat index is an appropriate metric for evaluating potential impacts of project operations on Delta Smelt fall habitat. Draft EIS, Appendix 9-G at pp. 203. These studies also raise significant questions as to whether salinity can be used to change Delta Smelt distribution and expand the available habitat. For example, Delta Smelt might inhabit the

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[6] Manly, B.F.J., Fullerton, D., Hendrix, A.N., Burnham, K.P. 2013. Comments on Feyrer *et al.* "Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish." Coastal and Estuarine Research Federation. Available: DOI 10.1007/s12237-014-9905-3.

[7] Latour, R. 2015. Explaining patterns of pelagic fish abundance in the Sacramento-San Joaquin Delta. *Estuaries and Coasts.* Published online. DOI 10.1007/s12237-01509968-9.

[8] Kimmerer, W.J., MacWilliams, M.L., Gross, E.S. 2013. Variation of Fish Habitat and Extent of the Low-Salinity Zone with Freshwater Flow in the San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 11(4). Available: http://scholarship.org/ic/item/3pz7x1x8.

[9] Bennett, W.A., Burau, J.R. 2014. Riders on the storm: selective tidal movements facilitate the spawning and migration of threatened Delta Smelt in the San Francisco Estuary. *Estuaries and Coasts*. pub. online. DOI 10.1007/s12237-014-9877-3.

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low salinity zone due to its proximity to productive wetland areas, or some other geographically oriented factor, irrespective of the location of the X2 isohaline. Even if the volume of the low salinity zone is a meaningful descriptor of Delta Smelt habitat, changes in the location of X2 have not been directly linked to changes in species abundance. Kimmerer *et al.* (2013) at p. 13 explains that X2, or the volume of the low salinity zone, is not a driver of Delta Smelt abundance, which calls into question the potential biological significance of any change in the location of X2 in the fall.

SWC 27 continued

b) The Draft EIS improperly assumes that SWP-CVP operations have caused the location of X2 to move further upstream in the fall (September-December).

The EIS improperly uses analyses from the 2008 FWS biological opinion to conclude that there have been project-related changes in the location of X2 (September –December). Draft EIS Appendix 9G at p.2; EIS at p. 9-73. The Draft EIS should consider Hutton *et al.* (in press)[10] which shows that the full period of record demonstrates a statistically significant trend toward a more westerly (i.e. fresher) X2 location in September and no statistically significant trend in October. Hutton *et al.* further explains that the full record does reveal a statistically significant trend toward a more easterly (i.e. saltier) X2 location in November. However, there is no statistically significant difference between pre-project (water years 1922-1967) and post-project (water years 1968-2012) November X2 position in wet and above normal water years (the water year categories targeted under the current RPA). Even though there is a statistically significant easterly trend in November X2 location using the full period of record, the cause of the trend is uncertain because there are multiple diverters in the Bay-Delta watershed of a total magnitude comparable to that of the CVP-SWP.

SWC 28

Relevance: A comparison of the pre-project and post-project time periods informs the question of project-related effects on outflow. The data do not support the conclusion that project operations have significantly moved X2 more easterly in September and October compared to pre-project conditions and project operations have only potentially impacted X2 location in November.

c) The Drat EIS fails to acknowledge the significant scientific uncertainty associated with the interpretation of the Longfin Smelt average Jan.-June X2: FMWT correlation.

There is a statistically significant relationship between Longfin Smelt FMWT and average January-June X2 location (Jassby *et al.* 1995,[11] Kimmerer 2004,[12] Kimmerer *et al.* 2009,[13]

SWC 29

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[10] Hutton, P.H., Rath, J.S., Chen, L., Ungs, M.J., Roy, S.B. (*In Review*) Nine Decades of Salinity Observations in the San Francisco Bay and Delta: Modeling and Trend Evaluation. *ASCE Journal of Water Resources Planning and Management.*

[11] Jassby, A.D., Kimmerer, W.J., Monismith, S.G., Armor, C., Cloern, J.E., Powell, T.M., Schubel, J.R., Vendlinski, T.J. 1995. Isohaline position as a habitat indicator for estuarine populations. *Ecological Applications*, 5(1), pp. 272-289.

[12] Kimmerer, W. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. *San Francisco Estuary and Watershed*. 2(1).

[13] Kimmerer, W.J., Gross, E.S., MacWilliams, M.L. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuarines and Coasts*, 32, p. 375-389.

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SWC 29 continued

Kimmerer 2013[14]). The uncertainty and the disputes between experts are related to how that correlation should be interpreted, and whether it can reasonably be used to predict project related effects on Longfin Smelt.

The Draft EIS analysis assumes that Longfin Smelt spawn upstream of the confluence, spring outflows carry the larvae downstream for feeding, and then the species migrate out of the Delta (*i.e.*, larval transport hypothesis). *See e.g.*, Draft EIS, Appendix 9G at p. 3. Since the location of X2 (used to define the location of the low salinity (LSZ) habitat) is the only constituent of early life stage habitat being analyzed, the Draft EIS is assuming that the mechanism underlying the Longfin Smelt FMWT: January-June X2 correlation changes in the volume or location of early life stage LSZ habitat. The analysis uses the Kimmerer *et al.* (2009) correlation between Longfin Smelt FMWT: January:June X2 to predict future changes in species abundance based on changes in the location of X2 over the entire January-June averaging period. *Ibid.* The Draft EIS therefore concludes that winter and spring outflow is the largest factor driving abundance. *See e.g.*, Draft EIS, at p. 67 [also evidenced by no other flow other than outflow being evaluated in the analysis].

The Draft EIS fails to acknowledge the dispute between experts and the high degree of uncertainty, as described below:

(1) The Draft EIS fails to acknowledge that because the underlying biological mechanism is unknown, any interpretation of the Longfin Smelt FMWT correlation is uncertain.

SWC 30

The literature has cautioned against doing the type of analysis contained in the Draft EIS because the biological mechanism(s) explaining the Longfin Smelt abundance: winter-spring X2 correlations are largely unknown. As Kimmerer *et al.* (2002),[15] p. 1285 explained, "Predicting these responses is contingent on understanding the mechanisms underlying the flow relationships." Experts cannot reliably predict how Longfin Smelt abundance would respond to changes in reservoir releases, as compared to changes in outflow originating from (for example) wet hydrology and/or inflows to tributaries to the Bay, because the biological mechanism that would explain the observed statistical relationship is unknown. If the biological mechanism is, for example, turbidity, then increasing reservoir releases will have no effect because turbidity does not increase with reservoir releases. Kimmerer *et al.* (2002), p. 1285, explains:

> Even for a single species, the timing and duration of flow-based management should coincide with the mechanism by which the species responds to flow. This implies knowledge of the species' mechanism. A mechanism involving an increase in brackish habitat during the rearing season (mechanism 10, Table 1) may require a long period of increased flow, and opportunities for efficiency will be limited; a mechanism involving tidal stream transport and gravitational circulation in the lower estuary (mechanism 11) may occur over a relatively brief period of larval or juvenile recruitment into the estuary.

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[14] Kimmerer, W.J., MacWilliams, M.L., Gross, E.S. 2013. Variation of Fish Habitat and Extent of the Low- Salinity Zone with Freshwater Flow in the San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 11(4). Available: http://scholarship.org/ic/item/3pz7x1x8.

[15] Kimmerer, W.J. 2002. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages. Mar. Ecol. Prog. Ser., 243, pp. 39-55.

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SWC 30

> As a more specific example, Sacramento splittail clearly respond to increasing flow through inundation of floodplains during early spring (Sommer *et al.* 1997). This effect may occur through access to spawning habitat, in which case the period of effectiveness would be fairly brief, or rearing habitat, which would require a longer period of inundation. Distinguishing between these mechanisms and determining their importance to overall abundance of the species are important research objectives….

The Longfin Smelt life cycle model by Maunder *et al.* further illustrates this point (Maunder *et al.* 2015).[16] The results of that model suggest that flow may be important to species abundance, but just as Kimmerer observed above, the question is "which flow?" Hydrology, Delta outflow, X2 and inflows to the Bay from smaller tributaries are all cross-correlated. The Maunder and Deriso model selected Napa River flow, which could be used as a surrogate for Bay inflow, as being the strongest predictor of increased Longfin Smelt abundance. If the model is correct, the most effective Longfin Smelt management action may be restoration activities within the Bay's smaller tributaries or restoration of the marshes around the Bay.

Relevance: Since the biological mechanism is unknown, it cannot be assumed that X2 is directly related to Longfin Smelt abundance. It is equally possible that Longfin Smelt abundance is being driven by some other flow or environmental condition that is cross-correlated with flow. The Draft EIS should explain that the FMWT: January-June X2 correlation cannot be interpreted reliably until the underlying biological mechanism is identified.

(2) The Draft EIS improperly assumes that the biological mechanism underlying the Longfin Smelt FMWT: Jan-June X2 correlation is a change in LSZ habitat.

SWC 31

The Draft EIS analysis defines Longfin Smelt habitat only in terms of salinity, and equates project effects to changes in the size and location of low salinity conditions. (Draft EIS Appendix 9G, p. 3 [larval transport/LSZ habitat mechanism].) However, the literature does not support the assumption that the size and location of the winter-spring LSZ is the biological mechanism underlying the FMWT: January- June X2 correlation.

In the original Jassby *et al.* (1995) paper, X2 was characterized as an estuarine habitat indicator. However, that doesn't mean that the size of the LSZ is the mechanism underlying the species abundance: X2 relationships. As Kimmerer *et al.* (2013), p. 5, explained:

> …it is important to distinguish between the LSZ as a particular habitat and the numeric value of X2 as a measure of the wide variety of the physical responses of the estuary to flow (Kimmerer 2002b). In particular, abundance of various fish species may respond to X2 or its correlates through mechanisms that are not directly related to LSZ characteristics (Kimmerer 2002b, Kimmerer et al. 2009).

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[16] Maunder, M.N., Deriso, R.B., Hanson, C.H. 2014. Use of state-space population dynamics models in hypothesis testing: advantages over simple log-linear regressions for modeling survival, illustrated with application to longfin smelt (*Spirinchus thaleichthys*). Fisheries Research, 164, pp. 102-111.

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SWC 31 continued

Kimmerer *et al.* (2013), p. 15, investigated whether the size of the LSZ, rather than the numerous other non-salinity components of habitat, is the mechanism underlying the various species abundance:X2 relationships and they concluded that:

> Despite the similarity among the relationships of habitat index to X2, the abundance-X2 relationships (Kimmerer *et al*. 2009) differed greatly among the species (Fig. 8). This finding together with the lack of correspondence for some species between the habitat-X2 and abundance-X2 relationships (Fig. 8), suggest that variation in the volume (or area, not shown) of physical habitat as defined by salinity is not a strong influence on abundance of many of these fish.

See also, Reed *et al.* 2014, p. 33.[17] Longfin Smelt is one of the species where changes in the size of the LSZ habitat was considered and rejected as an explanatory mechanism. This conclusion has been confirmed on several occasions. Kimmerer *et al*. (2013), p. 14, concluded:

> Nevertheless, the observed [longfin smelt] X2-abundance relationships are inconsistent with a mechanism that involved extent of low-salinity habitat…

Kimmerer *et al.* (2009), p. 10, concluded:

> Confidence limits for relationships of abundance with X2 for longfin smelt, bay shrimp, and starry flounder did not overlap with those of any of the corresponding habitat estimates. Thus, other mechanisms are likely operating to cause these species to increase in abundance with increasing flow.

And,

> The modest slope of habitat to X2 would allow for only about a twofold variation in abundance index over that X2 range. Furthermore, the extent of the longfin smelt population in terms of distance up the axis of the estuary decreases with increasing flow. Therefore, although increases in quantity of habitat may contribute, the mechanisms chiefly responsible for the X2 relationship for longfin smelt remains unknown. It may be related to the shift by young fish toward greater depth at higher salinity, possibly implying a retention mechanism.

Kimmerer (2002), p. 1283 concluded:

> Data for striped bass and longfin smelt both fail to support a mechanism by which habitat area increase with flow.

These conclusions should not be surprising as Kimmerer, one of the Jassby *et al.* (1995) co-authors who advised caution when interpreting the longfin smelt abundance:X2 correlation. "Jassby *et al.* (1995) recognized that other factors that influence species abundance, but are not correlated with

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[17] Reed, D., Hollibaugh, J., Korman, J., Peebles, E., Rose, K., Smith, P., Montagna, P. 2014. Workshop on Delta Outflows and Related Stressors Panel Summary Report. Prepared for Delta Stewardship Council, Delta Science Program.

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X2, should be considered, and cautioned against 'blind adherence' to X2 as a management tool." Reed *et al.* (2014), p. 22, citing Jassby *et al.* (1995), p. 275.

SWC 31 continued

Relevance: Since the biological mechanism is unknown, it cannot be assumed that X2 is directly related to Longfin Smelt abundance. It is equally possible that Longfin Smelt abundance is being driven by some other flow or environmental condition that is cross-correlated with flow. The Draft EIS should explain that the assumed biological mechanism of changes in the size or volume of LSZ habitat is uncertain.

(3) The Draft EIS assumes that Longfin Smelt spawn on the Sacramento River upstream of the confluence, and that flows are needed to transport larvae to Suisun Marsh and ultimately to the Bay. In so doing, the Draft EIS assumes that the biological mechanism explaining the Longfin Smelt FMWT: January-June X2 correlation is larval transport. This assumption is unsupported.

SWC 32

The Draft EIS assumes that the mechanism underlying the Longfin Smelt FMWT: January-June correlation is larval transport. Draft EIS Appendix 9G, p. 3 (larval transport/LSZ habitat mechanism). The Draft EIS also assumes that the geographic location of Longfin Smelt larvae is closely associated with the position of X2. *See, e.g.,* Draft EIS, at p. 9-67; EIS at p. 9B-138.[18] These assumptions are not supported by best available science.

There is little support for the assumption that the mechanism underlying the Longfin Smelt FMWT: January-June X2 correlation is larval transport. In fact, the fishery agencies have concluded that the mechanism underlying the Longfin Smelt correlation is unknown. For example, in its Longfin Smelt listing decision, the United States Fish and Wildlife Service acknowledged that the mechanism underlying the Longfin Smelt FMWT: January-June X2 correlation is unknown, listing larval transport as only one of several potential mechanisms. The 2012 FWS Longfin Smelt listing decision states: "Despite numerous studies of Longfin Smelt abundance and flow in the Bay Delta, the underlying causal mechanisms are still not fully understood." 77 Fed. Reg. 19,756 – 19,766 (April 2, 2012).

In several of Kimmerer's publications he also agreed that the mechanism underlying the Longfin Smelt X2 correlation is unknown. *See, e.g.,* Kimmerer *et al.* (2009), p. 11. During the 2010 SWRCB flow proceedings, Kimmerer further explained that while Longfin Smelt have a strong abundance-flow relationship, they are generally distributed at locations downstream of the LSZ, and therefore the mechanism explaining the abundance-flow relationship is likely related to conditions far outside of the LSZ Dr. Kimmerer, SWRCB, WQCP Workshop 1, Day 1, video available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/comp_review_workshops.shtml.

The Delta Regional Ecosystem Restoration Implementation Plan ("DRERIP"), which is the working conceptual model for the fishery agencies and Bay-Delta scientific community, concludes similarly at p. 9 stating:

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[18] Contrary to statements in the Draft EIS at p. 9-67, a preliminary analysis of Dege and Browns 2004 data does not support the conclusion that the center of the Longfin Smelt distribution is a X2 (Grimaldo, *unpub.*).

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SWC 32 continued

> The mechanism behind this relationship is not completely understood, and it is quite likely that more than one mechanism is behind the overall effect. High flows may increase available spawning habitat, increase hatching success, decrease predation on LFS larvae, increase success of larval-juvenile transformation (e.g., by increasing food sources), or some combination of these factors. Baxter (1999) and Dege and Brown (2004) observed that larval densities did not respond significantly to freshwater flow conditions. This argues against mechanisms that produce positive correlation between egg-larval increase in available spawning territories or improved egg hatching success and for mechanisms that increase success of larvae-juvenile transition….

As explained in the DRERIP model, Longfin Smelt spawning in the upper estuary is not correlated well with outflow. In wet years, there are generally low numbers of larvae captured in the upper Estuary, a likely explanation is that Longfin Smelt descend into the San Pablo Bay to spawn (Tracy Fish Facilities Report, Vol. 38, p. 41). Longfin Smelt spawning density is higher in the upper Estuary in dry years, particularly in Suisun Bay (Tracy Fish Facilities Report, Vol. 38, p. 41). Therefore, it is unlikely that increased spawning and larvae survival in the upper estuary in high outflow years is the biological mechanism behind the Longfin Smelt abundance: X2 relationship.

There is uncertainty regarding whether the geographic location of Longfin Smelt larvae is closely associated with the position of X2. *See, e.g.*,Draft EIS, at p. 9-67; *id.* at p. 9B-138.) The analysis in the EIS also fails to account for the Longfin Smelt that spawn outside of the Delta. For Longfin Smelt spawning downstream of the Delta, larval transport from the Delta cannot be a biological mechanism explaining the correlation.

The IEP surveys do not include larval sampling in the low salinity zone areas within the tributaries to the Bay, so the existence and magnitude of spawning downstream of the confluence is unknown.[19] However, there is enough evidence to suggest that downstream spawning could be substantial, particularly in wet years. Rosenfield (2010) at p. 6 explained:

> The CDFG 20 mm survey catches relatively large numbers of LFS larvae in the Napa River estuary, especially during wet winters (CDFG 20mm Survey database), indicating that spawning habitat may be periodically available in that area as well. Finally, some maturing LFS migrate into the South Bay during the fall and winter suggesting that spawning may occur in tributaries to the South Bay (*e.g.*, Coyote Creek).

In Merz *et al.* (2013),[20] the authors mapped the distribution of larval Longfin Smelt. The maps suggest that the Delta is the eastern edge of the species range. It also suggests that longfin spawn east of the confluence.

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[19] The Bay Study did perform larval surveys in the 1980s, but those surveys sampled the channels rather than the shore areas where larvae would be expected, and therefore have limited informational value.

[20] Merz, J.E., Bergman, P.S., Melgo, J.F., Hamilton, S. Longfin smelt: spatial dynamics and ontogeny in the San Francisco estuary, California. California Fish and Game, 99(3), pp. 122-148.

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SWC 32 continued

There have been several limited surveys of the tributaries to the Bay, and those surveys identified Longfin Smelt larvae. In 2001 (a dry year), the Department of Fish and Wildlife ("DFW") performed the 20 mm survey in the Napa River near the City of Napa and identified densities of Longfin Smelt larvae that were an order of magnitude higher than in the Sacramento River.[21] DFW completed another survey in the Napa Estuary portion of the Napa River north of Vallejo in 2006 and again identified numbers of Longfin Smelt larvae that were an order of magnitude higher than in the Sacramento River. Delta smelt larval survey data available at ftp://ftp.delta.dfg.ca.gov/Delta%20Smelt. Stillwater Sciences, a consultant to the City of Napa, sampled in the Napa River near the City of Napa in 2001-2005, and found large densities of Longfin Smelt larvae in 2001 and 2003 (dry years). (U.S. Army Corps of Engineers, 2005).[22] In the 1980s, large numbers of Longfin Smelt larvae and juveniles were captured in the Napa River (Tracy Fish Facilities Report, Vol. 38, p. 39[23] ("Juveniles are abundant in the Napa River…. ")). The sampling during this period was in the open channel so it is possible that even higher densities would have been identified in shallows, where spawning is thought to occur. The 20 mm survey consistently catches Longfin Smelt at high densities in the Napa River between Vallejo and a few miles north of Mare Island. The 20 mm survey does not start until March, which is after spawning has begun, but it nevertheless suggests that Longfin Smelt are spawning in the area.

The Draft EIS should have also discussed the more recent larval Longfin Smelt sampling studies, some of which were funded by Reclamation. These studies have also shown that Longfin Smelt spawning occurs in the tidal marshes surrounding Suisun Bay, and early results show Longfin Smelt larvae presence in Napa Marsh Complex, Petaluma River, Suisun Bay, and South Bay. (Grimaldo, Delta Science Conference presentation, 2014; Parker *et al.*, IEP Poster, 2014.)

The Draft EIS should explain that the scientific community generally agrees that the mechanism underlying the FMWT: January-June X2 correlation is unknown. The Draft EIS should have also acknowledged that here is compelling evidence suggesting that larval transport is not the mechanism underlying the correlation.

__Relevance:__ Since the biological mechanism is unknown, the analysis is uncertain because it cannot be assumed that X2 is directly related to Longfin Smelt abundance. It is equally possible that Longfin Smelt abundance is being driven by some other flow or environmental condition that is cross-correlated with flow.

(4) The Draft EIS fails to acknowledge the significant uncertainty associated with Longfin Smelt abundance trends.

SWC 33

The Draft EIS should have discussed uncertainties created by different survey efficiencies. For example, the EIS should have acknowledged that the FMWT or the 20 mm survey only covers a small fraction of the Longfin Smelt's range. *See e.g.*, Draft EIS p. 9- 67; *id.* at p. 9B-138. The

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[21] 20mm survey data available at ftp://ftp.delta.dfg.ca.gov/Delta%20Smelt.

[22] U.S. Army Corps of Engineers, Sacramento District. 2006. Napa River Fisheries Monitoring Program Annual Report 2005. Contract # DACW05-01-C-0015. Prepared by: Stillwater Sciences.

[23] Bureau of Reclamation. 2007. Tracy Fish Facilities Studies, spawning, early life stages, and early life histories of the Osmerids found in the Sacramento- San Joaquin Delta of California, Vol. 38.

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SWC 33 continued

Draft EIS should have also discussed Latour's 2015 findings false zeros were associated with turbidity, which suggests turbidity related survey bias.

Longfin Smelt abundance trends are uncertain, which may be a result of survey inefficiencies. For example, the mid-water trawl and the otter trawl suggest different abundance trends, with the otter trawl suggesting much less of a decline in abundance (Acuna *et al*., Delta Science Conference, 2014). Therefore, there is uncertainty as to which surveys are the more representative of species abundance trends, and whether the differences suggest significant survey bias in the fall midwater trawl.

Relevance: The reliability of the surveys is relevant to all conclusions regarding species biology and project-related effects that are based on those surveys.

d) There is significant uncertainty about the effects of the CVP-SWP on salmonids related to Delta hydrodynamics, route selection, reach specific survival, and the effects of salvage.

SWC 34

The Affected Environment of the Draft EIS, in particular section 9.3.4.12.1 (Fish in the Delta), relies heavily on fish survival and entrainment information from 2000-2009, the majority of which was collected from mark-recapture studies with coded wire tagged fish. There is an abundance of more recent data developed in the past 5 years that provides additional information on Delta hydrodynamics, route entrainment, reach specific survival and effects of salvage. For the Draft EIS, the results from a few more recent acoustic tagging studies are used for specific analyses, e.g., changes in salvage, but they are not applied broadly. In some cases, these study results have called into question the validity of using the more historic results to infer effects under more recent Delta conditions as well as the applicability of current model(s) to predict fish and flow relationships. A list of citations for relevant studies and analyses that should be incorporated into the Draft EIS are provided in the reference list below.

SWC 35

This lack of updated information is also apparent in the use of the Delta Passage Model ("DPM"). The DPM was used to evaluate baseline conditions and changes in Fish Passage and Routing (Section 9.4.1.3.4). As it is described in Appendix 9J, this model has weaknesses that call into question its utility in predicting passage differences among the Draft EIS Alternatives. The DPM should have been updated to reflect the current state of the science. Specific comments on the DPM include:

- The source documents used to develop the biological functionality of the model are too limited and result in a simplistic depiction of Delta hydrodynamics and fish biology that does not reflect current conditions. Key critical documents that address Delta hydrodynamics, fish entrainment and survival are missing including: Perry *et al.* 2015,[24]

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[24] Perry, R. W., P. L. Brandes, J. R. Burau, P. T. Sandstrom, and J. R. Skalski. 2015. Effect of Tides, River Flow, and Gate Operations on Entrainment of Juvenile Salmon into the Interior Sacramento–San Joaquin River Delta. Transactions of the American Fisheries Society 144:445-455.

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SWC 35
continued

Cavallo *et al.* 2015,[25] Buchanan *et al.* 2015,[26] Delaney *et al.* 2014,[27] Zeug and Cavallo 2013,[28] SJRGA 2013,[29] Buchanan *et al.* 2013.[30]

- The DPM operates on a daily average time step using daily average flows even though this level of analysis is too course to capture flow conditions that fish experience at junctions. Cavallo *et al.* (2013)[31] suggest that the DSM2 model run at a spatial-temporal resolution of every 15 minutes is more consistent with the probability of flow and fish entrainment patterns.

- The DPM treats the Interior Delta region as a single model reach. Recent studies with acoustic tagged fish have shown significant differences in reach and junction specific hydrodynamics (Cavallo *et al.* 2015) as well as fish entrainment and survival (Delaney *et al.* 2014, Buchanan *et al.* 2013, SJRGA 2013). In addition, data from tagging studies in the downstream Delta reaches suggest that steelhead smolts are not simply moving with flows but may be utilizing selective tidal stream transport (Delaney *et al.* 2014). These data provide biological information that could be used to refine the model for the interior Delta to incorporate separate reaches or, as an alternative, conduct a sensitivity analysis of the model to evaluate its ability to predict reach-specific entrainment and survival within the Interior Delta.

- Model documentation indicates that migration speed is modeled as a function of reach specific flow for three reaches (Sac 1, Sac 2, and GEO/DCC). No information is provided as to what data informs the migration speed for the other model reaches.

- The model uses flow to inform fish behavior at junctions and assumes proportional flow for each route except for Junction C (DCC/GEO) where a non-proportional relationship, based on acoustic data, was used. No citation is provided to facilitate an evaluation of the relationship provided at Junction C nor to understand why this is the only location where a non-proportional flow relationship is used. Cavallo *et al.* (2015) suggest that fish are less likely to enter a distributary channel than would be expected based on the proportion of flow entrained there. This is consistent with the other literature that suggest that fish

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[25] Cavallo, B., P. Gaskill, J. Melgo, and S. C. Zeug. 2015. Predicting juvenile Chinook Salmon routing in riverine and tidal channels of a freshwater estuary. Environmental Biology of Fishes 98:1571-1582.

[26] Buchanan, R., P. Brandes, M. Marshall, J. S. Foott, J. Ingram, D. LaPlante, T. Liedtke, and J. Israel. 2015. 2012 South Delta Chinook Salmon Survival Study: Draft report to USFWS. Ed. by P. Brandes. 139 pages.

[27] Delaney, D., P. Bergman, B. Cavallo, and J. Malgo. 2014. Stipulation Study : Steelhead Movement and Survival in the South Delta with Adaptive Management of Old and Middle River Flows.

[28] Zeug, S. C. and B. J. Cavallo. 2014. Controls on the entrainment of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) into large water diversions and estimates of population-level loss. Plos One 9:e101479.

[29] San Joaquin River Group Authority. 2013. 2011 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board in compliance with D-1641. Available at: http://www.sjrg.org/technicalreport/.

[30] Buchanan, R. A., J. R. Skalski, P. L. Brandes, and A. Fuller. 2013. Route Use and Survival of Juvenile Chinook Salmon through the San Joaquin River Delta. North American Journal of Fisheries Management 33:216-229.

[31] Cavallo, B., P. Gaskill, and J. Melgo. 2013. Investigating the influence of tides, inflows, and exports on sub-daily flow in the Sacramento-San Joaquin Delta. Cramer Fish Sciences Report. 64 pp. Available online at: http://www.fishsciences.net/reports/2013/Cavallo_et_al_Delta_Flow_Report.pdf .

SWC 35 continued

movement patterns are influenced by other factors including diurnal fish behavior (Delaney *et al.* 2014), tidal cycle (Perry *et al.* 2015, Cavallo *et al.* 2015, Delaney *et al.* 2014, Zeug and Cavallo 2014), velocity (Perry *et al.* 2015, SJRGA 2013, Michel *et al.* 2015)[32], and turbidity (Michel *et al.* 2015). Furthermore, Cavallo *et al.* (2015) lists seven junctions within the Interior Delta where the tidal cycle mediates any effects of inflows and exports on route selection. It seems prudent to suggest that the DPM should consider these data and the potential effects on route selection and if the model cannot be refined to incorporate some of the more recent relationships (e.g., Cavallo *et al.* 2013), then some analysis of the models sensitivity to diversion from a 1:1 fish to flow relationship is needed to evaluate the utility of the model for comparative analysis.

- Model documentation indicates that reach specific survival is predicted using daily flow for seven reaches (Sac 1, 2, 3, 4, SS, Interior Delta via SJR, Interior Delta via OR) and exports for one reach (Interior Delta via GEO/DCC). Only the GEO/DCC and Yolo reaches are informed by means and standard deviations from survival studies. Yet, some authors have reviewed years of data and failed to demonstrate a relationship between hydrodynamics and survival (Zeug and Cavallo 2014)[33], or exports and survival (Delaney *et al.* 2014) and have suggested that there is no one hydrodynamic metric that can characterizes all patterns in the Delta. These researchers (Zeug and Cavallo 2014) as well as Michel (2010) have demonstrated that other environmental factors, independent of inflow and exports, affect salmonid survival to the ocean including select water quality parameters, temperature, and fish size.

<u>Relevance</u>: The failure to use up-to-date information raises significant questions about the validity and reasonableness of all conclusions related to the CVP-SWP effects on salmonid entrainment and indirect effects.

5. The Draft EIS contains numerous technical errors, including failure to cite or misapplication of scientific literature.

SWC 36

The Draft EIS fails to accurately describe the conclusions of many of the studies it cites. The Draft EIS also fails to properly disclose the error bars and limitations of the studies it cites. In many locations, the Draft EIS fails to provide a scientific citation to support conclusions regarding the biology of the species, which is contrary to the NEPA regulations which require, "a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment." 40 C.F.R. §1502.22. The weight of evidence approach the Draft EIS purports to apply in its decision-making is therefore significantly compromised. Examples include, but are not limited to:

- <u>Kimmerer 2008:</u> The Draft EIS uses the approach to estimating Delta Smelt entrainment adopted and incorporated into the 2008 biological opinion RPAs that is partially based on

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[32] Michel, C. J., A. J. Ammann, E. D. Chapman, P. T. Sandstrom, H. E. Fish, M. J. Thomas, G. P. Singer, S. T. Lindley, A. P. Klimley, and R. B. MacFarlane. 2013. The effects of environmental factors on the migratory movement patterns of Sacramento River yearling late-fall run Chinook salmon (*Oncorhynchus tshawytscha*). Environmental Biology of Fishes 96:257-271

[33] Zeug, S. C. and B. J. Cavallo. 2014. Controls on the entrainment of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) into large water diversions and estimates of population-level loss. Plos One 9:e101479.

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SWC 36 continued

Kimmerer 2008, however the Draft EIS fails to disclose the limitations of Kimmerer's analysis. The error bars in Kimmerer 2008 are very large. In the case of Delta Smelt, the range of estimated loss was between 0-50%. Kimmerer (2008) is also based on numerous untested assumptions. For example, Miller (2014) at Table 9 identified 11 upwardly biased assumptions but was only able to correct for approximately 3 of those. The Draft EIS only references one upward bias assumption. (Draft EIS, p. 9G-2.) The Draft EIS also fails to include Kimmerer's own qualification of his work where he explains that even though his estimates of the percent of the Delta Smelt population entrained in the CVP-SWP are periodically large, there is no evidence that entrainment has had a population level effect (Kimmerer (2008) at p. 25, "… no effect of export flow on subsequent midwater trawl abundance is evident).

SWC 37

- Feyrer *et al.* 2011: The Draft EIS states, "*Feyrer et al. (2011) demonstrated that Delta Smelt abiotic habitat suitability in the fall in the West Delta, Suisun Bay, and Suisun Marsh subregions, as well as smaller portion of the Cache Slough, South Delta, and North Delta subregions, is correlated with X2 location. Feyrer et al. used X2 as an indicator of the suitable salinity and water transparency for rearing older juvenile Delta Smelt.*"

  These statements are incorrect. Feyrer *et al.* showed a correlation between salinity and species presence-absence. Feyrer *et al.* did not demonstrate that habitat suitability in the fall is correlated with X2. See discussion, above, regarding scientific uncertainty of what Feyrer *et al.* did conclude.

SWC 38

- Merz *et al.* 2011[34]: The Draft EIS at p. 9B-126 states that, "*…in low outflow years, Delta Smelt occur primarily in the lower Sacramento River, with the area near Decker Island consistently exhibiting greatest catch over time. In years of very high outflow, however, their distribution extends into San Pablo Bay and the Napa River (Bennett 2000),*" and, "*They typically require low-salinity, shallow openwater habitat in the estuary (Moyle 2002).*"

  As Merz *et al.* (2011) illustrates, Delta Smelt are widely distributed in all years, with Decker Island consistently exhibiting the highest catch in all water-year types. Merz *et al.* further illustrates that Delta Smelt are caught in Suisun Marsh and Suisun Bay, which contradicts the EIS statements that Delta Smelt require low salinity shallow open water.

SWC 39

- Feyrer *et al.* 2007[35]: The Draft EIS cites Feyrer *et al.* (2007) to support the premise that when the habitat index is higher, it has a positive effect on subsequent abundance. (Draft EIS at p. 9B-129.) Kimmerer *et al.* 2013 directly contradicts Feyrer *et al.* findings as to the relationship between X2 and species abundance.

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[34] Merz., J.E., Hamilton, S., Bergman, P.S. Cavallo, B. 2011. Spatial perspective for delta smelt: a summary of contemporary survey data. *California Fish and Game*, 97(4), pp. 164-189.

[35] Feyrer, F., Nobriga, M., Sommer, T. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California. *Can. J. Aquat. Sci.* 64: 723-734.

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- Kimmerer 2011:[36] The Draft EIS at p. 9B-130 states, "*Thus, if numbers of adults or adult fecundity decline, juvenile production will also decline (Kimmerer 2011).*" However, the Draft EIS fails to state that Kimmerer's statement was theoretical. He did not show it to be true. SWC 40

- Bennett *et al.* 2008; Feyrer *et al.* 2007, 2011; Maunder and Deriso 2011[37]. The Draft EIS states at p. 9B-130 that, "*The mechanism causing carrying capacity to decline is likely due to the long-term accumulation of adverse changes in both physical and biological aspects of habitat during summer and fall (Bennett et al. 2008; Feyrer et al. 2007, 2011; Maunder and Deriso 2011.)*" The citations do not support this statement and there is no broad agreement on this point as the EIS is suggesting. SWC 41

- Baxter *et al.* 2010;[38] Feyrer *et al.* (2007, 2011): The Draft EIS states that, "*The overlap of the low salinity zone (or X2) with the Suisun Bay/Marsh is believed to lead to more favorable growth and survival conditions for Delta Smelt in the Fall. (Baxter et al. 2010; Feyrer et al. 2007, 2011).*" The citations do not support this conclusion. Baxter *et al.* is a description of a conceptual model to be tested. The Feyrer *et al.* papers do not show such a relationship. The proposed relationship is theoretical and has not been substantiated. SWC 42

- Cavallo *et al.* 2015 and Perry *et al.* 2015: The Draft EIS states at p. 9-137 that: "The DCC gate operations would be modified to reduce loss of emigrating salmonids…." However, gate closure decreases fish entering the Delta through DCC, but does not affect the overall number of fish entering Georgiana Slough (Cavallo *et al.* 2015 and Perry *et al.* 2015). SWC 43

- Newman and Brandes (2010):[39] The Draft EIS states at p. 9-137 that: "The closure of the DCC gates would increase the survival of salmonid emigrants through the Delta, and the early closures would reduce loss of fish with unique and valuable life history strategies in the spring-run Chinook Salmon and Central Valley steelhead populations." However, this statement assumes fish go with flow but data on route selection suggests it is more complicated. In addition, Newman and Brandes (2010) suggest survival through Georgiana Slough is not related to exports. SWC 44

- Delaney *et al.* 2104; Zeug and Cavallo 2013; SJRGA 2013: The Draft EIS states at p. 9-137 that: "This action suite includes actions to reduce the vulnerability of emigrating steelhead within the lower San Joaquin River to entrainment into the channels of the South Delta and at the export facilities by increasing the inflow to export ratio." However, recent SWC 45

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[36] Kimmerer, W.J. 2011. Modeling Delta Smelt losses at the south Delta export facilities. San Francisco estuary and Watershed. 9(1).

[37] Maunder, M. and Deriso, R. 2011. A state-space multistage life cycle model to evaluate population impacts in the presence of density dependence illustrated with application to delta smelt (*Hyposmesus transpacifics*). *Can. J. Fish. Aquat*. Sci. 68: 1285-1306.

[38] Baxter, R., Breur, R., Brown, L., Conrad, L., Feyrer, F., Fong, S., Gehrts, K., Grimaoldo, L., Herbold, B., Hrodey, P., Mueller-Solger, A., Sommer, T., Souza, K. 2010. Interagency Ecological Program, 2010 Pelagic Organism Decline Work Plan and Synthesis of Results.

[39] Newman, K.B., Brandes, P.L. 2009. Hierarchial modeling of juveneil Chinook salmon survival as a function of Sacramento-San Joaquin delta water exports. *Northern American Journal of Fisheries Management*, 30, pp. 157-169.

studies do not show strong effect of exports and inflows on route selection although hydrodynamics are junction specific (Delaney *et al.* 2014, Zeug and Cavallo 2013). OMR flows did not appear to affect steelhead route selection (SJRGA 2013) and Delaney *et al.* (2014) showed no relationship between arrival at facilities and exports. SWC 45 continued

- SJRGA 2013, Zeug and Cavallo 2014, Buchanan *et al.* 2015: The Draft EIS states at p. 9-138 that: "This is anticipated to increase the likelihood of survival of steelhead emigrating from the San Joaquin River. Reducing the risk of diversion into the central southern Delta waterways also could increase survival of listed salmonids…." Coded wire tagging and acoustic tagging studies show survival to be reach specific for both Chinook salmon and steelhead, with recent data indicating very little difference in survival between mainstem routes and central southern Delta routes. (SJRGA 2013, Zeug and Cavallo 2014, Buchanan *et al.* 2015). SWC 46

- Cavallo *et al.* 2015, Perry *et al.* 2015: The Draft EIS states at p. 9-152 that: "Operation of the gates can have a direct effect on the entrainment rate and hence the functioning of the Sacramento River as a migratory corridor. Without the modifications to DCC gate operations to reduce loss of emigrating salmonids and green sturgeon…." Recent data suggests that gate operations do not effectively alter entrainment rate, they just change the source and location of entrainment (Cavallo *et al.* 2015, Perry *et al.* 2015). SWC 47

- SJRGA 2013 and Zeug and Cavallo 2014: The Draft EIS states at p. 9-150 that: "Under the Second Basis for Comparison in 2030, many years will have passed without seasonal limitation on OMR reverse (negative) flow rates, with the anticipated result that fish entrainment would occur at levels comparable to recent historical conditions. Future pumping would continue to expose fish to the salvage facilities and entrainment losses into the future." However, recent data on salvage from SJRGA (2013) and Zeug and Cavallo (2014) indicates that salvage may actually be reducing losses relative to mortality occurring in SJR and elsewhere in the southern Delta. SWC 48

- Delany *et al.* 2014: The Draft EIS Appendix 9L states at p. 9L-2 that: "The entrainment analysis is applicable to spring- and winter–run Chinook Salmon even though only fall- and late-fall-run Chinook Salmon were used to construct the statistical model." While the Draft EIS' assumptions indicate that the analysis developed for spring- and winter-run Chinook salmon is also applicable for fall- and late-fall-run Chinook salmon (which is itself questionable), no acknowledgement is made about the applicability of this model for steelhead and yet it is used in the effects analysis for evaluating differences in steelhead entrainment. Delaney *et al.* (2014) suggest DSM2 may not predict steelhead movement. SWC 49

- Cavallo *et al.* 2015: The Draft EIS Appendix 9J at p. 9J-5 states: "At each junction in the model, smolts move in relation to the proportional movement of flow entering each route." But this is not a valid assumption. Cavallo *et al.* (2015), reported that at 7 of 9 junctions modeled tide was dominant influence and flow had "little effect on predicted routing of salmonids." SWC 50

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- Weighted Useable Area (WUA) analysis: The Draft EIS at pp. 9-108 to 9-109 incorporates the use of WUA as one of the metrics for making comparisons of different salmonid species and life-stages for a selected set of streams and rivers between the different alternatives. It is unclear why differences in monthly average WUA of greater than 5% between alternatives is considered biologically meaningful. The use of WUA as an indicator of overall habitat (of a particular species and life stage) within a stream under different flow conditions is at best a rough approximation of the available habitat. Additionally, the magnitude of some of the WUA estimates can exceed 1.5 million (see Table C 12-2) to more than 2 million sq. feet (see Table C-10-6). Therefore, the 5 % difference in WUA to denote a biological effect attributes greater accuracy to the calculation of WUA than what can be reasonably made, and presumes a relatively tight relationship between WUA and actual fish abundance, which is typically not the case given the suite of other factors that serve to control fish populations. Moreover, it is not clear whether and how the 5% difference was ever applied. SWC 51

  Inspection of the Draft EIS sections pertaining to impacts analysis that focused on Changes in Weighted Useable Area indicates that for the majority of cases, there would be little (< 5%) to no difference in WUA amounts for all species and life stages across all alternatives. An exception to this was noted in one instance (see page 9-176)– No Action Alternative versus Second Basis of Comparison for the Sacramento River, where a > 20% difference occurred (*see* Draft EIS, at p. 9-176). However, there is no explanation provided as to what would cause this difference and even the discussion of such was confusing – "Lesser amounts in long-term average spawning WUA during September (prior to the peak spawning period) under the No Action Alternative compared to the Second Basis of Comparison would be relatively large (more than 20 percent), with smaller decreases ….." It is unclear what is actually being stated here. Clarification is needed as to why WUA was even determined or considered as one of the metrics for comparison if overall changes in river flows do not differ or only slightly differ between alternatives?

  At the same time, the results/relationships presented in the WUA-Flow tables do not appear to be the same as those presented in the source documents. For example, fall-run WUA curves for the American River depicted in Table 9E.B.10 peak at flows around 4,500 cfs; while source document (USFWS 2003) shows peak around 2,500 cfs; likewise the steelhead curve for the lower American River in Table 9E.B.11 shows peak around 4,500 cfs whereas source document shows peak around 2,500 to 2,800 cfs. Likewise the curves depicted for the Feather River for fall-run Chinook and steelhead spawning (Tables 9E.B.8 and 9) do not appear to correspond with those in the source documents (CDWR 2004); fall-run Chinook peak at 7,500 cfs in Table 9E.B.11 but around 2,000 cfs in source document (see Table 5.5-2); steelhead peak at 5,000 cfs in Table 9E.B.9 but around 1,000 cfs in the source document. The appendix needs to explain these differences.

- Lack of scientific citation: The document improperly cites policy documents and agency documents describing untested conceptual models and uses them to support important conclusions regarding entrainment risk (*i.e.*, California Resources Agency 2000 and Baxter *et al.* 2008). Draft EIS, at p. 9B-130. Examples of lack of scientific citation include but are not limited to: SWC 52

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- The Draft EIS at p. 9B-132 also states, "*Therefore, it is now thought that the Delta Smelt population decline has occurred for two basic reasons….*" There is no scientific citation for this statement. The prevailing view is that declines in species abundance are for multiple reasons, there is no agreement as to the two cited. SWC 52 continued

- The Draft EIS rejects without explanation multiple life-cycle models, all of which did not find that fall X2 is important to species abundance. Draft EIS, at p. 9-115. There is no scientific support for ignoring the weight of the evidence that does not support the 2008 FWS biological opinion's RPAs. The Draft EIS identifies Reed *et al.* (2014) as a life-cycle model, which it is not (it is the Delta Science Program's panel report on outflow and other stressors). SWC 53

- The Draft EIS states without supporting scientific citation that: "Several interrelated factors affect Coho Salmon abundance and distribution in the Trinity River. These factors include water temperature, water flow, habitat suitability, habitat availability, hatcheries, predation, competition, disease, ocean conditions, and harvest." Draft EIS, at p. 9-28. SWC 54

- The Draft EIS states without supporting scientific citation that: "Pulse flows that occur during precipitation events tend to stimulate downstream movement along the Sacramento River." Draft EIS, at p. 9-28. SWC 55

- The Draft EIS states without supporting scientific citation or data that: "Warm water temperatures stress juvenile steelhead rearing in the American River, particularly during summer and early fall." Draft EIS, at p. 9-50. SWC 56

- The Draft EIS states that: "Cunningham *et al.* (2015) found a negative influence of the export/inflow ratio on the survival of fall-run Chinook populations and a negative influence of increased total Delta exports on the survival of spring-run Chinook populations." Draft EIS, at p. 9-77. Cunningham *et al.* (2015) is missing from the reference list so this conclusion could not be verified. Moreover, the stated conclusion is in contrast to Zeug and Cavallo (2014) who analyzed 10 years of tag recoveries and showed little to no evidence that large scale exports and inflows affect ocean recoveries. SWC 57

- The Draft EIS states at pp. 9-137 to 9-138: "Historical data suggests that high San Joaquin River flows in the spring result in higher survival of out-migrating Chinook salmon smolts and greater returns of adults. The data also suggest that when the ratio between spring flows and exports increase, Chinook salmon production increases." More recent data suggests that no direct relationship between inflow and survival exists. Hydrodynamics are more complicated than suggested in the Draft EIS due to the number of covariates and high correlation between in-flow and export rate. SWC 58

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6. **The Draft EIS selectively updates the science that was contained in the BiOps finalized approximately 7 years ago, and as a result, the Draft EIS' conclusions are not based the best available science.**

SWC 59

The Draft EIS generally relies on studies that are at least 6-7 years old, often older. There are a limited number of locations where the Draft EIS cites a newer study and then it is not consistently applied.

CEQ regulations require an EIS to contain "high quality" information. Daniel R. Mandelker §10.33.20 NEPA Law and Litigation (2013 Ed.). The federal agency must "insure the professional integrity, including scientific integrity, of the discussion and analyses in environmental impact statements." 40 C.F.R. § 1502.24. "An EIS must contain an adequate compilation of relevant data and information, and must present accurate and complete information to decisionmakers to allow informed decisions." Daniel R. Mandelker, NEPA Law and Litigation, (2013 Ed.), §10.33.20, collecting cases. The CEQ regulations require "a summary of existing credible scientific evidence which is relevant to evaluating the reasonably foreseeable significant adverse impacts on the human environment." 40 C.F.R. § 1502.22.

The failure to consider up-to-date data and highly relevant literature undermines the rational basis for the Draft EIS' conclusions. The collective scientific understanding of the species and potential project-related impacts has matured since the biological opinions, and this understanding should have been reflected in the analysis and conclusions of the Draft EIS. The specific explanation for how this newer literature would change the Draft EIS' analysis is contained in the paragraphs, above, and in the proposed operational alternative, attached. Examples[40] of recent literature that the Draft EIS should have considered includes:

Acuna *et al*., Delta Science Conference, 2014.

Bennett, W.A., Burau, J.R. 2014. Riders on the storm: selective tidal movements facilitate the spawning and migration of threatened Delta Smelt in the San Francisco Estuary. *Estuaries and Coasts*. pub. online. DOI 10.1007/s12237-014-9877-3.

Buchanan, R. 2013. OCAP 2011 Steelhead Tagging Study: Statistical Methods and Results. Prepared for Bureau of Reclamation, Bay Delta Office, Sacramento CA. August 9, 2013. 109 p.

Buchanan, R. 2015. OCAP 2012 Steelhead Tagging Study: Statistical Methods and Results. Prepared for Bureau of Reclamation, Bay Delta Office, Sacramento CA. December 18, 2014. 114 p.

Buchanan, R., P. Brandes, M. Marshall, J. S. Foott, J. Ingram, D. LaPlante, T. Liedtke, and J. Israel. 2015. 2012 South Delta Chinook Salmon Survival Study: Draft report to USFWS. Ed. by P. Brandes. 139 pages.

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[40] Copies of the referenced studies are provided on a CD.

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SWC 59
continued

Buchanan, R. A., J. R. Skalski, P. L. Brandes, and A. Fuller. 2013. Route Use and Survival of Juvenile Chinook Salmon through the San Joaquin River Delta. North American Journal of Fisheries Management 33:216-229.

Buchanan, R. A., J. R. Skalski, and A. E. Giorgi. 2010. Evaluating Surrogacy of Hatchery Releases for the Performance of Wild Yearling Chinook Salmon from the Snake River Basin. North American Journal of Fisheries Management 30:1258-1269.

Bureau of Reclamation. 2007. Tracy Fish Facilities Studies, spawning, early life stages, and early life histories of the Osmerids found in the Sacramento- San Joaquin Delta of California, Vol. 38.

California Department of Water Resources. 2011a. South Delta Temporary Barriers Project: 2008 South Delta Temporary Barriers Monitoring Report. July 2011.

California Department of Water Resources. 2011b. South Delta Temporary Barriers Project: 2009 South Delta Temporary Barriers Monitoring Report. July 2011.

California Department of Water Resources. 2012. 2011 Georgiana Slough Non-physical barrier performance evaluation project report. California Department of Water Resources, Sacramento, California.

California Department of Water Resources. 2015. An Evaluation of Juvenile Salmonid Routing and Barrier Effectiveness, Predation, and Predatory Fishes at the Head of Old River, 2009–2012. April 2015.

Cavallo, B., P. Bergman, J. Melgo, K. Jones, and P. Gaskill. 2012. Status Report for 2012 Acoustic Telemetry Stipulation Study. Prepared for California Department of Water Resources. Cramer Fish Sciences, 30 p.

Cavallo, B., P. Gaskill, and J. Melgo. 2013. Investigating the influence of tides, inflows, and exports on sub-daily flow in the Sacramento-San Joaquin Delta. Cramer Fish Sciences Report. 64 pp. Available online at: http://www.fishsciences.net/reports/2013/Cavallo_et_al_Delta_Flow_Report.pdf .

Clark, K., M. Bowen, R. Mayfield, K. Zehfuss, J. Taplin, and C. Hanson. 2009. Quantification of Pre-Screen Loss of Juvenile Steelhead in Clifton Court Forebay. State of California.

Delaney, D., P. Bergman, B. Cavallo, and J. Malgo. 2014. Stipulation Study : Steelhead Movement and Survival in the South Delta with Adaptive Management of Old and Middle River Flows.

Delta Science Program Review Panel. 2010. The Vernalis Adaptive Management Program (VAMP): report of the 2010 review panel. Prepared for the Delta Science Program. p. 45.

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SWC 59
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Gordon, E., and B. Greimann. 2015. San Joaquin River Spawning Habitat Suitability Study. Pages 1415-1426 *in* Proceedings of the 3rd Joint Federal Interagency Conference on Sedimentation and Hydrologic Modeling, April 19-23, 2015, Reno, Nevada.

Grimaldo, Delta Science Conference presentation, 2014.

Harvey, B. N., D. P. Jacobson, and M. A. Banks. 2014. Quantifying the Uncertainty of a Juvenile Chinook Salmon Race Identification Method for a Mixed-Race Stock. North American Journal of Fisheries Management 34:1177-1186.

Hendrix, N., A. Criss, E. Danner, C. M. Greene, H. Imaki, A. Pike, and S. T. Lindley. 2014. Life cycle modeling framework for Sacramento River winter-run Chinook salmon. NOAA Technical Memorandum NOAA-TM-NMFS-SWFSC 530.

Hutton, P.H. Rath, J.S., Chen, L., Ungs, M.J., Roy, S.B. (*In Review*) Nine Decades of Salinity Observations in the San Francisco Bay and Delta: Modeling and Trend Evaluation. *ASCE Journal of Water Resources Planning and Management.*

Kimmerer, W. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. *San Francisco Estuary and Watershed*. 2(1).

Kimmerer, W.J. Gross, E.S., MacWilliams, M.L. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco estuary explained by variation in habitat volume? *Estuarines and Coasts*, 32, p. 375-389.

Kimmerer, W.J. 2011. Modeling Delta Smelt losses at the south Delta export facilities. San Francisco estuary and Watershed. 9(1).

Kimmerer, W.J., MacWilliams, M.L. Gross, E.S. 2013. Variation of Fish Habitat and Extent of the Low- Salinity Zone with Freshwater Flow in the San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 11(4). Available: http://scholarship.org/ic/item/3pz7x1x8.

Latour, R. 2015. Explaining patterns of pelagic fish abundance in the Sacramento-San Joaquin Delta. *Estuaries and Coasts.* Published online. DOI 10.1007/s12237-01509968-9.

Maunder, M. and Deriso, R. 2011. A state-space multistage life cycle model to evaluate population impacts in the presence of density dependence illustrated with application to delta smelt (Hyposmesus transpacifics). *Can. J. Fish. Aquat*. Sci. 68: 1285-1306.

Maunder, M.N. Deriso, R.B., Hanson, C.H. 2014. Use of state-space population dynamics models in hypothesis testing: advantages over simple log-linear regressions for modeling survival, illustrated with application to longfin smelt (*Spirinchus thaleichthys*). Fisheries Research, 164, pp. 102-111.

Merz, J.E., Hamilton, S., Bergman, P.A., Cavallo, B. 2011. Spatial perspective for delta smelt: a summary of contemporary survey data. *California Fish and Game*, 97(4), pp. 164-189.

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Merz, J.E. Bergman, P.S., Melgo, J.F., Hamilton, S. Longfin smelt: spatial dynamics and ontogeny in the San Francisco estuary, California. California Fish and Game, 99(3), pp. 122-148.

Michel, C.J. 2010. River and estuarine survival of yearling Sacramento River Chinook salmon (*Oncorhynchus tshawytscha*) smolts and the influence of environment. Master's Thesis. University of California-Santa Cruz.

Michel, C. J., A. J. Ammann, E. D. Chapman, P. T. Sandstrom, H. E. Fish, M. J. Thomas, G. P. Singer, S. T. Lindley, A. P. Klimley, and R. B. MacFarlane. 2013. The effects of environmental factors on the migratory movement patterns of Sacramento River yearling late-fall run Chinook salmon (*Oncorhynchus tshawytscha*). Environmental Biology of Fishes **96**:257-271.

Monismith, S., M. Fabrizio, M. Healey, J. Nestler, K. Rose, and J. Van Sickle. 2014. Workshop on the Interior Delta Flows And Related Stressors, Panel Summary Report.

Murphy, D., Hamilton, S. Eastward Migration or Marshward Dispersal: Exercising Survey Data to Elicit an Understanding of Seasonal Movement of Delta Smelt. 2013. *San Francisco and Estuary Watershed Science*. 11(3).

Paulsen, S. and W.-L. Chiang. 2008. Effect of Increased Flow in the San Joaquin River on Stage, Velocity, and Water Fate, Water Years 1964 and 1988. Pages 1-108.

Parker *et al.*, IEP Poster, 2014.

Perry, R. W. 2010. Survival and Migration Dynamics of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin River Delta. Ph.D. Dissertation. University of Washington.

Perry, R. W., P. L. Brandes, J. R. Burau, A. P. Klimley, B. MacFarlane, C. Michel, and J. R. Skalski. 2012a. Sensitivity of survival to migration routes used by juvenile Chinook salmon to negotiate the Sacramento-San Joaquin River Delta. Environmental Biology of Fishes **96**:381-392.

Perry, R. W., P. L. Brandes, J. R. Burau, P. T. Sandstrom, and J. R. Skalski. 2015. Effect of Tides, River Flow, and Gate Operations on Entrainment of Juvenile Salmon into the Interior Sacramento–San Joaquin River Delta. Transactions of the American Fisheries Society **144**:445-455.

Perry, R. W., J. G. Romine, A. C. Pope, N. S. Adams, A. Blake, J. R. Burau, S. Johnston, and T. Liedke. 2014a. Using acoustic telemetry to assess the effect of a floating fish guidance structure on entrainment of juvenile salmon into Georgiana Slough. Presentation at the 2014 Bay-Delta Science Conference.

Perry, R. W., J. G. Romine, N. S. Adams, A. R. Blake, J. R. Burau, S. V. Johnston, and T. L. Liedtke. 2014b. Using a Non-Physical Behavioural Barrier to Alter Migration Routing of

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Juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta. River Research and Applications **30**:192-203.

Perry, R. W., and J. R. Skalski. 2008. Migration and survival of juvenile Chinook salmon through the Sacramento-San Joaquin River Delta during the winter of 2006-2007. Report to U.S. Fish and Wildlife Services, Stockton, California. . University of Washington, Seattle, Washington.

Perry, R. W., and J. R. Skalski. 2009. Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento–San Joaquin River Delta during the Winter of 2007-2008. Report to U.S. Fish and Wildlife Services, Stockton, California. . University of Washington, Seattle, Washington.

Romine, J. G., R. W. Perry, S. J. Brewer, N. S. Adams, T. L. Liedtke, A. R. Blake, and J. R. Burau. 2013. The Regional Salmon Outmigration Study—Survival and migration routing of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta during the winter of 2008–09. U.S. Geological Survey Open-File Report 2013-1142, 36 p.

Romine, J. G., R. W. Perry, S. V. Johnston, C. W. Fitzer, and S. W. Pagliughi. 2014. Identifying when tagged fishes have been consumed by piscivorous predators: application of multivariate mixture models to movement parameters of telemetered fishes. Animal Biotelemetry **2**:3.

Sabel, M. 2014. Interactive effects of non-native predators and anthropogenic habitat alterations on native juvenile salmon. Master's thesis. University of California, Santa Cruz.

San Joaquin River Group Authority. 2013. 2011 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board in compliance with D-1641. Available at: http://www.sjrg.org/technicalreport/.

Steel, A. E., P. T. Sandstrom, P. L. Brandes, and A. P. Klimley. 2012. Migration route selection of juvenile Chinook salmon at the Delta Cross Channel, and the role of water velocity and individual movement patterns. Environmental Biology of Fishes **96**:215-224.

Stillwater Sciences. 2013. Lower Tuolumne River instream flow study. Final Report – April 2013. Prepared for Turlock Irrigation District and Modesto Irrigation District.

U.S. Army Corps of Engineers, Sacramento District. 2006. Napa River Fisheries Monitoring Program Annual Report 2005. Contract # DACW05-01-C-0015. Prepared by: Stillwater Sciences.

Vogel, D. 2010. Evaluation of Acoustic-tagged Juvenile Chinook Salmon Movements in the Sacramento - San Joaquin Delta during the 2009 Vernalis Adapted Management Plan. Natural Resource Scientists, Inc.

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Vogel, D. 2011. Evaluation of acoustic-tagged juvenile Chinook salmon and predatory fish movements in the Sacramento – San Joaquin Delta during the 2010 Vernalis Adaptive Management Program. Natural Resource Scientists, Inc. October 2011. 19 p. plus appendices.

Vogel, D. 2013. Evaluation of Fish Entrainment in 12 Unscreened Sacramento River Diversions. Final Report. Prepared for CVPIA Anadromous Fish Screen Program (U.S. Fish and Wildlife Service and U.S. Bureau of Reclamation) and Ecosystem Restoration Program (California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, and NOAA Fisheries).

Zeug, S. C. and B. J. Cavallo. 2013. Influence of estuary conditions on the recovery rate of coded-wire-tagged Chinook salmon (*Oncorhynchus tshawytscha*) in an ocean fishery. Ecology of Freshwater Fish **22**:157-168.

Zeug, S. C. and B. J. Cavallo. 2014. Controls on the entrainment of juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) into large water diversions and estimates of population-level loss. Plos One **9**:e101479.

Zeug, S. C., K. Sellheim, C. Watry, J. D. Wikert, and J. Merz. 2014. Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America. Fisheries Management and Ecology **21**:155-168.

III. THE CUMULATIVE EFFECTS ANALYSIS IS INADEQUATE

SWC 60

As the Draft EIS correctly states that a cumulative impact "is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. "Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 C.F.R. § 1508.7.) CEQ guidance on the subject explains that "cumulative effects may arise from single or multiple actions and may result in additive or interactive effects." CEQ, *Considering Cumulative Effects under the National Environmental Policy Act*, at p. 9 (1997). The CEQ guidance goes on to state that in the discussion of environmental consequences of an action, the relevant agency should implement a multi-step approach beginning with cause-and-effect relationships between stresses and environmental resources. *Id.* The agency should then assess how the resource responds to the environmental change, including by evaluating the magnitude of the effect. *Id.* Importantly, cumulative actions must be evaluated in combination because of the potential for synergistic effects of multiple actions. 40 C.F.R. § 1508.25 subd. (a)(2). The Ninth Circuit has held that all reasonably foreseeable actions that have potential impacts must be addressed. *See, e.g., Oregon Natural Resources Council Fund v. Goodman*, 505 F.3d 384 (9th Cir. 2007); *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208 (9th Cir. 1998).

Reclamation is obligated to go beyond simply identifying factors that impact environmental resources in the Daft EIS. As the CEQ guidance states:

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> Analysts must tease from complex networks of possible interactions those that substantially affect the resources. Then, they must describe the response of the resource to this environmental change using modeling, trends analysis, and scenario building when uncertainties are great.

SWC 60 continued

The cumulative effects analyses in the Draft EIS are so cursory as to be of no use to the public and agency decision-makers. The Ninth Circuit has made clear that general statements about possible effects in a cumulative effects analysis are insufficient and that the agencies are obliged, where possible, to include quantified or detailed information. *Klamath-Siskiyou Wildlands Center v. Bureau of Land Management*, 387 F.3d 989 (9th Cir. 2004).

A. The Cumulative Effects Discussion in the Draft EIS Fails to Account for Reasonably Foreseeable Water Supply Projects.

SWC 61

As noted in Chapter 5, Section III, the Draft EIS explains that under the No Action Alternative and Second Basis of Comparison, it is assumed that, on a regional scale, water demands would be met on a long-term basis and in dry and critical dry years using a combination of conservation, CVP and SWP water supplies, other imported water supplies, groundwater, recycled water, infrastructure improvements, desalination water treatment, and water transfers and exchanges. The same assumptions apply for the comparison of the No Action Alternative and Alternative 1, but there is no adequate impacts analysis of utilizing other imported supplies, groundwater pumping, additional infrastructure projects, desalination, or other means of satisfying demands. Generally, the inclusion of the projects listed in the cumulative impacts section, coupled with the assumption that these projects can reduce impacts from supply reductions, highlights the issues with the use of the 2030 projected study period, as well as the problems created by selecting an improper No Action alternative and baseline that includes the implementation of the action under review. It is difficult to discern how these projects can be assumed to be creating or ameliorating impacts of the proposed action when many of them are still in the planning and development stages. The assumption is supported only by the 2030 projected study period, but this does not excuse a failure to evaluate the cumulative effects of the actions. A discussion of the impacts of cumulative projects should be provided.

B. The Cumulative Effects Discussion in the Draft EIS Fails to Account for Known Aquatic Species Stressors.

SWC 62

The Draft EIS fails to identify important, known factors that impact environmental resources. For example, with respect to aquatic resources, even though ocean harvest is a known cause of mortality of the several runs of Chinook salmon described in chapter 9 of the Draft EIS, the cumulative effects analysis in Chapter 9 does not mention ocean harvest. Ocean harvest impacts to Chinook salmon are shown in information in Chapter 9, but not analyzed (*see, e.g.*, Table 9.2, p. 9-118). Furthermore, the National Marine Fisheries Service, in its *California Central Valley Salmon & Steelhead Recovery Plan* (2014), identified ocean harvest as one of the highest category of stressors on winter-run Chinook salmon.

The Draft EIS cumulative effects analysis also fails to identify continued enforcement of sport-fishing regulations by the California Department of Fish and Wildlife, which protect non-native black bass and striped bass, as a factor that impacts Chinook salmon. The National Marine

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SWC 62 continued

Fisheries Service has submitted a written request to the State of California to eliminate those regulations due to their deleterious effects to salmonid populations in the Central Valley, yet it was not analyzed here. The fact that predation by non-native species harms Chinook salmon populations is established in the *California Central Valley Salmon & Steelhead Recovery Plan* (2014); *see also* S.T. Lindley and M. S. Mohr, Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River Winter-run Chinook salmon (*Oncorhynchus tshawytscha*), *Fisheries Bulletin* 101:321-331 (2003).

The U.S. Army Corps of Engineers estimates its future dredging will result in entrainment in the dredging equipment of 394 to 3,694 Delta smelt each year. U.S. Army Corps of Engineers, *Draft Environmental Assessment/Environmental Impact Report for the Maintenance Dredging of the Federal Navigation Channels in San Francisco Bay, Fiscal Years 2015-2024* (2014). Here too, Reclamation is required to, but has not, described the response of Delta smelt to the losses. Reclamation is obligated to use readily available analytical tools together with best available data to conduct the cumulative effects analysis. Therefore, not only is the agency required to identify Army Corps dredging in the Bay-Delta as a factor that affects Delta smelt, Reclamation must make a good faith effort to use available data and tools to assess the magnitude of the effect on the species. The requisite analysis is cumulative, taking into consideration the additive or synergistic effects of multiple stresses on the species.

As stated in the CEQ guidance, Reclamation is required to describe the response of Delta smelt to this level of population loss using prevailing tools such as modeling and trend analysis. The agency has not fulfilled its responsibility in SWC 80 [illegible]. The problems with the cumulative effects analyses extend beyond the aquatic resourc [illegible] f the Draft EIS, as we indicated in our prior comments. The cumulative effects analyses respecting agricultural resources, groundwater resources, terrestrial species resources, and other environmental resources are similarly cursory and facially deficient.

IV. THE DRAFT EIS DISCUSSION OF THE REGULATORY ENVIRONMENT IS INACCURATE.

SWC 63

The Draft EIS does not include an accurate discussion of the regulatory environment. Appendix 3A pages 3-5 through 3-7 describe the Agreement between the United States of America and the State of California for coordinated operation of the Central Valley Project and the SWP (COA). This description is general in its nature and does not appear to accurately reflect relevant portions of the COA.

For example, the document lists as a change since 1986 new Delta standards. However, the new Delta standards do not constitute a changed condition with respect to the implementation of the COA. Article 11 provides that if new Delta standards are established and the United States determines that operation of the CVP is in conformity with the new standards is not inconsistent with Congressional directives, then Exhibit A to the COA should be amended to conform with new Delta standards. Thus, the COA anticipated and provided for the new Delta standards.

The Draft EIS also makes reference to 195,000 acre feet of SWP capacity used for exporting CVP water supply ("replacement pumping"). The document seems to incorrectly characterize this provision. The COA provides that the State will transport up to 195,000 acre feet of CVP water

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SWC 63 continued

"at times that diversions do not reduce State Water Project yield." (See COA Article 10 (b)). This replacement pumping was included in the COA as a compromise between SWP and CVP because at the time the CVP argued that it did not need to comply with SWRCB standards, like the striped bass regulations in D-1485. This compromise allowed the CVP to comply with the standard without impacts. Since that time, the CVP now acknowledges that it does need to comply with SWRCB standards. Additionally, since the COA was signed, the striped bass regulations are no longer in effect and there are new regulations related to other fish and wildlife in D-1641. The document should correctly characterize the background and COA provisions. Reclamation should correct the above inaccuracies.

V. THE DRAFT EIS FAILED TO RIGOROUSLY EXPLORE AND OBJECTIVELY EVALUATE ALL REASONABLE ALTERNATIVES AND MITIGATION MEASURES THAT COULD REDUCE THE SIGNIFICANT IMPACTS OF THE RPAS.

SWC 64

The Draft EIS failed to rigorously explore and objectively evaluate all reasonable alternatives that could mitigate the effects of the RPAs.

The alternatives analysis is the heart of an EIS. 40 C.F.R. §1502.14. Consistent with CEQ regulations, Reclamation must "[r]igorously explore and objectively evaluate all reasonable alternatives . . . ." *Id.* at 1502.14 subd. (a). The alternatives analyzed must cover "the full spectrum of alternatives." CEQ, *Forty Most Asked Questions,* 46 Fed. Reg. 18,026 (March 23, 1981). The Draft EIS falls short of this obligation. There are other reasonable alternatives that could be adopted that could both avoid jeopardy and minimize water supply impacts to the CVP and SWP water contractors. Examples of possible alternative operations are provided in Attachment 2. These proposed alternative operations could provide mitigation for the significant water supply, groundwater, and agricultural impacts associated with the RPAs. (40 C.F.R §1502.16(h) and §1502.14(f) [EIS shall include a discussion of means to mitigate adverse environmental impacts.] and [The EIS shall include a discussion of mitigation measures not already included in the proposed action or alternatives.].) The proposed alternative operation actions could be considered as a single stand-alone alternative or as a menu mitigation options that could be adopted to mitigate the negative environmental impacts of the RPAs.

SWC 65

Additionally, the Draft EIS fails to consider alternatives previously proposed by the Coalition for a Sustainable Delta (Coalition), even though those alternatives are within the full spectrum of reasonable alternatives. Reclamation has adopted an analytical approach that masks benefits associated with the Coalition's alternatives, for example, the benefit to salmonids that would result from implementation of a trap and haul program. Reclamation is required to analyze and disclose the environmental impacts of a full range of alternatives, which should include alternatives with differing operational criteria to address the Action's impacts on listed fish as well as differing non-operational criteria to accomplish the same goal.

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VI. CONCLUSION

SWC thanks Reclamation for the opportunity to review and submit comments on the Draft EIS.

Sincerely,

Stefanie Morris

Stefanie Morris
Acting General Manager

Attachments

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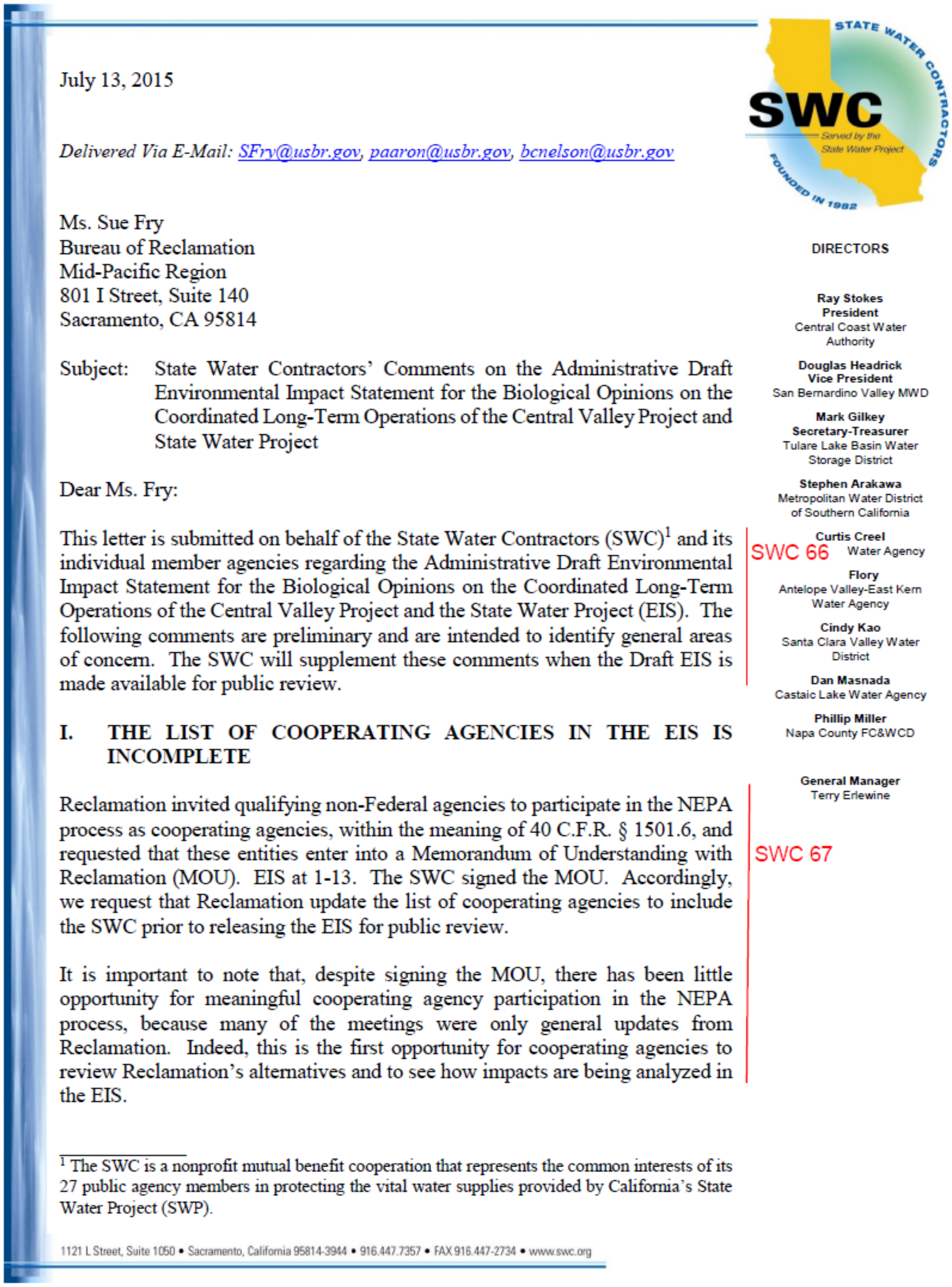
ATTACHMENT 1.
PRELIMINARY COMMENTS.



July 13, 2015

Delivered Via E-Mail: SFry@usbr.gov, paaron@usbr.gov, bcnelson@usbr.gov

Ms. Sue Fry
Bureau of Reclamation
Mid-Pacific Region
801 I Street, Suite 140
Sacramento, CA 95814

Subject: State Water Contractors' Comments on the Administrative Draft Environmental Impact Statement for the Biological Opinions on the Coordinated Long-Term Operations of the Central Valley Project and State Water Project

Dear Ms. Fry:

SWC 66

This letter is submitted on behalf of the State Water Contractors (SWC)[1] and its individual member agencies regarding the Administrative Draft Environmental Impact Statement for the Biological Opinions on the Coordinated Long-Term Operations of the Central Valley Project and the State Water Project (EIS). The following comments are preliminary and are intended to identify general areas of concern. The SWC will supplement these comments when the Draft EIS is made available for public review.

I. THE LIST OF COOPERATING AGENCIES IN THE EIS IS INCOMPLETE

SWC 67

Reclamation invited qualifying non-Federal agencies to participate in the NEPA process as cooperating agencies, within the meaning of 40 C.F.R. § 1501.6, and requested that these entities enter into a Memorandum of Understanding with Reclamation (MOU). EIS at 1-13. The SWC signed the MOU. Accordingly, we request that Reclamation update the list of cooperating agencies to include the SWC prior to releasing the EIS for public review.

It is important to note that, despite signing the MOU, there has been little opportunity for meaningful cooperating agency participation in the NEPA process, because many of the meetings were only general updates from Reclamation. Indeed, this is the first opportunity for cooperating agencies to review Reclamation's alternatives and to see how impacts are being analyzed in the EIS.

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[1] The SWC is a nonprofit mutual benefit cooperation that represents the common interests of its 27 public agency members in protecting the vital water supplies provided by California's State Water Project (SWP).

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Moreover, Reclamation has only made this EIS available for eight business days, and it has stated that it will circulate a draft for public comment on July 31, 2015. This short time-frame not only precludes cooperating agencies from providing meaningful detailed feedback, but also makes it unlikely that Reclamation will have time to address even generalized concerns before it circulates a draft for public comment. Consequently, Reclamation is likely to forego the opportunity to receive and address feedback from agencies with considerable practical, scientific, and legal expertise, which would assist Reclamation in developing the most legally adequate EIS to ensure it makes a fully informed decision. SWC 68

II. THE STATEMENT OF PURPOSE AND NEED IS UNDULY NARROW AND UNSUPPORTED

The EIS defines the Purpose of the Action to include operations of the Central Valley Project (CVP) in coordination with the operation of the SWP in a manner that "is similar to historic [sic] operational parameters with certain modifications." EIS at 2-1. This is unduly narrow because it appears to limit the alternatives range, and precludes considering potentially feasible operations that differ from the existing biological opinions. Indeed, such operational alternatives could meet Endangered Species Act (ESA) requirements while reducing adverse impacts on sensitive species, water quality, water supplies, and related indirect environmental impacts. SWC 69

III. THE ALTERNATIVES ANALYSIS IS INADEQUATE

It was improper for Reclamation to include the 2008 and 2009 reasonable and prudent alternatives (RPAs) in the No Action Alternative. See *Pit River Tribe v. U.S. Forest Service*, 469 F. 3d. 769 (9th Cir. 2006). SWC 70

The inclusion of the RPAs in the No Action Alternative inherently biases the alternatives analysis. Currently, the impact of each alternative—including Alternative 1 (the Second Basis for Comparison)—is measured against the No Action Alternative, which includes the RPAs. Reclamation used the RPAs as the analytical metric by which changes in the environment are assessed. The result is that deviations from the RPAs are identified as adverse environmental effects. That is, when existing RPAs are the benchmark against which other operational changes are measured, the operational changes are intrinsically disadvantaged. This is problematic for several reasons, not the least of which is that it biases the decision making process and significantly undermines Reclamation's obligation to take a "hard look" at the environmental effects of the Action. *Washington Crab Producers, Inc. v. Mosbacher,* 924 F.2d 1438, 1441 (9th Cir.1990).

While Reclamation may contend that inclusion of the Second Basis for Comparison remedies the issues described above, it does not. The impacts analyses' focal point is on the difference between each alternative and the No Action Alternative as described above. It is also the case because the Second Basis for Comparison purportedly excludes the RPAs, but in fact includes certain components of the RPAs, namely, Component 4 of the U.S. Fish and Wildlife Service RPA and Action I.6.1 of the National Marine Fisheries Service RPA. As a consequence, the EIS includes no analysis of the alternatives as compared to a true no action baseline that excludes implementing the RPAs. SWC 71

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IV. THE ANALYSIS OF THE ACTION'S EFFECTS ON AQUATIC SPECIES IS INADEQUATE

SWC 72

The EIS fails to include published scientific literature that has been finalized since the biological opinions. Selective reliance on analyses that have been qualified or superseded by more recent studies and the information cited in support of now nearly seven-year-old biological opinions, rather than more recent research, cannot satisfy NEPA, and could lead Reclamation to adopt an alternative that thwarts the underlying project purpose.

For example, the EIS describes Delta Smelt migrating upstream during the winter and references Sommer et al. (2011).[2] EIS at 9-65. But the EIS fails to reference or describe the implications of Murphy and Hamilton (2013), which calls into question the conclusions presented in Sommer et al. (2011). Murphy and Hamilton conducted an analysis of Delta Smelt movement across seasons and found that inter-seasonal dispersal is more circumscribed than has been previously reported. Likewise, the EIS includes extensive discussions of Delta Smelt habitat and relies on an index of such habitat developed by Feyrer et al. (2011). EIS at 9-319, 9-371, 9G-2. The EIS fails to reference or describe the implications of Manly et al. (2015), which identified significant statistical errors in Feyrer et al. 2011. When the statistical errors are corrected, it is clear that salinity (X2) alone is not a useful indicator of Delta Smelt habitat, only explaining 2.8% of the species presence. While the EIS and biological opinion are premised on the notion that the location of X2 is a defensible proxy for Delta Smelt habitat, e.g., EIS at 9-121, numerous studies (for example, Merz et al. (2011)) demonstrate that Delta Smelt occupy water with a range of salinity concentrations. Further, the EIS relies heavily on Kimmerer 2008, a modeling exercise intended to estimate entrainment that incorporated a series of assumptions, many of which were demonstrated to be upwardly bias by Miller (2011) and by Kimmerer himself in Kimmerer 2011.

Two multivariate studies of Delta Smelt and Longfin Smelt that should inform many assertions were not referenced (Maunder and Deriso 2011 and 2014). The EIS also excluded consideration of recent Longfin Smelt field studies (Parker et al, IEP poster, 2015; Grimaldo, Delta Science Conference Presentation, 2014[3]) and the Delta Smelt effective population size analysis (Cramer, IEP Science Conference, 2014). The annual independent science reviews of the implementation of the biological opinions were excluded as well. (Anderson et al. 2010, 2011, 2012, 2013, 2014.) These reviews include much pertinent information, concluding, for example:

- Five years into implementation of the RPA actions, it is not possible to determine whether the actions have been effective. *See* Anderson et al. (2011) at 22; Anderson et al. (2013) at 3; Anderson et al. (2014) at 11, 42.
- The use of particle tracking to model adult delta smelt behavior is improper. Anderson et al. (2010) at 15; Anderson et al. (2013) at 19.
- Historical levels of salvage related to Old and Middle River flows may not provide an adequate basis for setting take levels. Anderson et al. (2011) at 21.
- There is a lack of evidence for, and it is counter-intuitive that, delta smelt depend on the first flush to trigger migration. Anderson et al. (2013) at 20.

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[2] Please see Exhibit 1 (attached hereto) for a References List.

[3] Study partially funded by Reclamation.

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- The "assumed" relationship between the fall midwater trawl abundance index and the delta smelt population is "questionable at best." Anderson et al. (2013) at 26

SWC 72 continued

SWC 73

The EIS also fails to report confidence intervals associated with its results or describe the extent of uncertainty that accompanies them. e.g., EIS at App. 9G. This is of consequence because certain quantitative impacts attributable to alternatives are sufficiently small that they may be within the error bars associated with modeling results. For example, the change in proportional entrainment of adult Delta Smelt attributed to Alternative 3 as compared to the No Action Alternative is reported as 0.3 percent in Chapter 9 and 0.25 percent in Appendix 9G. This is reported as an adverse effect on Delta Smelt, EIS at 9-319, but a 0.3 change in proportional entrainment may equate to no effect because of the associated error bars. It is also important to report confidence intervals because it informs the certainty of the EIS' conclusions. See e.g., Reed et al. 2014.

The precision with which certain results are reported, such as those in Appendix 9G, contrasts the assessment – both qualitatively or quantitatively – of non-Project actions. For example, the authors state it is not possible to assess the outcomes of a predator control program. e.g., EIS at 9-323. In addition, while the authors acknowledge that a trap and haul program would benefit fall-run Chinook salmon and steelhead smolts, EIS at 9-339, they provide no qualitative or quantitative assessment of the magnitude of the benefits.

SWC 74

The EIS fails to provide a description of its analyses that can be easily interpreted. It is consistently difficult to comprehend Reclamation's analysis. By way of example, section 9.4.4.4 analyzes Alternative 3 relative to the No Action Alternative and Alternative 1. It appears impact assessment occurs region-by-region and then is broken out into sequential species-specific analyses. But even within regions, there appear to be multiple sections that address the same species. Furthermore, the discrete species-specific sections appear to be conflated. For example, the analysis of steelhead in the Sacramento River region begins at page 9-305. But beginning on page 9-307, the EIS refers to impacts to late fall-run Chinook rather than steelhead. Then on page 9-308 the analysis reverts to steelhead.

There is no explanation for how quantitative modeling results were translated into conclusions, and there is no ability to determine the biological significance of the comparative analysis. For example, the summary of effects on steelhead, presented on page 9-314, indicates that Alternative 3 would have "somewhat greater adverse effects" on the species than the No Action Alternative. It is difficult to understand what "somewhat greater" means and whether the species would perceive any difference.

The existence of numerous summaries of effects for each species makes it impossible to compare impacts associated with the alternatives. Moreover, the alternatives analysis does not address each alternative in the same level of detail, and in places it is difficult to determine if statements are describing the existing environment, one of the environmental baselines, or an alternative. These deficiencies are contrary to the NEPA mandate that EISs "be written in plain language . . . so that decision makers and the public can understand them." 40 C.F.R. § 1502.8. Thus, the relevant sections should be revised for clarity to ensure that the average layperson can readily understand Reclamation's conclusions. One critical, necessary step is to synthesize the discrete summaries of effects in order to allow for comparison among alternatives. When this is done, the syntheses should be accompanied by explanation of the relative degree of uncertainty associated with the impact assessment.

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V. THE ANALYSIS OF THE ACTION'S EFFECTS ON SURFACE WATER, WATER SUPPLIES, AND AGRICULTURAL RESOURCES IS INADEQUATE

SWC 75

The EIS includes analysis of the impacts of various alternatives on surface water, water supplies, and agricultural resources that is based on false assumptions. For example, Chapter 5 states:

> The No Action Alternative assumes that groundwater would continue to be used even if groundwater overdraft conditions continue or become worse. It is recognized that in September 2014, the Sustainable Groundwater Management Act (SGMA) was enacted. The SGMA provides for the establishment of Groundwater Sustainability Agencies (GSAs) to prepare Groundwater Sustainability Plans (GSPs) that will include best management practices for sustainable groundwater management. . . . The SGMA requires the formation of GSPs in groundwater basins or subbasins that DWR designates as medium or high priority based upon groundwater conditions identified using the CAGESM results by 2022. Sustainable groundwater operations must be achieved within 20 years following completion of the GSPs. In some areas with adjudicated groundwater basins, sustainable groundwater management could be achieved and/or maintained by 2030. However, to achieve sustainable conditions in many areas, measures could require several years to design and construct water supply facilities to replace groundwater, such as seawater desalination. Therefore, it does not appear to be reasonable and foreseeable that sustainable groundwater management would be achieved by 2030; and it is assumed that groundwater pumping will continue to be used to meet water demands not fulfilled with surface water supplies or other alternative water supplies in 2030.

EIS at 5-73-75 (emphasis added). Similarly, Chapter 12 states:

> The analysis only reduces groundwater withdrawals based upon an optimization of agricultural production costs. The analysis does not restrict groundwater withdrawals based upon groundwater overdraft or groundwater quality conditions. As described in Chapter 7, Groundwater Resources and Groundwater Quality, The Sustainable Groundwater Management Act requires preparation of Groundwater Sustainability Plans (GSPs) by 2020 or 2022 for most of the groundwater basins in the Central Valley Region. The GSPs will identify methods to implement measures that will achieve sustainable groundwater operations by 2040 or 2042. The analysis in this chapter is focused on conditions that would occur in 2030. If local agencies fully implement GSPs prior to the regulatory deadline, increasing groundwater use would be less of an option for agricultural water users. However, to achieve sustainable conditions, some measures could require several years to design and construct new water supply facilities, and sustainable groundwater conditions are not required until the 2040s. Therefore, it was assumed that Central Valley agriculture water users would not reduce groundwater use by 2030, and that groundwater use would increase in response to reduced CVP and SWP water supplies.

EIS at 12-25 (emphasis added).

The California Legislature passed historic groundwater legislation that requires groundwater managers to adopt groundwater sustainability plans that manage a groundwater basin so there are not undesirable results. Cal. Water Code § 10735.2. Undesirable results include "significant and

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unreasonable land subsidence that substantially interferes with surface land uses" and prevents basins from operating in overdraft. Cal. Water Code § 10721(w)(5). The assumption built into the EIS that any water demands not met as a consequence of restrictions imposed on operation of the CVP and SWP will be met by drawing on groundwater resources is incorrect. It allows Reclamation to mask multiple adverse impacts, including but not limited to economic impacts, associated with such restrictions. In sum, it is incorrect to assume that groundwater pumping will occur regardless of the proposed Action.

SWC 75 continued

VI. THE EIS FAILS TO ADEQUATELY DISCLOSE THE ACTION'S EFFECTS ON CLIMATE CHANGE

The EIS appears to include only a qualitative analysis of climate change, EIS at 1-12, although elsewhere the EIS suggests that a limited quantitative analysis was performed. EIS at 16-25. If the EIS does in fact quantify the Action's GHG emissions, that information is not presented clearly in the EIS. *See, generally,* EIS, Chapter 16. Since Reclamation has done global climate change modeling of project operations in other planning processes, a different approach in this document would be difficult to justify.

SWC 76

VII. THE CUMULATIVE EFFECTS ANALYSES ARE IMPERMISSIBLY GENERAL

The discussion of the cumulative impacts in the EIS is entirely cursory. For example, the EIS provides that Alternative 5 may result in decreased water storage under certain conditions, but fails to identify the extent of this impact. EIS at 5-169. Similarly, with respect to cumulative effects on groundwater resources, the EIS fails to identify the extent of impacts to groundwater levels, groundwater use and quality and subsidence, nor does it quantify such potential adverse effects. EIS at 7-171. The analysis in the EIS of cumulative effects for other resources areas suffers from the same error. *See, e.g.,* EIS Section 9.4.4.8 (Fish and Aquatic Resources); EIS Section 10.4.4.8 (Terrestrial Biological Resources); and EIS Section 12.4.4.8 (Agricultural Resources).

SWC 77

VIII. CONCLUSION

The SWC thanks Reclamation for the opportunity to review and submit comments on the EIS and look forward to continuing to work with Reclamation in further refining the EIS.

Sincerely,

Stefanie Morris

Stefanie D. Morris
Acting General Manager and General Counsel

Attachment

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Exhibit 1

References List

Anderson, J.J., R.T. Kneib, S.A. Luthy & P.E. Smith. *Report of the 2010 Independent Review Panel (IRP) on the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria and Plan (OCAP) for State/Federal Water Operations,* Delta Stewardship Council, Delta Science Program (2010).

Anderson, J.J., J.A., Gore, R.T. Kneib, M.S. Lorang & J. Van Sickle. *Report of the 2011 Independent Review Panel (IRP) on the Implementation of Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria And Plan (OCAP) for State/Federal Water Operations,* Delta Stewardship Council, Delta Science Program (2011).

Anderson, J.J., J.A., Gore, R.T. Kneib, M.S. Lorang & J. Van Sickle, *Report of the 2012 Delta Science Program Independent Review Panel (IRP) on the Long-term Operations Opinions (LOO) Annual Review,* Delta Stewardship Council, Delta Science Program (2012).

Anderson, J.J., J.A. Gore, R.T. Kneib, M.S. Lorang, J.M. Nestler & J. Van Sickle, *Report of the 2013 Delta Science Program Independent Review Panel (IRP) on the Long-term Operations Biological Opinions (LOBO) Annual Review*, Delta Stewardship Council, Delta Science Program (2013).

Anderson, J.J., J.A. Gore, R.T. Kneib, N.E. Monsen, J.M. Nestler & J. Van Sickle, *Independent Review Panel (IRP) Report for the 2014 Long-term Operations Biological Opinions (LOBO) Annual Science Review, Delta Stewardship Council, Delta Science Program* (2014).

Cramer, IEP Science Conference, 2014.

Feyrer, F, K. Newman, M. Nobriga, and T. Sommer, *Modeling the Effects of Future Freshwater Flow on the Abiotic Habitat of an Imperiled Estuarine Fish,* Estuaries and Coasts 34: 120-128 (2014).

Grimaldo, Delta Science Conference Presentation, 2014.

Kimmerer, W. J., *Losses of Sacramento River Chinook Salmon and Delta Smelt (Hypomesus transpacificus) to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta*, San Francisco Estuary and Watershed Science. Vol. 6, Issue 2 (June), Article 2 (2008).

Kimmerer, W.J. *Modeling Delta Smelt Losses at the South Delta Export Facilities*, San Francisco Estuary and Watershed, 9(1), pp. 1-9 (2011).

Manly, Bryan F.J., D. Fullerton, Albert N. Hendrix & K. Burnham. *Comments on Feyrer et al. "Modeling the effects of future outflow on the abiotic habitat of an imperiled estuarine fish"*. Estuaries and Coasts (2015). DOI: 10.1007/s12237-014-9905-3.

Maunder, M.N., and R. B. Deriso, *A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (Hyposmesus transpacificus*), Can. J. Fish. Aquat. Sci. 68: 1285–1306 (2011).

Maunder, M.N., Deriso, R.B., Hanson, C.H. *Use of state-space populations dynamics models in hypothesis testing: advantages over simple log-linear regressions for modeling survival, illustrated with application to longfin smelt (Spirinchus thaleichthys)*, Fisheries Research 164, pp. 102-111 (2015).

Merz, Joseph E., Scott Hamilton, Paul S. Bergman & Bradley Cavallo, *Spatial perspective for delta smelt: a summary of contemporary survey data*, 97(4) California Gish & Game 164-189 (2011).

Miller, William J., Bryan F. J. Manley, Dennis D. Murphy, David Fullerton & Rob Roy Ramey, *An investigation of the factors affecting the decline of delta smelt (Hypomesus transpacificus) in the San Francisco-San Joaquin estuary*, 20(1) Reviews in Fisheries Sci. 1-19 (2012).

Murphy, Dennis D., & Scott A. Hamilton, *Eastward Migration or Marshward Dispersal: Exercising Survey Data to Elicit an Understanding of Seasonal Movement of Delta Smelt*, 11(3) San Francisco Estuary & Watershed Sci. 1-20 (2013).

Parker et al, IEP poster, 2015.

Reed, D., Hollibaugh, J., Korman, J., Peebles, E., Rose, K., Smith, P., Montagna, P. *Workshop on Delta Outflows and Related Stressors, Panel Summary Report*, Delta Science Program, 2014.

Sommer, T., F. Mejia, M. Nobriga, F. Feyrer, and L. Grimaldo, *The Spawning Migration of Delta Smelt in the Upper San Francisco Estuary*, San Francisco Estuary and Watershed Science: 9(2) (2011).

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ATTACHMENT 2.
PROPOSED ACTIONS

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ATTACHMENT 2

OPERATIONS CRITERIA AND PLAN ("OCAP") ENVIRONMENTAL IMPACT STATEMENT ON BIOLOGICAL OPINION RPAS PROPOSED OPERATION ALTERNATIVES

There are feasible alternative RPAs that could be adopted that would both avoid jeopardy and minimize water supply impacts to the Central Valley Project and State Water Project ("CVP-SWP"). These alternative RPAs could provide some level of mitigation for the significant water supply impacts associated with the 2008 Delta Smelt biological opinion and the 2009 salmonid biological opinion. These alternative RPAs could be considered as a single stand-alone alternative or as a menu of mitigation options.

DELTA SMELT TURBIDITY TRIGGER (EARLY WARNING SURVEY)

Proposed Operation: The proposed operation is similar to what was done in water-year 2014-2015 as far as managing OMR based on turbidity and species presence. The modifications to the prior study effort include locating early warning monitoring stations in areas mostly south of those identified in 2014-2015, and allowing a wider range of OMR operations.

The proposed early warning monitoring stations are Bacon Island at Old River (BAC), Middle River at Holt (HLT), and Prisoner's Point (PPT). These stations are located along the route that turbidity and Delta Smelt would likely follow if they were moving toward the south Delta pumping facilities from the Sacramento River and western Delta. In most cases, these stations are also closer to the water projects than the stations used in 2014-2015, thereby providing a more meaningful indication of changing conditions in the south Delta and the risk of potential Delta Smelt entrainment. These stations also avoid concerns associated with the stations used in 2014-2015, like Holland Cut, which is heavily influenced by turbidity from Frank's Tract, rather than turbidity moving through the system from the Sacramento River; and Jersey Point which is too far removed from the water projects to be a good indicator of potential Delta Smelt entrainment.

The proposed levels of concern associated with changing conditions, and resulting potential OMR operational range, are as follows:

1.) Low concern (low turbidity and no Delta Smelt): When turbidity is below 12 NTU at all three monitoring stations (BAC, HLT, PPT) and adult Delta Smelt are not present, OMR could be between -7,500 and -5,000 based on a 14-day running average. Delta Smelt monitoring should be at PPT and at a location near Old and Middle River, possibly BAC, if feasible;

2.) Medium concern (turbidity bridge may be forming but no Delta Smelt present): Turbidity bridge may be forming as evidenced by turbidity 12 NTU or higher at two of the three monitoring stations, and Delta Smelt are not present at PPT nor a location near BAC, OMR could be between -3,000 and -5,000 based on a 14-day running average.

3.) High concern (turbidity bridge may be forming and Delta Smelt present): Turbidity bridge may be forming as evidenced by turbidity 12 NTU or higher at all three monitoring stations, and Delta Smelt are present at both PPT and a location near BAC, if feasible, and/or Delta Smelt have been identified in salvage, OMR could be between -3,000 and -2,000 based on a 14-day running average.

Each operation triggered by heightened concern would remain in effect for 10-days before conditions are reevaluated. The 10-day operational implementation period is based on the experience in 2014-2015 when turbidity after a rain event appeared to linger for about 10-days before dissipating.

This operation would apply from December through June. This operation replaces all OMR action contained in the current 2008 Delta Smelt biological opinion. The incidental-take levels identified in the 2008 Delta Smelt biological opinion would apply. Reclamation and DWR may voluntarily operate more restrictively at certain times to avoid exceeding the incidental take threshold.

Background: In 2014, Reclamation and the USFWS coordinated for several months to develop early warning surveys to provide information on adult Delta Smelt distribution to inform water-year 2015 operations. The over-all intent for the early warning surveys was to inform the agencies regarding whether, during freshets, substantial numbers of adult Delta Smelt are moving, or being moved, into areas potentially subject to entrainment. This information has helped to inform export operational decisions and allowed for flexibility in maximizing export opportunities early this year.

This action proposes that restrictions on reverse flows through the Old and Middle River (OMR) corridor be determined based on turbidity and the presence of adult Delta Smelt at Delta monitoring stations. In 2014, the four monitoring stations were Prisoner's Point, Jersey Point, Little Holland Tract, and Victoria Canal, although data from other stations may also have been considered. In general, pumping restrictions were contemplated when adult Delta Smelt were present at these locations and turbidity was at least 12 NTU and increasing. The monitoring stations could be modified to remove locations at Little Holland Tract, Jersey Point, and Victoria Island and to add new monitoring locations generally closer to the CVP-SWP pumping facilities, at Bacon Island at Old River and Middle River at Holt. The goal of the action is to avoid the creation of a turbidity bridge to the south Delta to prevent adult Delta Smelt from moving to the CVP-SWP pumping facilities. It is anticipated that this action would also result in lower larvae and juvenile salvage later in the season as turbidity is being managed to avoid drawing adult Delta Smelt into the south Delta prior to spawning.

The proposed alternative operation is based on Deriso (unpub.) 2011. See Figure 1, below. The Deriso analysis indicates that OMR could go as high as -10,000 cfs OMR when turbidity at Clifton Court is low (below 12 NTU). This proposal takes a more conservative approach the Deriso's analysis indicates is necessary by triggering changes in operation before turbidity reaches Clifton Court and also considers species distribution.

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ATTACHMENT 2

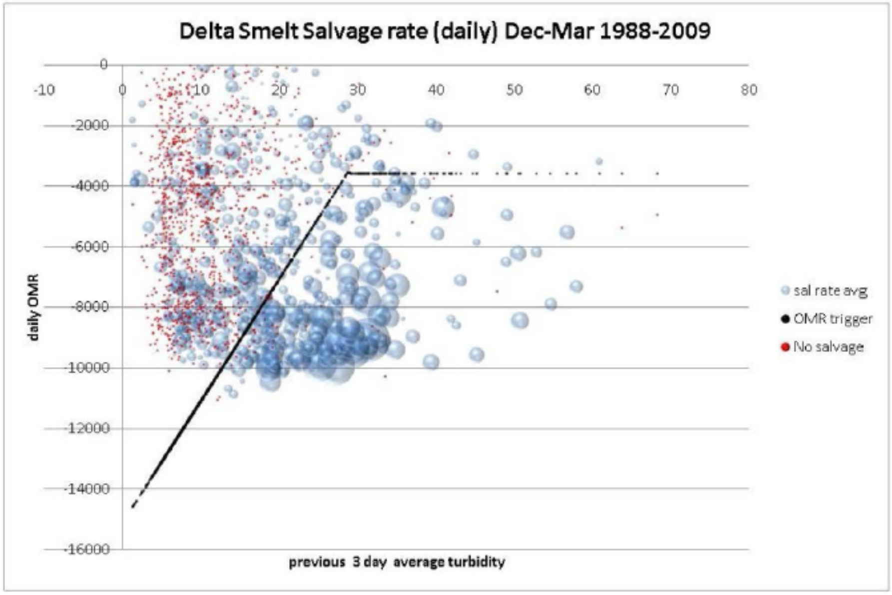

Figure 1. Delta smelt salvage rate (daily) December to March, 1988-2009. The y-axis is daily OMR flow. The x-axis is previous average turbidity of three days. The size of the bubble indicates the size of the salvage event. The red bubbles indicate no salvage event.

This operation would not be expected to jeopardize the species as the existing 2008 Delta Smelt biological opinion incidental take statement would apply. It is uncertain that entrainment, even historically, had a population level effect on Delta Smelt, except perhaps episodically. There have been multiple statistical analyses evaluating the effect of salvage on Delta Smelt abundance and the results have been disparate. The 2008 Delta Smelt biological opinion at p. 210 stated:

> The population-level effects of delta smelt entrainment vary; delta smelt entrainment can best be characterized as sporadically significant influence on populations dynamics…currently published analyses of long-term associations between delta smelt salvage and subsequent abundance do not support the hypothesis that entrainment is driving population dynamics year in and year out (Bennett 2005; Manly and Chotkowski 2006; Kimmerer 2008).

This operation would be designed to avoid sporadic entrainment events.

DELTA SMELT FALL X2 TRIGGER

Proposed Operation: This action would implement only the November Fall X2 Action as described in the 2008 FWS biological opinion as follows at p. 283,

> During any November when the preceding water year was wet or above normal as defined by the Sacramento Basin 40-30-30 index, all inflow into CVP/SWP reservoirs in the

> Sacramento Basin shall be added to reservoir releases in November to provide an additional increment of outflow from the Delta to augment Delta outflow up to the fall X2 of 74 km for Wet WY's or 81 km for Above Normal WYs, respectively. In the event there is an increase in storage during any November this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in SWRCB D-1641.

__Background__: First, a comparison of the pre-project and post-project time periods informs the question of project related effects on outflow. The data do not support the conclusion that project operations have significantly moved X2 more easterly in September and October compared to historical conditions. When the full hydrological record is considered (water years 1922-2012), Hutton *et al.* (in review), demonstrate a statistically significant trend toward a more westerly (*i.e.* fresher) X2 location in September and no statistically significant trend in October. Hutton *et al.* further explains that the full record does reveal a statistically significant trend toward a more easterly (*i.e.* saltier) X2 location in November. However, there is no statistically significant difference between pre-project (water years 1922-1967) and post-project (water years 1968-2012) November X2 position in wet and above normal water years (the water year categories targeted under the current RPA). Even though there is a statistically significant easterly trend in November X2 location using the full period of record, the cause of the trend is uncertain because there are multiple diverters in the Bay-Delta watershed of a total magnitude comparable to that of the CVP-SWP. Unless Delta Smelt response to X2 position or salinity has changed since historical conditions, then Delta Smelt should not be impacted by project operations in September and October, and only potentially impacted in November.

There is also no evidence suggesting that Delta Smelt are more sensitive to the location of X2 in the fall than they were historically (pre-project). The 2008 Delta Smelt biological opinion links X2 to the amount suitable abiotic habitat for Delta Smelt (2008 Delta Smelt biological opinion, p. 234). However, Feyrer *et al.* (2011) does not support the view that the position of X2, or the volume of the low salinity zone, is a meaningful predictor of Delta Smelt presence-absence. If salinity (X2) is not a good predictor and Delta Smelt presence-absence; then salinity (X2) is not a meaningful descriptor of Delta Smelt habitat.

Even if the volume of the low salinity zone in the spring and fall was a meaningful descriptor of Delta Smelt habitat, changes in the location of X2 are not directly linked to changes in species abundance. Kimmerer *et al.* (2013) at p.13 explains that X2, or the volume of low salinity zone, in the spring and fall are not drivers of Delta Smelt abundance and "[g]iven the difficulty in determining the controls on the delta smelt population, it is not surprising that such a simple descriptor of habitat is inadequate for this species."

Finally, Manly *et al.* (2014) reviewed Feyrer *et al.* (2011) and concluded that geography and salinity are cross-correlated and it is therefore not possible to determine which factor is most relevant to species distribution. In other words, Delta Smelt might inhabit the low salinity zone due to its proximity to productive wetland areas, or some other geographically oriented factor, irrespective of the location of the X2 isohaline, which suggests that it is highly uncertain that manipulating salinity (X2) would change species distribution or change the volume of available habitat. Manly *et al.* were not the only ones to observe that geography and salinity are highly correlated; Latour (2015) observed the same relationship and therefore only used geography in his analysis.

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ATTACHMENT 2

DELTA FLOW STANDARDS FOR SALMONIDS

The 2009 NMFS BiOp established two separate but closely related flow standards intended to be protective of juvenile salmonids in the Delta: the I:E ratio and OMR. Both of these flow metrics are predicated upon the assumption that water project operations (South Delta exports and river inflows) alter Delta hydrodynamics in ways consequential to juvenile salmonids. However, independent peer review has concluded that instantaneous velocities (not tidally averaged flows) is the key metric affecting juvenile salmondid behavior (Monismith *et al*. 2014). Yet, in most of the Delta (downstream of Stockton, San Joaquin River and downstream of Rio Vista, Sacramento River) instantaneous velocities are driven predominantly by tides, and are not appreciably influenced by water project operations (Monismith *et al*. 2014; Anderson *et al.* 2014; Cavallo *et al*. 2014, Cavallo *et al*. 2012). Instantaneous velocities are certainly altered at locations closer to the South Delta export facilities (*e.g.* south of Hwy 4), but this represents a dramatically smaller hydrodynamic footprint than was hypothesized by NMFS in their rationale for more stringent OMR and I:E flow standards specified in the 2009 salmonid biological opinion.

Some have argued the very presence of Sacramento Basin juvenile salmonids demonstrates export-altered hydrodynamics have pulled fish to the South Delta. This view is based upon the assumption that juvenile salmonids always move downstream and toward the ocean under natural conditions. In fact, juvenile salmonids are known to migrate substantial distances laterally (into off-channel habitats) or even upstream into tributaries other than those they originate from (Maslin *et al*., undated). This non-natal rearing is a strategy for juvenile salmonids seeking habitat to support further growth before reaching the ocean. Hearn *et al.* (2014), for example, studied late-fall Chinook movements in San Pablo Bay and consistently observed fish moving upstream into the Petaluma and Napa Rivers. Thus, it is not at all surprising that juvenile salmonids can be present in the South Delta regardless of export or OMR conditions.

I:E RATIO

Proposed operation: From April 1 through May 31, the Vernalis flow (cfs): CVP/SWP combined export ratio is 1:1 in all water year types. This action would adopt the critical water year operation from the 2009 salmonid biological opinion for all water-year types.

Background: As described previously, exports have little effect on instantaneous velocities in the Delta except at locations relatively close to the south Delta export facilities. As such, there is little scientific basis and no identified biological mechanism by which reduced exports as specified in the 2009 NMFS biological opinion I:E ratio could reasonably be expected to benefit juvenile salmonids in the Delta generally. The lack of a physical linkage between exports and altered Delta velocities is consistent with empirical studies looking for an effect of exports on juvenile salmonid survival. In the best available studies, researchers have not identified a negative relationship between CVP-SWP exports and out-migrating salmonid survival.[1] Newman and Brandes (2010) investigated the effect of exports on winter-run Chinook salmon surrogates using a Bayesian modeling approach and their model performed equally well regardless of whether exports were

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[1] The I:E ratio in the 2009 salmonid biological opinion was intended to protect Chinook salmon as well as steelhead. As there is limited information available to address steelhead directly, the biological opinion used Chinook salmon as a surrogate species. While it has not been determined that Chinook salmon are a good surrogate species for steelhead, this discussion adopts the same approach regarding surrogates as the biological opinion.

included in their statistical model. Newman (2008) analyzed the VAMP experimental data for San Joaquin River fall-run Chinook salmon and found a weak but positive relationship between exports and survival suggesting that CVP-SWP exports may improve survival. This outcome seems counter-intuitive but it could be explained by the recent tagging studies reported by Buchanan *et al.* (2013) which found survival was better for salmon salvaged at the CVP as compared to any other through-Delta routes, which suggests survival is not measurably improved by keeping salmonids in the San Joaquin River.

Previously identified relationships between flow and out-migrating San Joaquin River fall-run Chinook salmon survival are problematic for two reasons. First, most of these analyses have not identified where the flow-survival benefit is occurring. Given the hydrodynamic information described previously, a positive flow-survival relationship is most likely to occur in portions of the San Joaquin River where increased river flows influence instantaneous velocities. As such flow-survival benefits, if they occur, will happen upstream of the Delta or in the tidal transition zone (Head of Old River to Stockton) and outside the potential influence of export rates. There is no mechanistic basis CVP-SWP export operations (within the range of historic operations) to appreciably alter instantaneous velocities in the tidal Delta (points west of Stockton). The second problem with San Joaquin River flow and fall-run Chinook survival is that the relationship appears to have broken down in recent years. Recent tagging studies have not shown a positive relationship between San Joaquin River flow and salmonid survival in the Delta (wet years of 2006 and 2011, for example). See Figure A, below.

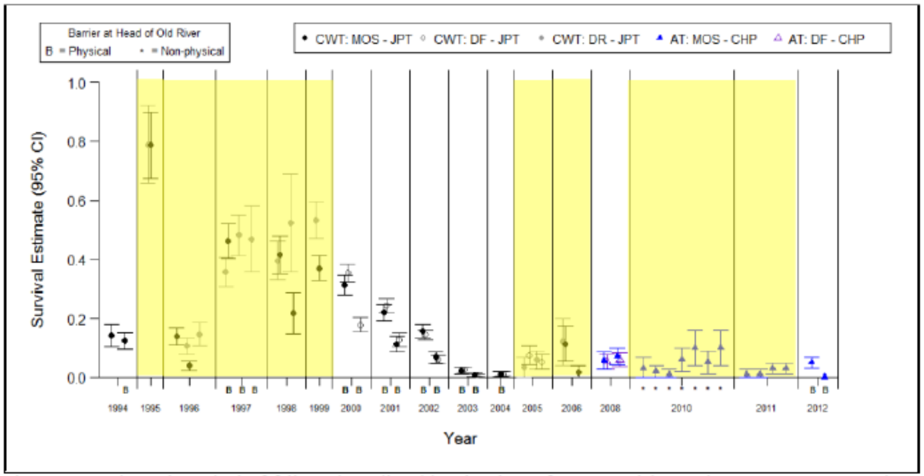

Figure A. Estimated survival of fall-run juvenile Chinook salmon from Mossdale, Durham Ferry, or Dos Reis to either Jersey Point (CWT) or Chipps Island (AT). Intervals are 95% confidence intervals. Yellow highlights indicate years with spring Vernalis flows greater than 5,000 cfs. Increased survival has not been observed with high flow events since 2000. Source: SJRGA 2013. USFWS 2014.

SALMONID OMR (JANUARY-JUNE):

Proposed Sub. Alternative A: In this alternative, Reclamation manages project operations in real-time to avoid exceeding annual incidental take thresholds for salmonids. This operation replaces all formal OMR actions and triggers in the current 2009 NMFS biological opinion. Reclamation would manage Delta Smelt OMR as described above and take any additional actions it deems necessary on a real-time basis to avoid exceeding the incidental take thresholds described in the 2009 salmonid biological opinion. Genetic testing of salvaged salmonids would be undertaken to verify race.

Proposed Sub. Alternative B: In this alternative, the proposed OMR operation would be based on identifying when ESA listed salmonids (or their surrogates) are approaching the south Delta where they are potentially vulnerable to entrainment. OMR actions would be taken when monitoring programs indicate a trigger level of juvenile salmonids are approaching the south Delta.

The early warning monitoring stations would be located in Old and Middle River corridors at two locations: 1) the north end of Bacon Island, and 2) the north end of Woodward Island. These stations would host real-time acoustic receivers capable of detecting acoustic tags in-use for studies of fish originating in the Sacramento River basin. When at least1-2% of acoustically tagged fish released at or upstream of Freeport reached the northern real-time detection arrays (i.e. Bacon Island), OMR would be reduced to approximately -5,000 cfs, on a 14-day running average. When at least 1-2% of the same release groups reached the southern real-time detection arrays (i.e. Woodward Island), OMR would be reduced to approximately -3,500 cfs, on a 14-day running average. Each OMR restriction triggered by exceedence of the 1-2% detection threshold would remain in effect for 10-days after which conditions would be re-evaluated. The 10-day trigger is based on the approximate average time period for salmonids to move through the system and is intended to facilitate juvenile salmonids exiting from the south Delta. The 1-2% of tagged fish detection threshold is intended to be conservative as salmonids identified at the proposed monitoring stations may never turn toward the CVP-SWP pumping facilities regardless of export rate.

This operation would apply from January through June (or until daily average water temperatures exceed 68°F). A minimum of 100 acoustically tagged Chinook salmon or steelhead will be present (or estimated to be present) downstream of Freeport in each of these months. When acoustically tagged fish from other studies are not available, up to 100 additional acoustically tagged fish (ESA surrogates) will be released at the beginning of each month.

Juvenile salmonids originating from the San Joaquin Basin will not be represented in this real-time monitoring effort because these fish can be expected to reach the south Delta regardless of export or OMR conditions. Thus, a meaningful pre-salvage trigger for San Joaquin Basin juvenile salmonids is not feasible. However, San Joaquin Basin fish will presumably benefit from actions triggered by acoustically tagged Sacramento Basin fish and by other management actions.

This operation replaces all OMR action contained in the current 2009 salmonid biological opinion. The annual incidental-take levels identified in the 2009 salmonid biological opinion would still apply. Reclamation and DWR may voluntarily operate more restrictively at certain times to avoid exceeding the incidental take threshold. Genetic testing of salvaged salmonids would be undertaken to verify race.

Background: As described previously, OMR is based upon tidally-averaged flows which expert review has concluded are not biologically important to juvenile salmonids. Altered instantaneous velocities which could adversely affect juvenile salmonids, could be indexed by OMR, but no such

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analysis supports existing OMR standards. In addition to there being no established linkage between OMR flows and altered instantaneous velocities, analysis of tagging data indicates OMR is not a good indicator of entrainment risk to juvenile salmonids (Zeug and Cavallo 2014). Zeug and Cavallo (2014) also demonstrate that proportional entrainment loss for winter Chinook and spring Chinook surrogates (late fall Chinook) almost never exceed 2% except when exports are greater than approximately 7,000 cf/s (200 m^3/s) [Figure B].

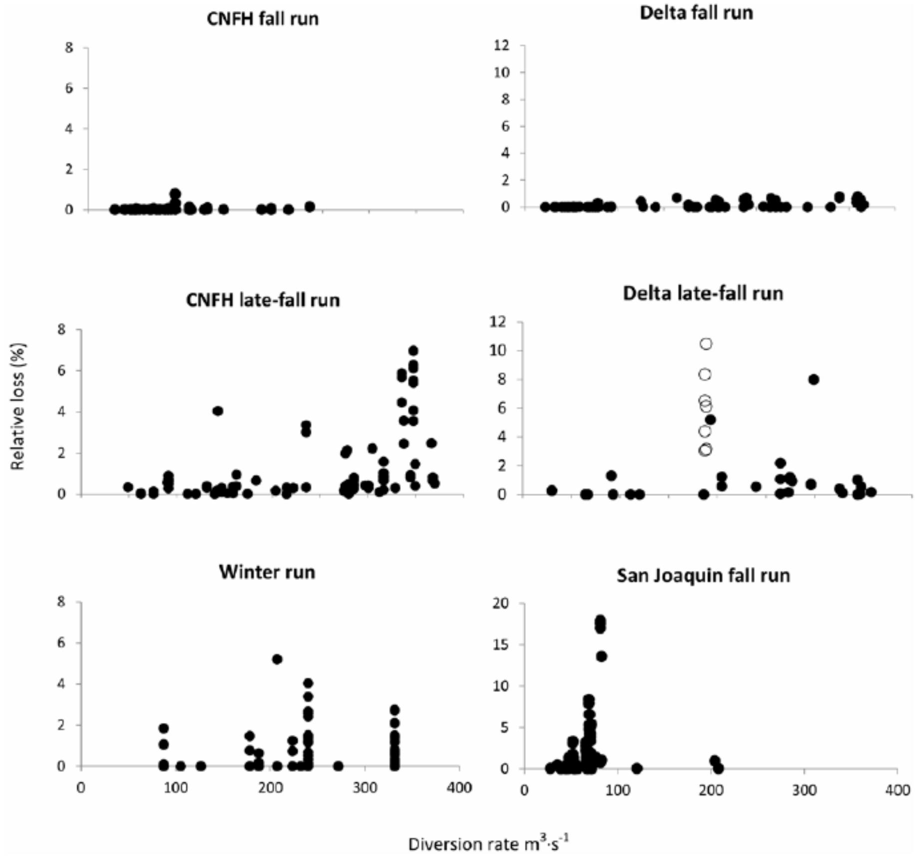

Figure B. Plot of the percentage of migration mortality accounted for by loss at the two diversions (relative loss) as a function of diversion rate for three runs of Chinook salmon released from the Coleman National Fish Hatchery (CNFH) or directly into the Delta. Open circles in the Delta late-fall run plot represent a set of releases that occurred within days of each other in 2007 and experienced unusually high loss. Note that the range of the y-axis changes among release locations. Source: Zeug and Cavallo (2014)

Despite the completion of numerous tagging studies, no evidence has been presented that suggests OMR standards are related to juvenile salmonid survival. The lack of empirical evidence for an OMR-juvenile salmonid survival relationship is the expected outcome given the absence of a clear physical linkage between OMR standards and altered Delta velocities. In addition to providing real-time protections to juvenile salmonids, this proposed operation would provide new data on the incidence, frequency and duration of Sacramento River basin juvenile salmonids approaching the south Delta in relation to OMR.

As both of the proposed sub. alternatives maintain the existing incidental take levels, these proposed sub. alternatives would be unlikely to cause jeopardy. The take limits in the existing 2009 NMFs biological opinion are 1-2% of the juvenile spring-run and winter-run entering the Delta annually; 3,000 unclipped steelhead; and 110 green sturgeon. At take levels which could occur under the proposed operation, it is unlikely the exports could appreciably influence viability or recovery. The limited reviews of the existing 2009 salmonid biological opinion supports this determination. As the recent Delta Science Program LOBO panel concluded, for example, even if the 2014 winter-run salmon JPE overestimated the total population by a factor of three, the actual take was only 4% of the annual take limit so winter-run is not likely endangered by water export operations. (Anderson *et al.* 2014.)

HEAD OF OLD RIVER BARRIER:

Proposed Operation: This action would not install the head of Old River barrier.

Background: It is uncertain whether the Head of Old River barrier ("HORB") provides protection for out-migrating salmonids. Moreover, the Fish and Wildlife Service took the position in its 2008 Delta Smelt biological opinion that the HORB was harmful to Delta Smelt. On balance, the uncertain salmonid benefit and the potential detrimental impact on Delta Smelt suggests that the HORB should not be installed.

The Delta Science Program's 2012 ("LOBO") review of the performance of the RPAs considered HORB operations. They concluded that the relative survival of smolts in Old and Middle River versus the San Joaquin River flow is about the same, supporting a conclusion that the HORB is ineffective at increasing survival. The LOBO Panel at pp. 30-31 identified several reasons why the effects of the HORB may be detrimental to smolt survival:

> There are several reasons one could reasonably speculate that the effects of the HORB were detrimental to survival of smolts. Given that the VAMP acoustic tag study results have indicated that Chinook smolt survival through the Delta is substantially greater when smolts are transported to Chipps Island from the CVP holding tank, routing smolts via the shortest river segments to the holding tank would seem the best option for protecting out-migrating salmonid smolts.
>
> The HORB inhibits passage along one of the shortest routes to the holding tanks from the upper San Joaquin watershed. Also, the HORB increases negative Old and Middle River flows and potential opportunities for smolts to become entrained along routes in the southern Delta, where survival in considerably lower.
>
> Also, it has simply been assumed that the HORB does not result in enhanced predation mortality on smolts as was shown to occur with the non-physical barrier tested in previous years. All of the calculations and recalculations of route-specific mortality on acoustic tagged smolts that resulted in increasing the number of entrained smolts required to trigger real-time decisions for adjusting water operations were all based on the assumption that the

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HORB was not associated with increased mortality from predators and other factors. Lacking evidence to the contrary, it is difficult to conclude that the HORB provided equal or greater protection for smolts.

DELTA CROSS CHANNEL GATE:

Proposed Operation (October-June): This action would operate the DCC on a daily basis. The timing of the opening of the DCC would be determined on a daily basis to coincide as closely as possible with the peak flood tide. The proposed operation would provide for a four hour gate opening to occur between the hours of 9am and 3pm. The start of the opening would be timed to maximize the peak flood tide period to the extent possible, with the mid. point of the four-hour gate opening determined each day based on forecasted tides. For example, if the peak flood tide is forecasted to occur at 12 noon, the gates would be opened from 10 am to 2 pm. If the peak flood tide is forecasted to occur at 3pm, then the gates would be opened from 11 am to 3pm.

Background: Day-night operations of the DCC gates have the potential to decrease Delta salinity and to increase water supplies south of the Delta while at the same time providing significant benefits to the Mokelumne River juvenile salmonids and protection of Sacramento River juvenile salmonids over fully open conditions. Recent acoustic telemetry studies (Plumb, *et.al. in review*; Blake and Burau, *in review*) have revealed that a majority of the acoustically tagged salmon outmigrants arrive at the DCC at night. This suggests that the gates could be closed at night when a majority of salmonids are susceptible to entrainment in the DCC and open during the day to increase the flow of Sacramento River water into the central Delta where it can be used to increase exports. The "nighttime" closures would include crepuscular periods (dawn and dusk) when fish are generally known to be more active. Thus, during this proposed experimental operation the gates would be closed at least 1 hour *before* sunset (at about 4 pm) and opened 1 hour *after* sunrise (at about 8 am). The gates would therefore be closed for at least ~16 hours each "night" out of a 24 hour day (or about 70% of the time) due to the shorter days in the winter in higher latitudes (~38 deg) in the northern hemisphere.

REFERENCES:

Anderson, J.J., Kneib, R. T., Luthy, S.A., Smith. 2010. Report of the 2010 Independent Review Panel (IRP) on the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria and Plan (OCAP) for State/Federal Water Operations. Prepared for Delta Stewardship Council, Delta Science Program. Available: http://deltacouncil.ca.gov/docs/2011-10-19/report-2010-independent-review-panel-irp-reasonable-and-prudent-alternative-rpa-acti

Anderson, J.J., Gore, A .G., Kneib, R. T., Lorang, M. S., Nestler, J. M., Van Sickle, J. 2012. Report of the 2012 Delta Science Program Independnet Review Panel (IRP) on the Long-Term Operations Opinion (LOBO) Annual Review. Prepared for Delta Science Program. Available: http://deltacouncil.ca.gov/sites/default/files/documents/files/Report_2012_DSPIRP_LOOAR_120112_final.pdf

Anderson, J.J., Gore, J.A., Kneib, R.T. Monsen, N.E., Nestler, J.M., Sickle, J.V. 2014. Independent

Review Panel (IRP) Report for the 2014 Long-Term Operations Biological Opinions (LOBO) Annual Science Review. Report for Delta Science Program.

Buchanan, R.A., Skalski J.R., Brandes, P.L., and Fuller, A. 2013. Route Use and Survival of Juvenile Chinook Salmon through the San Joaquin River Delta. *Series: North American Journal of Fisheries Management*, Vol. 33, Num. 1, Page(s): 216-229.

Cavallo, B., J. Merz, J. Setka. 2012. Effects of predator and flow manipulation on Chinook salmon (*Oncorhynchus tshawytscha*) survival in an imperiled estuary. *Environmental Biology of Fish*. Available: DOI 10.1007/s10641-012-9993-5

Cavallo, B., Gaskill, P., Melgo, J., Zueg, S.C. 2014. Predicting juvenile Chinook routing in riverine and tidal channels of a freshwater estuary. *Environmental Biology of Fishes*, 98(6): 1571-1582.

Feyrer, F., Newman, K., Nobriga, M., Sommer, T. 2011. Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish. *Estuaries and Coasts*, published online. DOI 10.1007/s12237-010-9343-9.

Hearn, A.R., Chapman, E.D., Singer, G.P., Brostoff, P.E., LaCivita, Kimley, A.P. 2014. Movements of out-migrating late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) smolts through the San Francisco Bay Estuary. Environmental Biology of Fishes, 97)8), pp. 851-863.

Hutton, P.H. Rath, J.S., Chen, L., Ungs, M.J., Roy, S.B. (*In Review*) Nine Decades of Salinity Observations in the San Francisco Bay and Delta: Modeling and Trend Evaluation. *ASCE Journal of Water Resources Planning and Management.*

Kjelson, M.A., Brandes, P.L. 1989. The Use of Smolt Survival Estimats to Quantify the Effects of Habitat Changes on Salmonid Stocks in the Sacramento-San Joaquin Rivers, California. Can. Spec. Publ. Fish Aquat. Sci. 105: 100-115.

Kimmerer, W. J. 2010. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. *San Francisco Estuary and Watershed Science*, 6(2): 1-27. Available: http://escholarship.org/ic/item/7v92h6fs.

Kimmerer, W.J., MacWilliams, M.L. Gross, E.S. 2013. Variation of Fish Habitat and Extent of the Low- Salinity Zone with Freshwater Flow in the San Francisco Estuary. *San Francisco Estuary and Watershed Science*, 11(4). Available: http://scholarship.org/ic/item/3pz7x1x8.

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to entrainment in Water Diversions in the Sacrament-San Joaquin Delta. *San Francisco Estuary and Watershed Science*, 6(2).

1

Latour, R. 2015. Explaining patterns of pelagic fish abundance in the Sacramento-San Joaquin Delta. *Estuaries and Coasts.* Published online. DOI 10.1007/s12237-01509968-9.

Manly, B.F.J., Fullerton, D., Hendrix, A.N., Burnham, K.P. 2013. Comments on Feyrer et al. "Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish." Coastal and Estuarine Research Federation. Available: DOI 10.1007/s12237-014-9905-3.

Maslin, P.E., W.R. McKinney, and T.L. Moore. Undated. Intermittent streams as rearing habitat for Sacramento River Chinook salmon. Available at: http://www.calwater.ca.gov/Admin_Record/D-022206.pdf

Monismith, S., Fabrizio, M., Healey, H., Nestler, Rose, J.K., and Van Sickle, J. 2014. Workshop on the Interior Delta Flows and Related Stressors Panel Summary Report. Delta Stewardship Council. Available: http://deltacouncil.ca.gov/sites/default/files/documents/files/Int-Flows-and-Related-Stressors-Report.pdf

Newman, K.B. 2008. An evaluation of four Sacramento-San Joaquin River Delta juvenile salmon survival studies. Report for United States Fish and Wildlife Service.

Newman K.B., and P.L. Brandes. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. *North American Journal of Fisheries Management,* 30:157-169.

San Joaquin River Group. 2011. Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP), prepared by the San Joaquin River Group Authority for the California Water Resources Control Board in compliance with D-1641.

San Joaquin River Group Authority. 2013. Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board in compliance with D 1641. Available: http://www.sjrg.org/technicalreport/.

Zeug S. and Cavallo B. 2014. Controls on the Entrainment of Juvenile Chinook Salmon (Oncorhynchus tshawytscha) into Large Water Diversions and Estimates of Population-Level Loss. *PLoS ONE* 9(7). Available: http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0101479

National Marine Fisheries Service, Southwest Region, Biological Opinion and Conference Opinion on the Long-Term Operation of the Central Valley Project and State Water Project, June 4, 2009. United States Fish and Wildlife Service, Biological Opinion on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP), 2008.

1D.1.15.1 Responses to Comments from State Water Contractors

SWC 1: Responses to comments included in the referenced the July 10, 2015 letter are provided below in the responses to Comments SWC 66 to SWC 77.

SWC 2: Please see responses to the remaining comments.

SWC 3: On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to include additional alternatives, which would require recirculation of an additional Draft EIS for public review and comment, nor does Reclamation believe additional analysis is required to constitute a sufficient EIS. Reclamation is committed to continue working toward improvements to the USFWS and NMFS RPA actions through either the adaptive management process, Collaborative Science and Adaptive Management Program (CSAMP) with the Collaborative Adaptive Management Team (CAMT), or other similar ongoing or future efforts.

SWC 4: As described in Section 3.3, Reclamation had provisionally accepted the provisions of the 2008 USFWS BO and 2009 NMFS BO, and was implementing the BOs at the time of publication of the Notice of Intent in March 2012. Under the definition of the No Action Alternative in the National Environmental Policy Act regulations (43 CFR 46.30), Reclamation's NEPA Handbook (Section 8.6), and Question 3 of the Council of Environmental Quality's Forty Most Asked Questions, the No Action Alternative could represent a future condition with "no change" from current management direction or level of management intensity, or a future "no action" conditions without implementation of the actions being evaluated in the EIS. The No Action Alternative in this EIS is consistent with the definition of "no change" from current management direction or level of management. Therefore, the RPAs were included in the No Action Alternative as Reclamation had been implementing the BOs and RPA actions, except where enjoined, as part of CVP operations for approximately three years at the time the Notice of Intent was issued (2008 USFWS BO implemented for three years and three months, 2009 NMFS BO implemented for two years and nine months).

As described in Section 3.3, Reclamation included the Second Basis of Comparison to identify changes that would occur due to actions that would not have been implemented without Reclamation's provisional acceptance of the BOs, as required by the District Court order. However, the Second Basis of Comparison is not consistent with the definition of the No Action Alternative used to develop the No Action Alternative for this EIS. Therefore, mitigation measures have not been considered for changes of alternatives as compared to the Second Basis of Comparison.

SWC 5: As described in Section 3.3.1.2 of Chapter 3, Description of Alternatives, several actions included in the 2008 USFWS BO and 2009 NMFS BO address items that were underway prior to issuance of the BOs, as summarized below.

- 2008 USFWS BO RPA Component 4, Habitat Restoration.
  - In 1987, Reclamation, DWR, CDFW, and the Suisun Resource Conservation District (SRCD) signed the Suisun Marsh Preservation Agreement (SMPA), which contains provisions for Reclamation and DWR to mitigate the adverse effects on Suisun Marsh channel water salinity from the CVP and SWP operations and other upstream diversions. The SMPA required Reclamation and DWR to prepare a timeline for implementing the Plan of Protection for the Suisun Marsh and delineate monitoring and mitigation requirements. In 2001, Reclamation, DWR, USFWS, NMFS, CDFW, SRCD, and CALFED directed the formation of a charter group to develop a plan for Suisun Marsh that would balance the needs of CALFED, the SMPA, and other plans by protecting and enhancing existing land uses, existing waterfowl and wildlife values including those associated with the Pacific Flyway, endangered species, and CVP and SWP water project supply quality. In 2014, Reclamation, CDFW, and USFWS adopted and initiated implementation of the Suisun Marsh Habitat Management, Preservation, and Restoration Plan (Suisun Marsh Management Plan). The USFWS and NMFS have issued biological opinions for the Suisun Marsh Management Plan.
  - The No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 assumes that the Suisun Marsh Management Plan will provide up to 7,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh with or without implementation of the 2008 USFWS BO. This would represent up to 87 percent (7,000 of 8,000 acres of this habitat type referenced in the 2008 USFWS BO under the No Action Alternative and Alternative 5.
- 2009 NMFS BO RPA Action I.1.3, Clear Creek Spawning Gravel Augmentation.
  - This effort was initiated in 1996 under the CVPIA Section 3406(b)(12). The Clear Creek fisheries habitat restoration program is being implemented by USFWS and Reclamation in accordance with CVPIA (Reclamation 2011a). By the year 2020 the overall goal is to provide 347,288 square feet of usable spawning habitat from Whiskeytown Dam downstream to the former McCormick-Saeltzer Dam, which is the amount that existed before construction of Whiskeytown Dam. Between 1996 and 2009, a total of approximately 130,925 tons of spawning gravel was added to the creek. The interim annual spawning gravel addition target is 25,000 tons per year, but due to a lack of funding, only an average of 9,358 tons has been placed annually since 1996 (Reclamation 2013a).
  - The No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 assume that the CVPIA program will continue through 2030.

- 2009 NMFS BO RPA Action I.1.4, Spring Creek Temperature Control Curtain Replacement.
  - In accordance with SWRCB Order 91-0, temperature control actions were initiated in the 1990s, including construction of the Spring Creek Temperature Control Curtain in 1993. The curtain was damaged and replaced as part of maintenance activities for the CVP facilities in 2011.
  - This action was completed prior to publication of the Notice of Intent for this EIS; therefore, this action is included in No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.
- 2009 NMFS BO RPA Action I.2.6, Restore Battle Creek for Winter-Run, Spring-Run, and Central Valley Steelhead.
  - The Battle Creek Salmon and Steelhead Restoration Project was initiated in the 1999 in accordance with the CVPIA Anadromous Fish Restoration Program. An Agreement in Principle was signed by Reclamation, NMFS, USFWS, CDFW, and Pacific Gas & Electric Company to pursue a restoration project for Battle Creek. A formal Memorandum of Understanding was signed in 1999 to provide funding for the program.
  - The program is consistent with provisions in the California State Salmon, Steelhead Trout, and Anadromous Fisheries Program Act (California Senate Bill 2261, 1990), CALFED Bay-Delta Ecosystem Restoration Program Plan, Upper Sacramento River Fisheries and Riparian Habitat Management Plan (developed in accordance with California Senate Bill 1086, 1989), 1990 CDFW Central Valley Salmon and Steelhead Restoration and Enhancement Plan, 1990 CDFW Steelhead Restoration Plan and Management Plan for California, 1993 CDFW Restoring Central Valley Streams: A Plan for Action, NOAA 1997 Proposed Recovery Plan for Sacramento River Winter-Run Chinook Salmon, and 1996 CDFW Actions to Restore Central Valley Spring-Run Chinook Salmon.
  - The Final EIS and the Record of Decision for the Battle Creek Salmon and Steelhead Restoration Project were completed in July 2005 and January 2009, respectively.
  - Construction was completed on the first phase in 2010. Construction will be completed prior to 2030 to reestablish approximately 42 miles of salmon and steelhead habitat on Battle Creek and an additional 6 miles of habitat on tributaries. The project includes removal of five dams, installation of new fish screens and fish ladders, provisions for increased instream flows in Battle Creek, improved access roads and trails, and decommissioned power plant canals that conveyed water between tributaries.
  - The Record of Decision and the funding agreements were completed prior to issuance of the 2009 NMFS BO. Construction was initiated prior to publication of the Notice of Intent for this EIS, and is anticipated to be

  complete before 2030. Therefore, this action is included in No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

- 2009 NMFS BO RPA Action I.3.1, Operate Red Bluff Diversion Dam with Gates Out.
  - The Final EIS and Record of Decision were completed in May 2008 for the Tehama-Colusa Canal Authority for the Tehama-Colusa Canal Fish Passage Improvement Project which included construction of the new intake at the Red Bluff Diversion Dam site and removal of the dam gates from the Sacramento River water. This action was initiated following the issuance of the 1993 NMFS BO that reduced the time that water could be diverted from the Sacramento River using the Diversion Dam gates.
  - Construction was initiated in March 2010 and funded by the 2009 American Recovery and Reinvestment Act. The new Red Bluff Pumping Plant began operation in 2012, and the gates no longer block the flow of water in the Sacramento River.
  - These existing facilities are included in No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.
- 2009 NMFS BO RPA Action I.5, Funding for CVPIA Anadromous Fish Screen Program.
  - This effort was initiated over 20 years ago under the CVPIA Section 3406(b)(21).
  - The No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 assume continued implementation of the program until the CVPIA program objectives are met which may or may not occur prior to 2030.
- 2009 NMFS BO RPA Action I.6.1, Restoration of Floodplain Habitat; and Action I.6.2, Near-Term Actions at Liberty Island/Lower Cache Slough and Lower Yolo Bypass; Action I.6.3, Lower Putah Creek Enhancements; Action I.6.4, Improvements to Lisbon Weir; and Action I.7, Reduce Migratory Delays and Loss of Salmon, Steelhead, and Sturgeon at Fremont Weir and Other Structures in the Yolo Bypass.
  - These actions are addressed in the ongoing Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan (Implementation Plan) that has been initiated by Reclamation and DWR.
  - The No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 assume completion of this Implementation Plan by 2030 with or without implementation of the 2009 NMFS BO.
  - In response to this comment, a sensitivity analysis was included in the Final EIS (Appendix 5E), that presents the results of CalSim II model runs with and without implementation of the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Implementation Plan.

- 2009 NMFS BO RPA Action II.1, Lower American River Flow Management.
  - In 2006, Reclamation began operating in accordance with the American River Flow Management Standard (FMS), as described in Appendix 3A, No Action Alternative: Central Valley Project and State Water Project Operations. The FMS operations were initiated to enhance the protections provided by SWRCB D-893 in accordance with an agreement between Reclamation, USFWS, NMFS, and CDFW.
  - The No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 assume continued operations under the FMS in 2030.

SWC 6: The EIS analyzed the alternatives at 2030 to consider full implementation of the provisions in each of the alternatives, such as completion of predation control plans in Alternatives 3 and 4 or fish passage programs in Alternative 5 and the No Action Alternative.

If the analyses were conducted at the present time, the existing conditions would include implementation of the operational provisions of the 2008 USFWS BO RPA and the 2009 NMFS BO RPA which had been provisionally accepted by Reclamation prior to the publication of the Notice of Intent in 2012.

SWC 7: Reclamation does not believe that conditions have been met for recirculation of the Draft EIS. Please see response to comment SWC 3. As described in response to Comment SWC 4, the No Action Alternative must include implementation of the 2008 USFWS BO and 2009 NMFS BO in accordance with the definition under NEPA of No Action Alternative.

SWC 8: Comment noted. Please see responses to Comments SWC 9 through SWC 59.

SWC 9: Changes in CVP and SWP water deliveries under Alternatives 1 through 5 are compared to the No Action Alternative, and changes under the No Action Alternative and Alternatives 1 through 5 are compared to the Second Basis of Comparison in Chapter 5, Surface Water Resources and Water Supplies, of the EIS. In Chapter 7, Groundwater Resources and Groundwater Quality, changes in groundwater elevations were analyzed for agricultural users related to changes in CVP and SWP water deliveries. In Chapter 12, the SWAP model was used to determine if the changes in groundwater elevations would result in land fallowing based upon economic reasons. In Chapter 19, the CWEST model was used to determine if alternative water supplies identified in urban water management plans developed by communities served by CVP and SWP water would be economical related to changes in CVP and SWP water deliveries. The alternative water supplies have been historically used during periods of reduced CVP and SWP water deliveries or have undergone analyses by communities, as described in Appendix 5D, Municipal and Industrial Water Demands and Supplies.

It should be noted that Figures 7.15 through 7.60 in Chapter 7, Groundwater Resources and Groundwater Quality, have been modified in the Final EIS to correct an error that increased the changes in groundwater elevation by a factor of 3.25. This miscalculation was due to an error in a model post-processor that generates the figures related to changing the values from CVHM Model output from meters to feet. Therefore, the results in these figures and the related text in Chapter 7 are less than reported in the Draft EIS. The figures and the text have been revised in the Final EIS. No changes are required to the CVHM model.

The revised results in the figures and the text in Chapter 7 are consistent with the findings of the SWAP model results presented in Chapter 12.

SWC 10: Projecting water transfer conditions is difficult, as described in the EIS. To analyze water transfers in detail, specific information is required to be defined by month and by water year type, including volume of transferred water, locations of the water to be transferred, locations of the delivery points for the transferred water, ability to store the transferred water in upstream reservoirs, flow limitations in the streams between the reservoirs and the Delta, timing to transfer water across the Delta (including the need to provide additional transferred water to meet water quality standards), and conveyance capacity in the Delta facilities and the downstream CVP and SWP conveyance facilities. The conveyance limitations for the CVP and SWP Delta facilities would change each month by water year and by the specific hydrologic and salinity conditions for that month in each alternative. Due to the complex nature of the CVP and SWP operations criteria in each alternative, it is not possible to only link the feasibility of water transfers to the available physical capacity in the CVP and SWP Delta facilities. Therefore, specific transfer actions were not defined or analyzed in the EIS.

The No Action Alternative in the EIS does include the current limitations for water transfers that were defined by Reclamation in the *Biological Assessment on the Continued Long-Term Operations of the Central Valley Project and the State Water Project* August 2008 document. These limitations were included in the 2008 USFWS BO and 2009 NMFS BO as the Proposed Action from the Biological Assessment. Water transfers are only undertaken with excess capacity and are not to have effects on CVP project operations. Reclamation based its proposal to limit water transfer conveyance to three months based on the general season of excess capacity, potential for demand for the transferred water, and biological and ecological factors.

SWC 11: The additional water demand in the Sacramento Valley has been identified in approved general plans and is included in the adopted urban water management plans of these communities. The increased demand are projected to be met through existing water rights in El Dorado, Nevada, Placer, and Sacramento counties and full use of CVP water contracts in Sacramento County. The water rights are senior to water rights held by Reclamation and DWR, and would need to be fulfilled in the future. Therefore, the additional water demands are included in the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

SWC 12: As described in Section 3.3, Reclamation had provisionally accepted the provisions of the 2008 USFWS BO and 2009 NMFS BO, and was implementing the BOs at the time of publication of the Notice of Intent in March 2012. Under the definition of the No Action Alternative in the National

Environmental Policy Act regulations (43 CFR 46.30), Reclamation's NEPA Handbook (Section 8.6), and Question 3 of the Council of Environmental Quality's Forty Most Asked Questions, the No Action Alternative could represent a future condition with "no change" from current management direction or level of management intensity, or a future "no action" conditions without implementation of the actions being evaluated in the EIS. The No Action Alternative in this EIS is consistent with the definition of "no change" from current management direction or level of management. Therefore, the RPAs were included in the No Action Alternative as Reclamation had been implementing the BOs and RPA actions, except where enjoined, as part of CVP operations for approximately three years at the time the Notice of Intent was issued (2008 USFWS BO implemented for three years and three months, 2009 NMFS BO implemented for two years and nine months).

As described in Section 3.3, Reclamation included the Second Basis of Comparison to identify changes that would occur due to actions that would not have been implemented without Reclamation's provisional acceptance of the BOs, as required by the District Court order. However, the Second Basis of Comparison is not consistent with the definition of the No Action Alternative used to develop the No Action Alternative for this EIS. Therefore, mitigation measures have not been considered for changes of alternatives as compared to the Second Basis of Comparison.

SWC 13: As discussed in the response to Comment SWC 9, Figures 7.15 through 7.60 in Chapter 7, Groundwater Resources and Groundwater Quality, have been modified in the Final EIS to correct an error that increased the changes in groundwater elevation by a factor of 3.25. This miscalculation was due to an error in a model post-processor that generates the figures related to changing the values from CVHM Model output from meters to feet. Therefore, the results in these figures and the related text in Chapter 7 are less than reported in the Draft EIS. The figures and the text have been revised in the Final EIS. No changes are required to the CVHM model. The revised results in the figures and the text in Chapter 7 are consistent with the findings of the SWAP model results presented in Chapter 12, Agricultural Resources.

As described in Chapter 7, the potential for and degradation of groundwater quality and land subsidence would increase with reduced groundwater elevations caused by reduced CVP and SWP water deliveries.

SWC 14: The CVHM groundwater model and SWAP agricultural economics model are regional models used in the EIS to analyze changes in Central Valley groundwater conditions and related agricultural production. Due to the regional nature of these models, specific impacts to individual farms or small locations cannot be discerned. As discussed in the EIS, it is likely that individual farms would make decisions that are different than the SWAP model projections which are based on economic optimization factors. Therefore, changes in individual farms may occur by 2030. However, regional groundwater use may change to maintain agricultural production as CVP and SWP water supplies change, as has occurred during the recent drought.

As described in Chapter 7, the potential for and degradation of groundwater quality would increase with reduced groundwater elevations caused by reduced CVP and SWP water deliveries. However, it is not anticipated that over the long-term groundwater use would change due to changes in groundwater quality by 2030.

SWC 15: Groundwater Sustainability Agencies will respond differently in the development and implementation of each Groundwater Sustainability Plan (GSP). Different regions of California will have different levels of progress depending upon ongoing programs and facilities. Depending upon the GSP, full implementation of groundwater sustainable actions may not be possible until facilities are constructed to provide replacement water supplies for current groundwater use. Construction of those facilities, following review of the GSP by DWR, could require several years for environmental review, design, permitting, and construction. Therefore, it would be speculative to assume that the GSP objectives can be fully met prior to 2030 when the GSPs have not been completed; and the implementation actions may require a timeframe longer than 2030. It is acknowledged that following full implementation of the GSPs, continued long-term overdrafting of the groundwater would not be allowed.

SWC 16: Please see response to Comment SWC 15 related to continued use of groundwater by 2030.

The EIS includes the prioritized list of groundwater basins issued by DWR in 2014. A draft revised list is currently being reviewed by DWR following the close of public comments in September 2015. Therefore, the proposed changes have not been incorporated into the Final EIS.

SWC 17: As shown in Table 19.78 and similar tables (see Tables 19.102 and 19.106), only a small share of a reduction in water supply availability is accommodated with infrastructure projects. In Table 19.106, for example, only 28,000 acre-feet out of 153,000 acre-feet reduction is new long-term supply investment. Most of the reduction in water supply is met with more groundwater pumping, water conservation, and, where local storage is available, changes in local water storage operations at the Year 2030. The costs in the tables are representative and appropriate measurements of the types and amounts of cost changes in Year 2030. These cost changes are generally very small and would not result in substantial changes.

Regarding comments related to Section 19.4.3.9.1, it is not the purpose of the EIS to analyze the costs and impacts of future water management projects included in the cumulative effects discussion. If they are developed, then they may help to reduce the economic costs and impacts of reductions in future water supplies.

SWC 18: Please see response to Comment SWC 17.

SWC 19: The SWAP model output is calculated based upon the output of several other models. The EIS impact analysis starts with use of the monthly CalSim II model to project CVP and SWP water deliveries. Results from the CalSim II model are further processed by the monthly CVHM model to project groundwater elevations. Results from the CVHM model are then used in the annual SWAP model. Because these models are using large time steps and regional geographic coverage, it was determined that changes in these models of 5 percent or less were related to the uncertainties in the model processing. Therefore, reductions of 5 percent or less in this comparative analysis are considered to be not substantially different, or "similar."

SWC 20: As described in responses to Comments SWC 13, 14, 15, and 19, increased use of groundwater is assumed to occur in 2030 if CVP and SWP water supplies are reduced. The increased cost of using additional groundwater is included in the SWAP analysis, and was determined to not result in substantial fallowing. The actual reductions in groundwater elevations considered in the SWAP model was consistent with the CVHM model output, and was less than shown in Figures 7.15 through 7.60 in Chapter 7, Groundwater Resources and Groundwater Quality, because the post-processing error was related to the preparation of the figures and not the CVHM model. As is noted in the comment, the EIS acknowledges that impacts to individual farmers may be more severe than for a region. However, the EIS is analyzing the alternatives at a regional basis. The results of the regional analysis was used to determine that there would not be any regional changes in dust generation (as described in Chapter 16, Air Quality and Greenhouse Gas Emissions) or agricultural employment (Chapter 12, Agricultural Resources).

More details have been included in Section 5.3.3 of Chapter 5, Surface Water Resources and Water Supplies, in the Final EIS to describe historical responses by CVP and SWP to recent drought conditions and associated SWRCB requirements, including reductions in recent deliveries of CVP and SWP water.

SWC 21: The analysis in Chapter 9 of the Draft EIS did not use the RPAs as metrics for comparing alternatives, although it is acknowledged that many of the same relationships in the relevant scientific literature that were used in the development of the RPAs also apply to the analysis in the DEIS such as the relationship between X2 and the abiotic habitat index for Delta smelt and the relationship between OMR flows and entrainment.

See response to Comment SWC-72 for additional discussion of Feyrer et al. (2011).

SWC 22: Text was added to Sections 9.4.1., 9.4.1.6, and 9.4.1.7 of the Draft EIS to clarify the methods used to evaluate Fish Passage, Predator Control Programs, and Ocean Salmon Harvest Restrictions, respectively.

SWC 23: The EIS includes the comparison of Alternatives 1 through 5 to the No Action Alternative enabling decision makers to compare the magnitude of environmental effects of the alternatives as compared to the No Action Alternative benchmark (in accordance with Question 3 of the CEQ Forty Most Asked Questions). The EIS analysis does not include a determination of significance thresholds or comparison of the results of impact assessment to the significance thresholds.

Text on page 108 and 110 of the Draft EIS was modified to reflect the basis for use of 5 percent change in flow and 0.5F° for temperature for identifying a change in flows and temperatures that may have an effect.

The aquatic resources models use output from the monthly CalSim II model. Because the CalSim II model uses monthly time steps and regional geographic coverage, it was determined that changes in the model output of 5 percent or less were related to the uncertainties in the model processing. Therefore, reductions of 5 percent or less in this comparative analysis are considered to be not substantially different, or "similar."

For comparison of differences within and among alternatives, qualitative descriptors were used to help put into perspective the magnitude of change for the reader. These descriptors were not intended to imply the significance of the effect. In most circumstances, these terms were followed by the actual numerical change. In making conclusions, these terms were used to describe the relative likelihood of a meaningful difference between alternatives based on the collective interpretation of multiple modeling outputs. For the NEPA analysis in the DEIS, these descriptors were not intended to be used in the ESA Section 7 context where the terms "no effect" and "likely to adversely affect" have defined meanings.

SWC 24: Please see response to Comment SWC-23. The analytical conclusions, along with the qualitative descriptors used in the analysis, were included in the summary table in Section 9.4 of Chapter 9, Fish and Aquatic Resources, for the purpose of providing a general and brief indication of the differences among alternatives. The summary table was not intended to present the logic behind the conclusions which are described within Section 9.4 subsections.

SWC 25: The box plots in Appendix 9J have the following explanation "The plus symbol indicates median, box represents the interquartile range, and the whiskers represent the minimum and maximum values." A similar explanation regarding the box-whisker plots has been added to the appropriate Appendices 9K, 9L, and 9M. No evaluation of the statistical significance of the differences in predicted metrics was conducted: however, text has been added to Section 9.4.1.3.3 and 9.4.1.3.4 regarding interpretation of the box-whisker plots presented in Appendices 9K, 9L, and 9M and used in the impacts analysis for comparison between alternatives. The interpretations of the graphs in the analysis sections of Chapter 9 have been modified for consistency.

SWC 26: The text in Chapter 9 has been modified to address the limitations and uncertainties in the references related to Delta Smelt, including references used in the development of the analytical tools used to evaluate conditions for Delta Smelt.

SWC 27: The text in Chapter 9 has been modified to address the limitations and uncertainties in the references, including references used in the development of the analytical tools.

SWC 28: The information provided in this comment suggests there is uncertainty associated with project operation and the position of fall X2 (Hutton et al.). Text in the Draft EIS (page 9-73) was revised to provide this clarification and add a reference to Hutton et al. (in press).

SWC 29: Text has been added to Appendix 9G and Chapter 9 to acknowledge the uncertainty in (1) the relationship between X2 and abundance, and (2) biological mechanisms contributing to this correlation. However, the impact analysis is unchanged because the Draft EIS is simply evaluating the potential effects on the longfin abundance using a published X2–longfin smelt relative abundance relationships developed based on the empirically observed relationships between Delta outflow and survival. The Draft EIS is not suggesting that the size and location of the winter-spring low salinity zone (LSZ) is the biological mechanism underlying the fall mid-water trawl (FMWT): January- June X2 correlation by acknowledging the uncertainties

SWC 30: Please refer to response to Comment SWC 29.

SWC 31: Please refer to response to Comment SWC 29.

SWC 32: Please refer to response to Comment SWC 29.

SWC 33: The text on page 9-67 in the Draft EIS has been modified to acknowledge the differences between the FMWT surveys and the Bay Study fish surveys.

SWC 34: The list of citations referred to in this comment were reviewed, and where appropriate, the text in the Final EIS has been modified. Additional details are provided in the response to Comment SWC 59.

SWC 35: This comment includes six specific sub-comments, but related comments on the Delta Passage Model (DPM). Each of the sub-comments are addressed individually below.

- The source documents used to develop the biological functionality of the model are too limited and result in a simplistic depiction of Delta hydrodynamics and fish biology that does not reflect current conditions. Key critical documents that address Delta hydrodynamics, fish entrainment and survival are missing including: Perry et al. 2015,[24] Cavallo et al. 2015,[25] Buchanan et al. 2015,[26] Delaney et al. 2014,[27] Zeug and Cavallo2013,[28] SJRGA 2013,[29] Buchanan et al. 2013.[30]
  - All of the documents cited in this comment have been previously examined for the potential inclusion in the DPM either within the interagency workgroup that has been evaluating the DPM or by Cramer Fish Sciences that developed the model. The paper by Perry et al. 2015 is a publication of data and relationships that appear in the dissertation by Perry (2010). The routing relationship at Georgiana Slough used in the DPM is based on the relationship that appears in Perry (2010). Thus, the Perry et al. 2015 paper contains the same information used to parameterize the DPM rather than newer information.

  - The publication by Cavallo et al. 2015 uses previous acoustic studies to develop a general model of routing at Delta junctions. However for this model to be applied in the DPM to estimate survival, there would need to be survival estimates from each junction to the exit of the Delta. Those data currently do not exist for most junctions (only Georgiana Slough, Steamboat and Sutter Slough and Head of Old River, all of which are included in the DPM).
  - Three of the referenced studies are on San Joaquin River-origin fish which were not modeled in the DPM (Buchanan et al. 2013; Buchanan et al. 2015; Delaney et al. 2014). The studies by Buchanan estimated survival of San Joaquin River-origin fall run without the inclusion of environmental covariates. These estimates are not useful for evaluating different operational scenarios because there is no quantitative linkage with flow, temperature or other parameter that could be affected by operations. The report by Delaney et al. (2014) was focused on steelhead and the DPM is a model of Chinook salmon. It is unknown to what extent steelhead and Chinook Salmon behavior are comparable. The report by the San Joaquin River Group Authority referenced in the comment (SJRGA 2013) contains the same data reported in Buchanan et al. 2013.
  - The study referenced as Zeug and Cavallo (2013) is actually Zeug and Cavallo (2014) according to the reference in the footnote. This study modeled the probability of salvage of coded wire tagged Chinook Salmon as a function of different hydrologic, physical and biological predictors. A statistical model is produced by this study as well as an estimate of the proportion of migration mortality accounted for by loss at the export facilities. However, the survival estimates used in the model already encompass this source of mortality, even though it is not specified explicitly. Thus, this proportion could be specified by the model but the value of survival would not change.
  - Although the information in Zeug and Cavallo (2014) and Cavallo et al. (2015) could not be directly integrated into the DPM, the data from these papers were used in the EIS to evaluate how routing at Delta junctions and salvage at the facilities would be affected by changed in operational scenarios. Thus, these data were integrated into the EIS.

- The DPM operates on a daily average time step using daily average flows even though this level of analysis is too course to capture flow conditions that fish experience at junctions. Cavallo et al. (2013)[31] suggest that the DSM2 model run at a spatial-temporal resolution of every 15 minutes is more consistent with the probability of flow and fish entrainment patterns.
  - The report by Cavallo et al (2013) focuses on an alternative to the Particle Tracking Method (PTM) approach of averaging hydrodynamics over a month or more to determine the fate of fish. It is likely that fish respond to instantaneous flow conditions; however, survival is not measured at those intervals which is why Cavallo et al. (2013) provided the caveated

  statement "…sub-daily flow conditions are more likely to be important for fishes with directed swimming behavior." A 24-hour roll up metric is used in the Cavallo et al. (2013) report and was the predictor of junction entrainment in Cavallo et al (2015). Thus, until survival data is available at finer time scales, the daily time step is sufficient to estimate survival and routing in a simulation framework.

- The DPM treats the Interior Delta region as a single model reach. Recent studies with acoustic tagged fish have shown significant differences in reach and junction specific hydrodynamics (Cavallo et al. 2015) as well as fish entrainment and survival (Delaney et al. 2014, Buchanan et al. 2013, SJRGA 2013). In addition, data from tagging studies in the downstream Delta reaches suggest that steelhead smolts are not simply moving with flows but may be utilizing selective tidal stream transport (Delaney et al. 2014). These data provide biological information that could be used to refine the model for the Interior Delta to incorporate separate reaches or, as an alternative, conduct a sensitivity analysis of the model to evaluate its ability to predict reach-specific entrainment and survival within the Interior Delta.
  - The studies referenced in this point cannot inform the DPM to split the interior Delta into finer scale reaches although we agree that those data would be useful to include in the model if and when they are available. The Buchanan et al. (2013) paper and SJRGA (2013) report contains the same data that found survival was different (but not statistically so) for San Joaquin origin fish entering head of Old River vs. fish remaining in the San Joaquin River at that junction. However, San Joaquin River-origin fish are not being modeled in the EIS with the DPM. Thus, although these data are important for understanding how the system functions, especially for San Joaquin River-origin Chinook salmon, they are not relevant to the current model framework. The study by Cavallo et al. (2015) reports a statistical model that describes the entrainment of acoustically tagged fish into the interior Delta as a function of the proportion of flow entering that junction. Although this information is important to understand the environmental influences on entrainment, there is no data on the survival of fish after they are entrained into individual routes. It would be possible to estimate the number of fish entering each junction but not the resulting survival. Thus, there would be no change in the value of survival calculated for each operational scenario with the DPM.
- Model documentation indicates that migration speed is modeled as a function of reach specific flow for three reaches (Sac 1, Sac 2, and GEO/DCC). No information is provided as to what data informs the migration speed for the other model reaches.
  - Only the reaches listed (Sac 1, Sac 2 and GEO/DCC) had a significant relationship between flow and migration rate. In all other reaches, migration rate is a random variable resampled every day from a

distribution informed by the mean and standard deviation of observed migration rates in each reach.

- The model uses flow to inform fish behavior at junctions and assumes proportional flow for each route except for Junction C (DCC/GEO) where a non-proportional relationship, based on acoustic data, was used. No citation is provided to facilitate an evaluation of the relationship provided at Junction C nor to understand why this is the only location where a non-proportional flow relationship is used. Cavallo et al. (2015) suggest that fish are less likely to enter a distributary channel than would be expected based on the proportion of flow entrained there. This is consistent with the other literature that suggest that fish movement patterns are influenced by other factors including diurnal fish behavior (Delaney et al. 2014), tidal cycle (Perry et al. 2015, Cavallo et al. 2015, Delaney et al. 2014, Zeug and Cavallo 2014), velocity (Perry et al. 2015, SJRGA 2013, Michel et al. 2015)32, and turbidity (Michel et al. 2015). Furthermore, Cavallo et al. (2015) lists seven junctions within the Interior Delta where the tidal cycle mediates any effects of inflows and exports on route selection. It seems prudent to suggest that the DPM should consider these data and the potential effects on route selection and if the model cannot be refined to incorporate some of the more recent relationships (e.g., Cavallo et al. 2013), then some analysis of the models sensitivity to diversion from a 1:1 fish to flow relationship is needed to evaluate the utility of the model for comparative analysis.
  - At Junction C (Georgiana Slough) the relationship between flow entering the interior delta and fish entering the interior delta was taken directly from Perry (2010). This is the only junction where formal statistical modeling has been performed to link hydrodynamics and entrainment of Chinook salmon at the scale of individual fish and conditions at the time that individual arrived at the junction. These are the same data that appear in Perry et al. (2015). The data in Michel et al. 2015 do not address junction entrainment. Delaney et al. (2014) is a study of steelhead rather than Chinook and it is unknown to what extent the behavior of these two species is similar. The paper by Zeug and Cavallo 2014 does not address junction entrainment but entrainment of coded wire tagged fish at the export facilities. The paper by Cavallo et al. (2015) indicates that inflow and exports are less important at tidally dominated junctions relative to junctions primarily under riverine influence. However, the junctions in the DPM are all riverine dominated including: Yolo Bypass and Sacramento River, Sutter-Steamboat and Sacramento River and Georgiana Slough/DCC and the Sacramento River. Within a comparative framework, the relative difference between scenarios would be the same because the same relationship would be applied under both scenarios. However, the estimate value of entrainment and through delta survival would vary.
- Model documentation indicates that reach specific survival is predicted using daily flow for seven reaches (Sac 1, 2, 3, 4, SS, Interior Delta via SJR, Interior

Delta via OR) and exports for one reach (Interior Delta via GEO/DCC). Only the GEO/DCC and Yolo reaches are informed by means and standard deviations from survival studies. Yet, some authors have reviewed years of data and failed to demonstrate a relationship between hydrodynamics and survival (Zeug and Cavallo 2014)33, or exports and survival (Delaney et al. 2014) and have suggested that there is no one hydrodynamic metric that can characterizes all patterns in the Delta. These researchers (Zeug and Cavallo 2014) as well as Michel (2010) have demonstrated that other environmental factors, independent of inflow and exports, affect salmonid survival to the ocean including select water quality parameters, temperature, and fish size.

– There remains considerable uncertainty in the relationship between hydrodynamics and survival in the Delta. However, the flow-survival relationships in the DPM are based on rigorous statistical analyses of acoustically tagged Chinook salmon smolts performed by Perry (2010) and the export-survival relationship is based on a peer-reviewed study by Newman and Brandes (2010). Both of these relationships contain variation that is characterized in the model and included through the Monte Carlo resampling. As more information is produced on these relationships, the model will need to be updated. However, the referenced studies are not able to inform the model in its current form. The study by Zeug and Cavallo (2014) did not address survival of Chinook Salmon through the Delta but rather the correlates of salvage at the export facilities and estimated loss of CWT release groups. The Michel (2010) study examined survival through the entire Sacramento River from Coleman National Fish Hatchery to the Golden Gate. Therefore, the EIS did not specifically evaluate flow-survival relationships in the Delta.

SWC 36: In response to this comment, additional information on the differences between Kimmerer (2008, 2011) and Miller (2011) was added to Appendix 9G.

With respect to the biases identified by Miller (2011) in Kimmerer (2008), Kimmerer (2011) only adjusted one of his assumptions slightly in response to Miller (2011) in his modeling exercise for proportional entrainment. This adjustment did not change the conclusions from his earlier paper.

SWC 37: This appears to be a comment on an earlier draft of the EIS. The referenced quote was not in the Draft EIS. Additional text has been added to pages 194 and 247 in the Draft EIS in the Final EIS to clarify the conclusions of Feyrer et al. (2010).

SWC 38: The text referred to in this comment has been modified in the Final EIS to delete the Moyle (2002) reference to salinity and to include distribution information as in Merz et al. (2011).

SWC 39: Although Feyrer et al. (2007) found that higher values of the habitat index (i.e., X2 west of confluence) were associated with greater relative abundance of juvenile Delta smelt, Kimmerer et al. (2013) found that there was no consistent relationship between salinity-based habitat area and abundance.

SWC 40: The text referred to in this comment incorrectly attributed the information to Kimmerer (2011), and has been deleted from the Final EIS.

SWC 41: The text referred to in this comment is intended as a broad statement regarding the factors that have contributed to a decline in the ability of the Delta to support Delta Smelt. The statement suggests that the cause is related to changes in multiple physical and biological factors. This broad statement inherently conveys uncertainty and the references are intended to provide examples of some of the factors that may contribute to the decline. The text in Appendix 9B was revised to reflect the uncertainty.

SWC 42: The text referred to in this comment on pages 9-64 and 9-115 has been modified in the Final EIS.

SWC 43: The text on page 137 of the Draft EIS was revised in the Final EIS to clarify scientific uncertainty.

SWC 44: The text on page 137 of the Draft EIS was revised in the Final EIS to clarify scientific uncertainty.

SWC 45: The text on page 137 of the Draft EIS was revised in the Final EIS to clarify scientific uncertainty.

SWC 46: A summary of Perry et al. (2015) has been added to the Final EIS on page 9-77 and incorporated as appropriate into Appendix 9B. The Cavallo et al. (2015) paper does not evaluate Delta Cross Channel gate operations; therefore, it is used in this context.

SWC 47: The Final EIS has been modified by adding a summary of Perry et al. (2015) within the text on page 9-77 of the Draft EIS and in Appendix 9B. The Cavallo et al. (2015) paper does not evaluate Delta Cross Channel gate operations.

SWC 48: The text on page 150 of the Draft EIS was revised in the Final EIS to clarify scientific uncertainty.

SWC 49: The junction analysis is only applicable to Chinook Salmon and should not have been used in the analysis of effects on steelhead. Therefore, this analysis was removed from the appropriate sections of Chapter 9.

Delaney et al. (2014) suggested that the DSM2 Hydro Particle Tracking Model (PTM) was not able to predict the movement of steelhead tags. The PTM was not used for the junction analysis.

SWC 50: The paper by Cavallo et al. (2015) indicates that inflow and exports are less important at tidally dominated junctions relative to junctions primarily under riverine influence. However, the junctions in the DPM (Appendix 9J) are all riverine dominated including: Yolo Bypass and Sacramento River, Sutter-Steamboat and Sacramento River and Georgiana Slough/DCC and the Sacramento River. Within a comparative framework, the relative difference between scenarios would be the same because the same relationship would be applied under both scenarios. However, the estimate value of entrainment and through delta survival would vary.

SWC 51: The 5 percent difference criterion used in the EIS is consistent with the uncertainty considerations in the CalSim II model which provides the input values to the Weighted Useable Area (WUA) model. The text on pages 9-108 and 9-109 of the Draft EIS has been modified to remove the reference to "biologically meaningful" and more rightly attribute the use of a 5 percent difference as the minimum difference that can be reasonably differentiated given the resolution of the CalSim II model and the subsequent calculation of WUA.

Even though WUA represents a "rough approximation of the available habitat" its use as a metric for describing potential differences in habitat availability between alternatives is appropriate because the magnitude of the WUA estimate is irrelevant when looking at relative differences. It is true that the magnitude of the WUA estimates is substantial (more than 2 million square feet); however, use of WUA and the 5 percent criterion for describing relative differences between alternatives is appropriate. No attempt is made to relate WUA to actual fish abundance.

The similarity (5 percent or less) in WUA amounts have been determined for all species and life stages across all alternatives, as noted in the comment. This is largely due to the small differences in flow predicted between alternatives. While WUA is related to flow, the form of the WUA relationship is such that even small changes in flow may result in large changes in WUA. Therefore, WUA was selected as a more appropriate metric for describing potential changes in habitat than flow changes. The text on page 9-176 has been modified.

The relationships presented in the WUA-Flow tables in Appendix 9E have been modified. Tables 9E.B.8, 9E.B.9, 9E.B.10, and 9E.B.11 have been revised to reflect the relationships in the appropriate source documents. The WUA analysis used the correct WUA relationships, and no changes to the analysis are required.

SWC 52: Although the conceptual models identified in California Resources Agency (2007 sic) and Baxter et al. (2008) are untested, they are based on numerous scientific investigations and field data. However, a discussion of entrainment is not appropriate in the life history discussion presented in Appendix 9B and this paragraph has been removed. The text on page 9B-132 of the Draft EIS identified in the comment has now been correctly attributed to USFWS (2012). Support for this conclusion is provided in the paragraphs following the statement.

SWC 53: The reference to Reed et al (2014) was included as a supportive reference to support not using a life cycle model, as noted on page 9-115 of the Draft EIS. The text has been modified to avoid confusion.

SWC 54: The list of factors affecting SONCC Coho Salmon on page 9-13 of the Draft EIS has been updated and expanded in the Final EIS with a citation to the 2014 Recovery Plan for the ESU.

SWC 55: The text on page 9-28 in the Draft EIS regarding movement has been revised in the Final EIS to include data on movement from Snider and Titus

(1998, 2000b, c, d); Vincik et al. (2006); and (Roberts 2007). The sentence on pulse flows has been removed from the Final EIS.

SWC 56: Citations supporting the statement on page 9-50 of the Draft EIS referred to in this comment have been added to the Final EIS.

SWC-57: The text on page 9-78 of the Draft EIS was modified in the Final EIS to describe methods used to quantify effects on exports on salmonid survival through the inclusion of Cunningham et al. (2015). A reference to Zeug and Cavallo (2012) also was included in the Final EIS to discuss the contrasting approaches and results.

SWC-58: The text has been modified in the Final EIS to include a discussion of recent evidence that suggests that there is a relationship between survival and exports and inflows (Cunningham et al. (2015). A reference to Zeug and Cavallo (2012) also was included in the Final EIS to discuss the contrasting approaches and results.

SWC 59: The references included in this comment have been reviewed, and where appropriate, the text in Section 9.3 of Chapter 9, Fish and Aquatic Resources, has been modified in the Final EIS.

SWC 60: Please see responses to Comments SWC 61 and 62 for response to this comment.

SWC 61: The cumulative effects analysis in Chapters 5 through 21 have been modified in the Final EIS to provide more clarity.

SWC 62: Text has been added to the cumulative effects discussion in Chapter 9, Fish and Aquatic Resources, to provide more clarity related to stressors on aquatic resources.

Please see response to Comment SWC 61.

SWC 63: The Coordinated Operation Agreement (COA) between the United States and the State of California was authorized by Congress in Public Law 99-546 and signed in 1986. Reclamation has reviewed the sections of the document discussing the COA and has modified the text where appropriate. However, as a general matter, Reclamation does not believe that the characterization of the provisions of the COA is inaccurate.

SWC 64: On October 9, 2015, the District Court granted a very short time extension to address comments received during the public review period, and requires Reclamation to issue a Record of Decision on or before January 12, 2016. This current court ordered schedule does not provide sufficient time for Reclamation to include additional alternatives, which would require recirculation of an additional Draft EIS for public review and comment, nor does Reclamation believe additional analysis is required to constitute a sufficient EIS. Reclamation is committed to continue working toward improvements to the USFWS and NMFS RPA actions through either the adaptive management process, Collaborative Science and Adaptive Management Program

(CSAMP) with the Collaborative Adaptive Management Team (CAMT), or other similar ongoing or future efforts.

SWC 65: As described in Section 3.4.2 of Chapter 3, Description of Alternatives, of the EIS, actions suggested by the Coalition for a Sustainable Delta were included in Alternatives 3 and 4. Two suggested actions were not included in Alternatives 3 or 4 for the following reasons.

- Accelerate the timing of upgrades at the Sacramento Regional Wastewater Treatment Plant from 2020 to 2017: This action is currently under construction to be fully completed prior to 2030. Therefore, these upgrades would be completed by 2030 under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. Because the EIS analysis is conducted at 2030, accelerating the completion of these actions would not change conditions at 2030.
- The limited water supply available to Reclamation on the Stanislaus River through water rights associated with the New Melones Reservoir are fully committed to multiple beneficial uses, including those on the Stanislaus River. The Vernalis Adaptive Management Program allowed for additional sources of water, other than available water within New Melones Reservoir to be used to maintain flow in the San Joaquin River. After the completion of this program, Reclamation does not have sufficient supply available in New Melones Reservoir to meet inflow targets suggested by CSD. Therefore, the I:E ratio can only be met through export limitations, and not through releases from New Melones Reservoir.

SWC 66: Comment noted.

SWC 67: The text in Section 23.4 of Chapter 23, Consultation and Coordination, of the Draft EIS included a discussion of the inclusion of the State Water Contractors and several other interest groups in the preparation of the EIS. However, these entities were not considered to be NEPA Cooperating Agencies because they are not public agencies, as required by NEPA (see 40 CFR 1508.5).

SWC 68: At the time of the review of the Administrative Draft EIS, the Amended Judgement dated September 30, 2014 issued by the United States District Court for the Eastern District of California (District Court) in the *Consolidated Delta Smelt Cases* required Reclamation to issue a Record of Decision by no later than December 1, 2015. Due to this requirement, Reclamation did not have sufficient time to extend the review period.

SWC 69: Reclamation was directed by the District Court to remedy its failure to conduct a NEPA analysis when it accepted and implemented the 2008 USFWS BO RPA and the 2009 NMFS BO RPA pursuant to the Federal Endangered Species Act of 1973 (ESA) as amended (United States Code [U.S.C.] 1531 et. seq.). In order to satisfy the Court's directive, Reclamation has analyzed operation of the CVP, in coordination with the operation of the SWP, consistent with the BOs, as well as alternatives which represent potential modifications to the continued long-term operation of the CVP in coordination with the SWP.

The purpose of the action, as described in Chapter 2, Purpose and Need, considers the purposes for which the CVP was authorized, as amended by CVPIA, as well as the regulatory limitations on CVP operations, including applicable state and federal laws and water rights. This purpose statement does not limit the analysis of the range of alternatives which includes alternatives with CVP and SWP operational assumptions substantially different than historic operational parameters.

SWC 70: As described in Section 3.3, Reclamation had provisionally accepted the provisions of the 2008 USFWS BO and 2009 NMFS BO, and was implementing the BOs at the time of publication of the Notice of Intent in March 2012. Under the definition of the No Action Alternative in the National Environmental Policy Act regulations (43 CFR 46.30), Reclamation's NEPA Handbook (Section 8.6), and Question 3 of the Council of Environmental Quality's Forty Most Asked Questions, the No Action Alternative could represent a future condition with "no change" from current management direction or level of management intensity, or a future "no action" conditions without implementation of the actions being evaluated in the EIS. The No Action Alternative in this EIS is consistent with the definition of "no change" from current management direction or level of management. Therefore, the RPAs were included in the No Action Alternative as Reclamation had been implementing the BOs and RPA actions, except where enjoined, as part of CVP operations for approximately three years at the time the Notice of Intent was issued (2008 USFWS BO implemented for three years and three months, 2009 NMFS BO implemented for two years and nine months).

As described in Section 3.3, Reclamation included the Second Basis of Comparison to identify changes that would occur due to actions that would not have been implemented without Reclamation's provisional acceptance of the BOs, as required by the District Court order. However, the Second Basis of Comparison is not consistent with the definition of the No Action Alternative used to develop the No Action Alternative for this EIS. Therefore, mitigation measures have not been considered for changes of alternatives as compared to the Second Basis of Comparison.

SWC 71: Please see response to Comment SWC 5.

SWC 72: In response to criticism of Feyrer et al. (2011) in Manly et al. (2015), Feyrer et al. (2015) agree that conductivity and secchi depth alone could not match observed proportions of delta smelt in certain regions as well as those variable and the 13 regional indicator variables constructed in Manly's paper could. However, they point out that dividing the Delta into 13 arbitrarily determined regions does not provide any insight into what other factors that affect Delta Smelt proportional abundance might be, and without support from a particular hypothesis, lead to mechanistically uninterpretable results that provide no insight for how climate change or other ecological processes might affect Delta Smelt distribution and abundance. While Delta Smelt can tolerate a range of salinities, there is a general consensus that the centroid of the population tends to be associated with the low salinity zone (Sommer et al. 2011). Murphy and

Hamilton (2013) do not convincingly refute the eastward migration of Delta Smelt pre-spawn movements. Their maps (Figures 3-6) lack resolution because they only contrast stations that collectively represent 90 percent of the catch to stations that collectively represent 9 percent of the catch. Thus, it is impossible to see proportional shifts in the population from their analysis. With respect to the biases identified by Miller (2011) in Kimmerer (2008), Kimmerer (2011) only adjusted one of his assumptions slightly in response to Miller (2011) in his modeling exercise for proportional entrainment. This adjustment did not change the conclusions from his earlier paper.

It is not clear from the comment which assertions should have been referencing Maunder and Deriso (2011 and 2014). And it is also not clear in what context the longfin smelt studies identified in poster and oral conference presentations should be mentioned. The effective population size analysis for Delta Smelt had wide confidence intervals and is undergoing further investigation by its authors.

The relevance of the independent science reviews of the RPA actions was considered. The findings are noted as information that indicates the uncertainties of the ongoing science and the need for continuation of the adaptive management process, and the Collaborative Science and Adaptive Management Program (CSAMP) with the Collaborative Adaptive Management Team (CAMT).

SWC 73: This was a comment on the Administrative Draft EIS, but has relevance to review of the Draft EIS when specific comments were not fully addressed by the changes made in the Draft EIS.

A change of greater than 5 percent in entrainment was considered substantial. It was concluded in Chapter 9, Fish and Aquatic Resources, that entrainment under Alternative 3 and the No Action Alternative would be similar.

The tables in Appendix 9G did not include rounded numbers as intended, and has been updated in the Final EIS.

Background information on the trap and haul program associated with Alternatives 3 and 4 was added to the Final EIS as Appendix 9O. This information was used in the qualitative assessment of the trap and haul program in preparation of the Draft EIS.

The species effect summaries under Alternatives 3 and 4 in the Final EIS were revised to include a qualitative assessment of the effects of the proposed trap and haul program for salmonids.

The discussion and analysis of the predator control program was substantially changed from the Administrative Draft EIS in the Draft EIS in response to this comment and similar comments.

SWC 74: More details have been included in Section 9.4.3 of Chapter 9, Fish and Aquatic Resources, in the Final EIS to qualitatively respond to RPA actions not included in the CalSim II model in the No Action Alternative and Alternatives 2 and 5.

SWC 75: Please see response to Comment SWC 15.

SWC 76: The quantitative effects of climate change with the implementation of the No Action Alternative, the Second Basis of Comparison, and Alternatives 1 through 5 are presented throughout the EIS. The effects of increased use of groundwater pumps driven by diesel engines on greenhouse gas emissions are discussed in Chapter 16, Air Quality and Greenhouse Gas Emissions. Because land use is not anticipated to substantially change under the alternatives, greenhouse gas emissions associated with agricultural production, industrial production, and water and wastewater treatment are not anticipated to change in the CVP and SWP water service areas.

SWC 77: Please see response to Comment SWC 61.

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1.D.2.1 Attachments to Comments of AquAlliance

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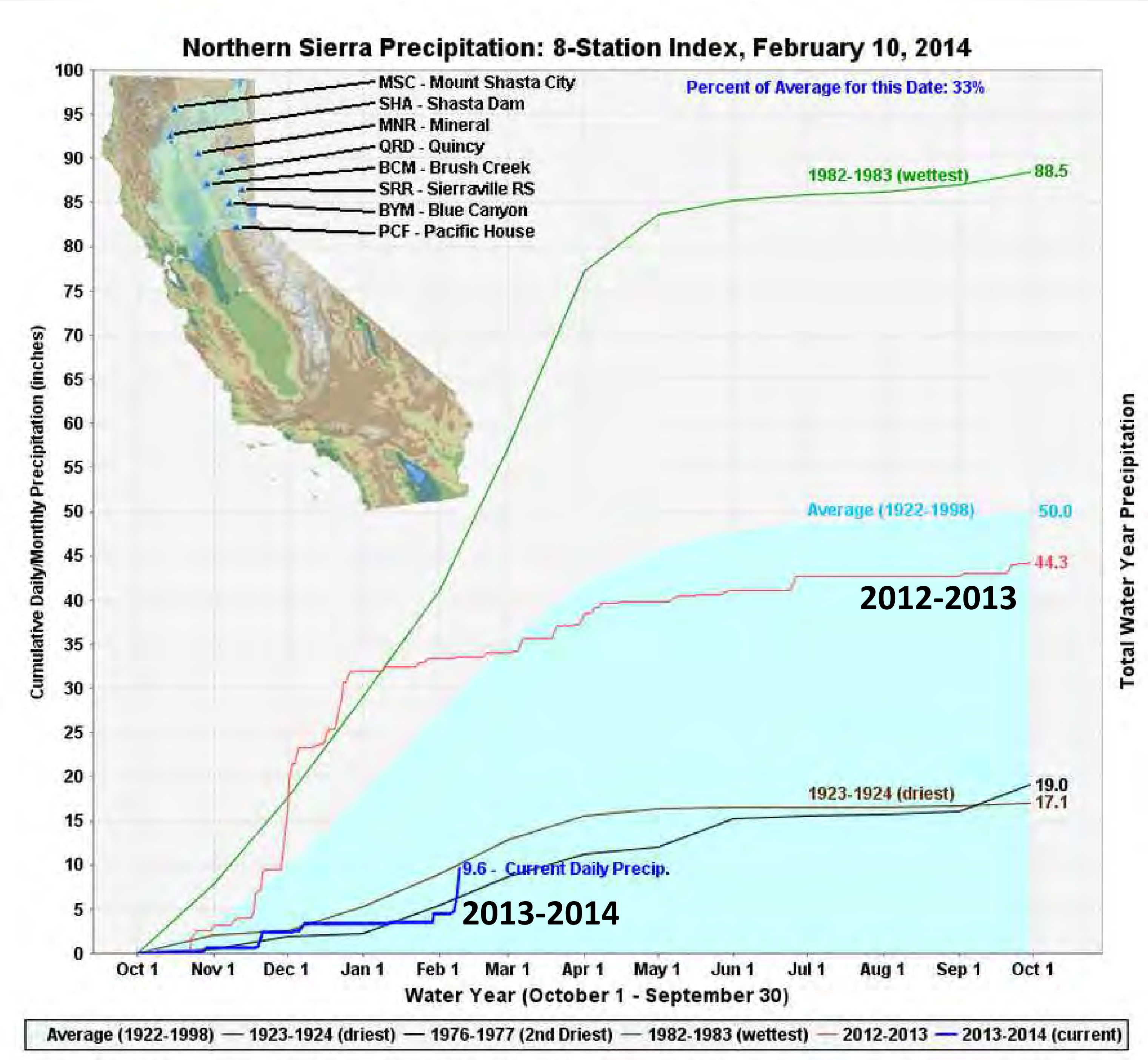
Groundwater Conditions in Butte County

Christina Buck, PhD
Water Resources Scientist
Dept. of Water & Resource Conservation

Durham Groundwater Meeting
February 10, 2014

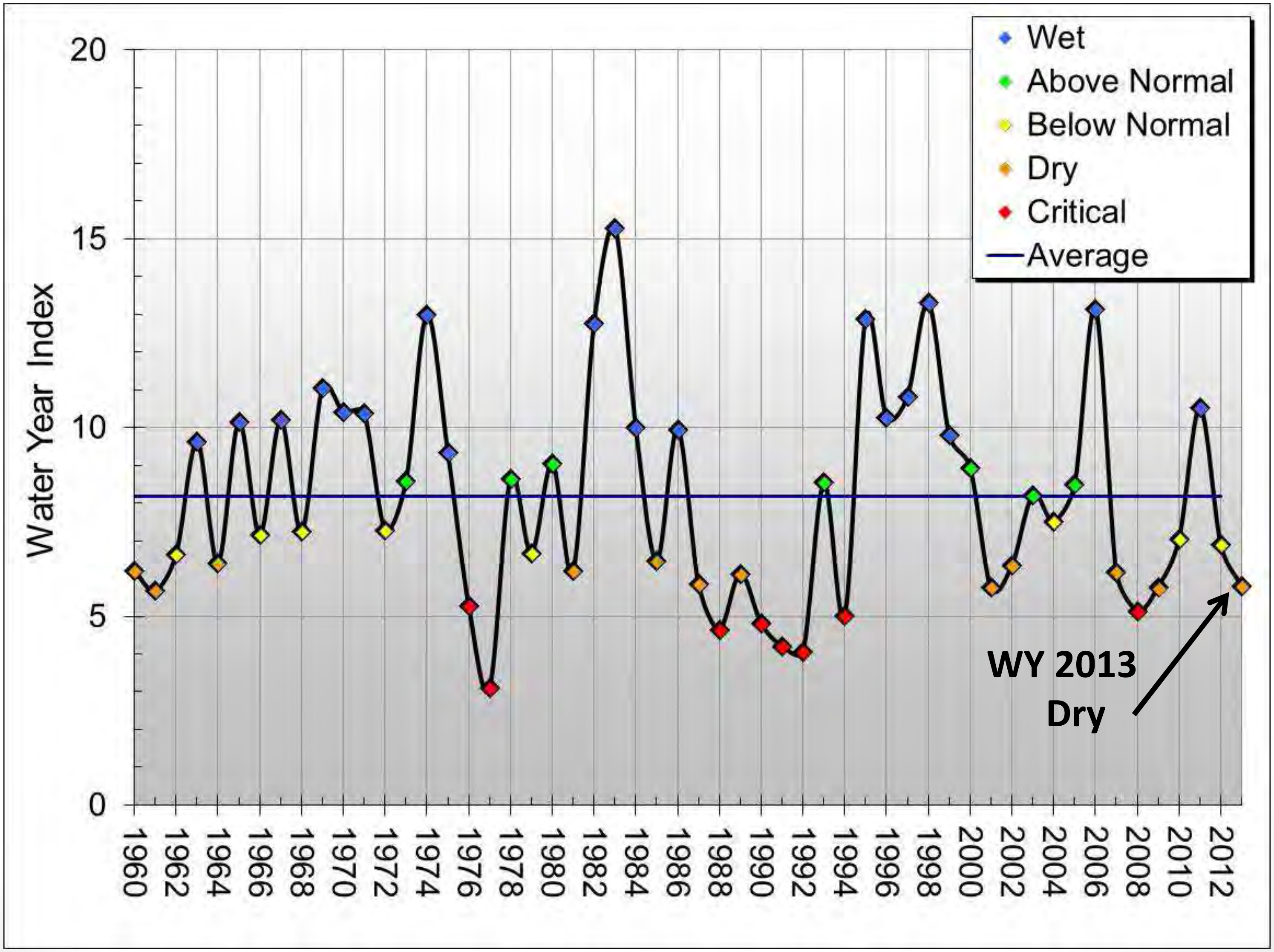
Understanding the Basin

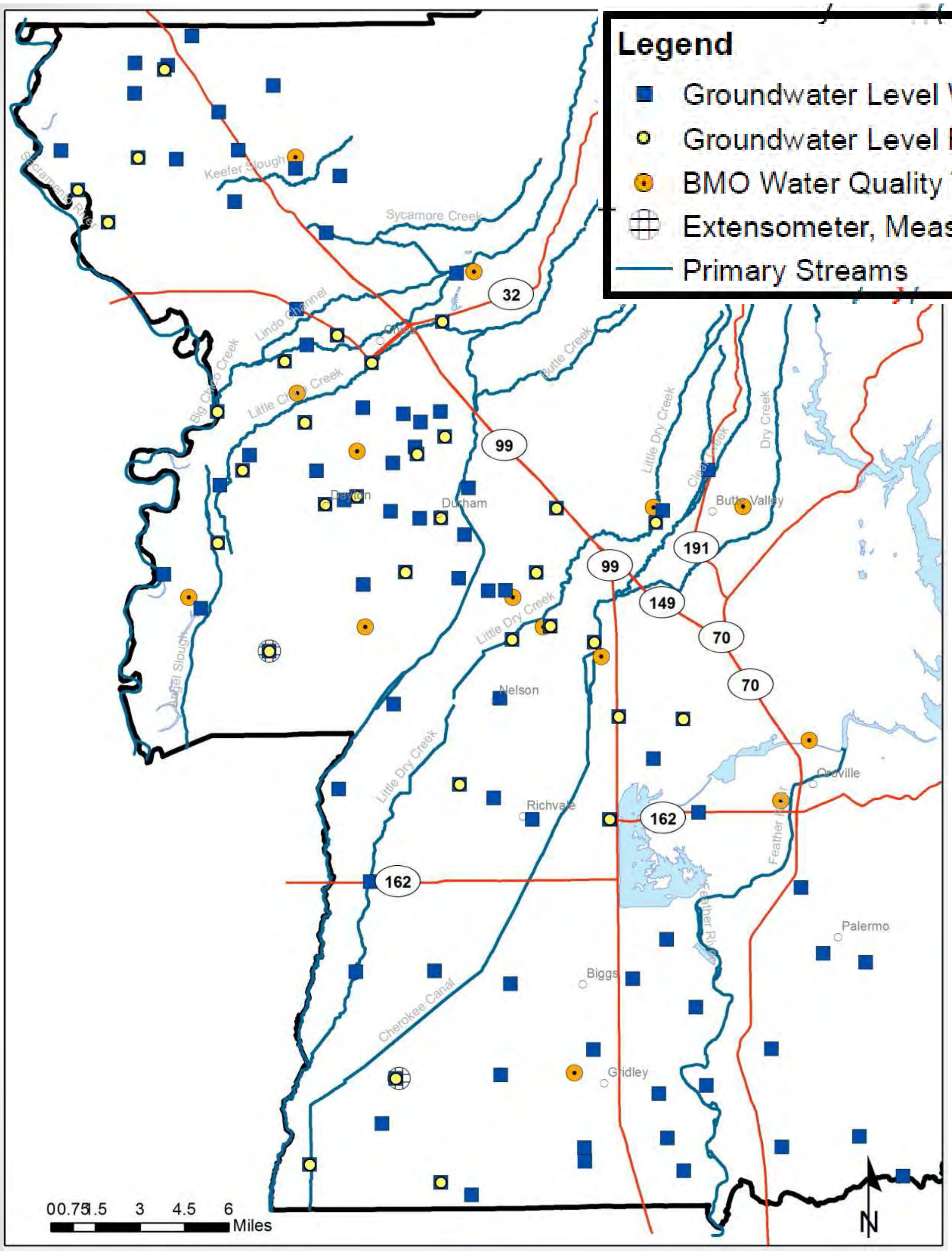
- Ongoing monitoring of groundwater levels tracks the result of hydrologic variability and groundwater use
- Research and modeling helps identify the inputs (hydrology, demands, geology, basin dynamics, etc.)



Northern Sierra Precipitation: 8-Station Index, February 10, 2014

Sacramento Valley Water Year Type Index





Monitoring Network

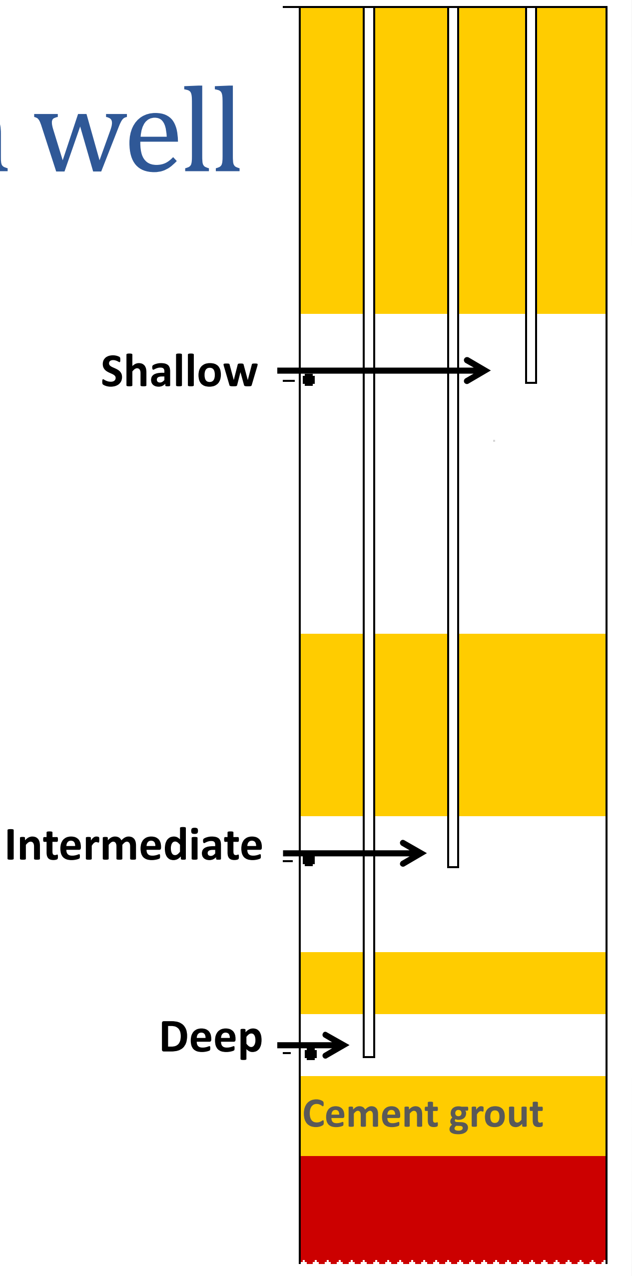
- 125 BMO wells
- 59 equipped with a data logger
- 77 assigned spring/fall alert levels
- 69 additional wells since 2000
- Data online (CASGEM and Water Data Library)

Domestic well

Irrigation well

Multi-completion well

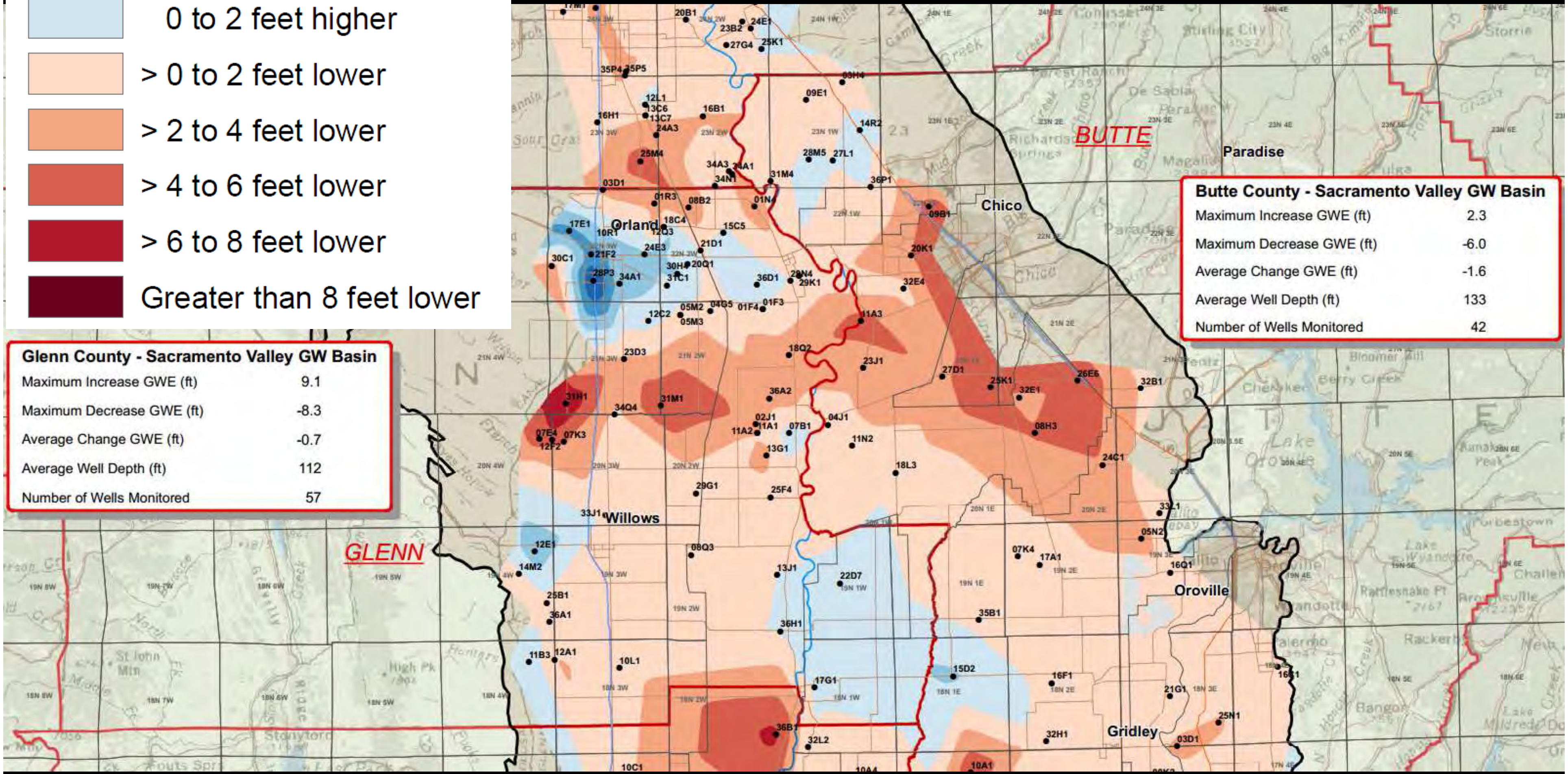
Multi-completion well



Change in Groundwater Elevation Map
Spring 2012 to Spring 2013
Shallow Aquifer Zone (<200 ft.)

Change in Groundwater Elevation

■	Greater than 8 feet higher
■	> 6 to 8 feet higher
■	> 4 to 6 feet higher
■	> 2 to 4 feet higher
■	0 to 2 feet higher
■	> 0 to 2 feet lower
■	> 2 to 4 feet lower
■	> 4 to 6 feet lower
■	> 6 to 8 feet lower
■	Greater than 8 feet lower



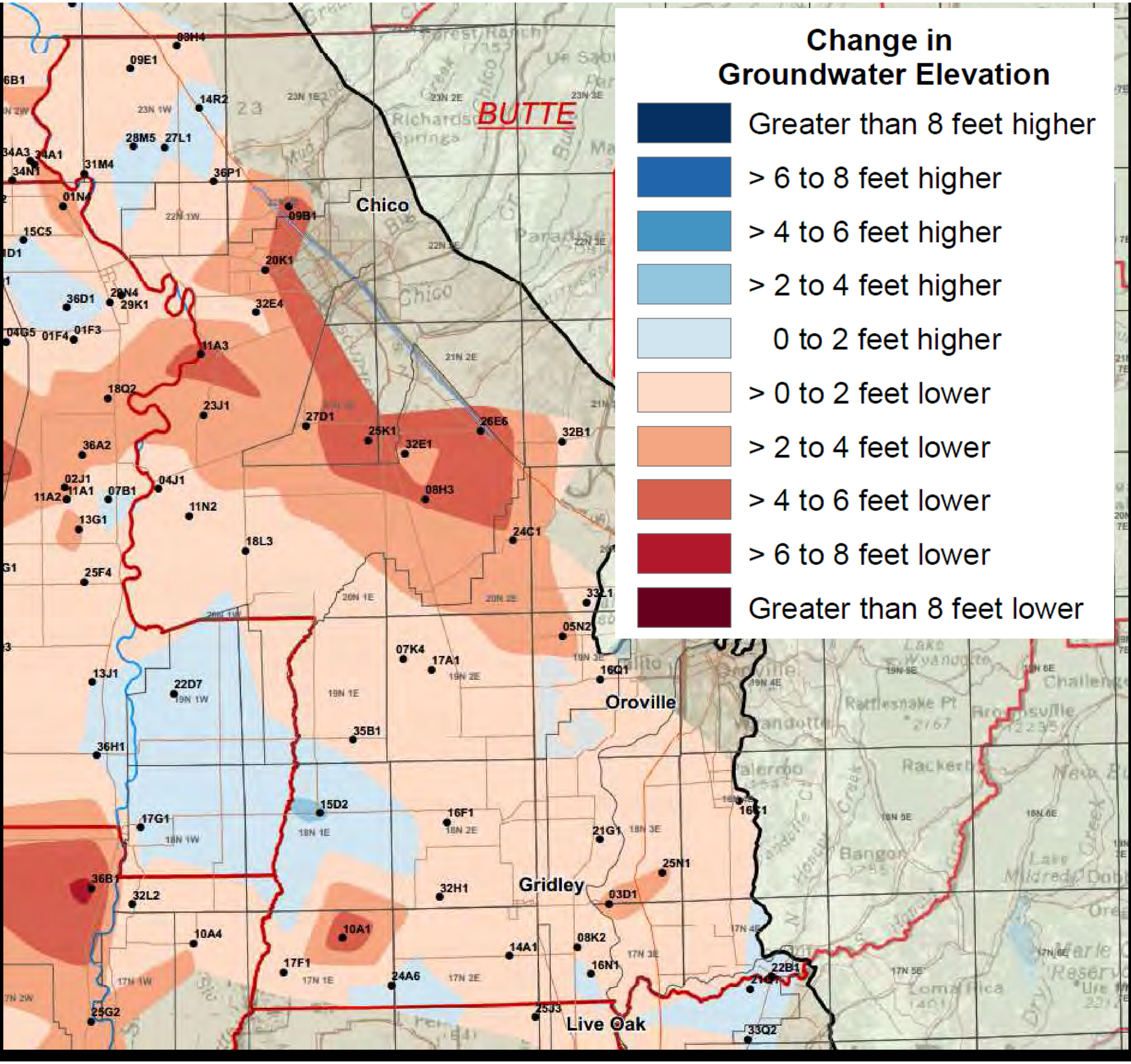
Glenn County - Sacramento Valley GW Basin

Maximum Increase GWE (ft)	9.1
Maximum Decrease GWE (ft)	-8.3
Average Change GWE (ft)	-0.7
Average Well Depth (ft)	112
Number of Wells Monitored	57

Butte County - Sacramento Valley GW Basin

Maximum Increase GWE (ft)	2.3
Maximum Decrease GWE (ft)	-6.0
Average Change GWE (ft)	-1.6
Average Well Depth (ft)	133
Number of Wells Monitored	42

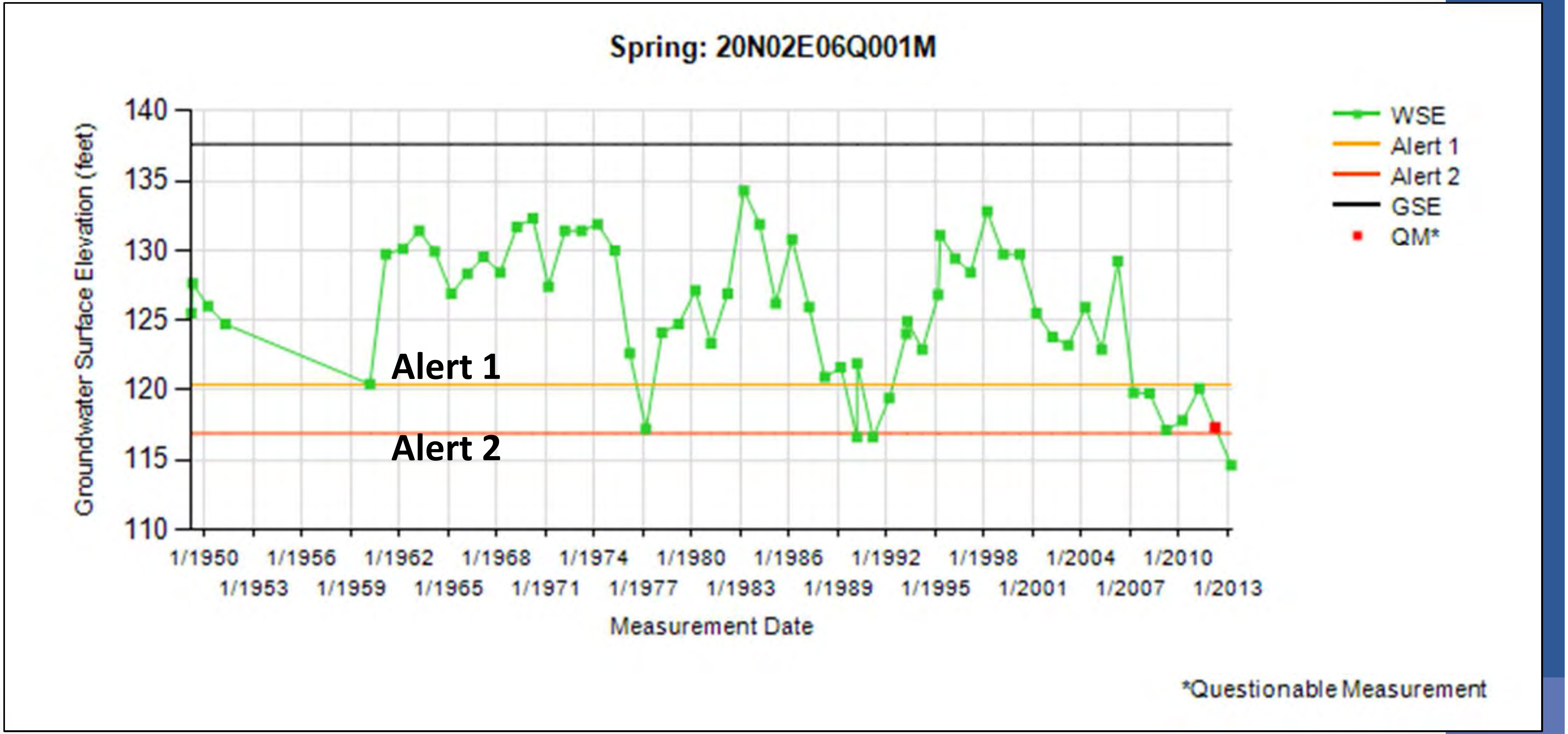
Produced by Department of Water Resources Northern Region Office



Change in Groundwater Elevation

■	Greater than 8 feet higher
■	> 6 to 8 feet higher
■	> 4 to 6 feet higher
■	> 2 to 4 feet higher
■	0 to 2 feet higher
■	> 0 to 2 feet lower
■	> 2 to 4 feet lower
■	> 4 to 6 feet lower
■	> 6 to 8 feet lower
■	Greater than 8 feet lower

Water Level Graphs & Alert Levels



Well in Durham/Dayton Sub-inventory Unit

BMO Alert Stage Frequency

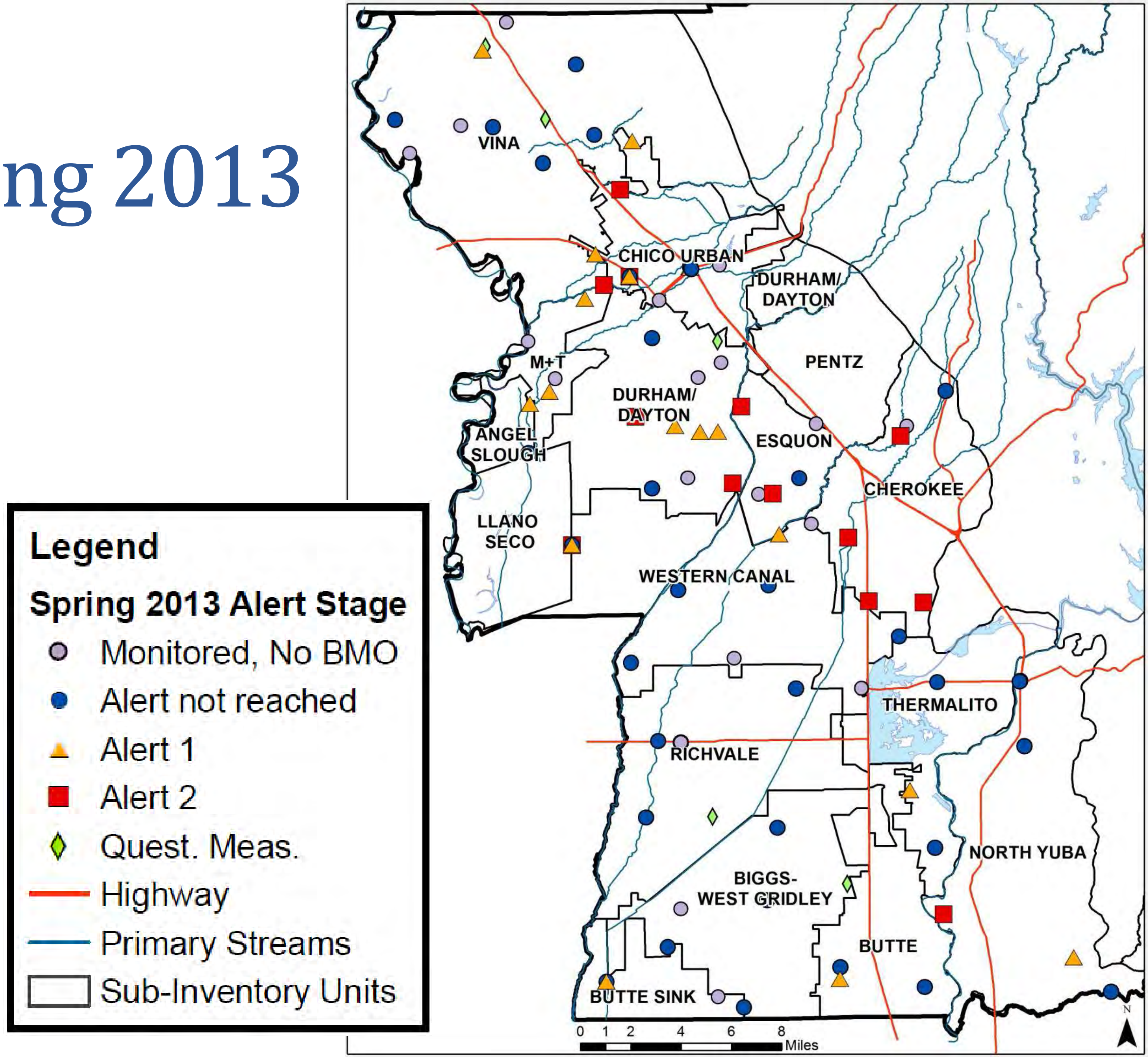
Spring: March 2013

	2008	2009	2010	2011	2012	2013
Alert 1	26	31	25	24	25	20
Alert 2	0	6	3	0	4	15

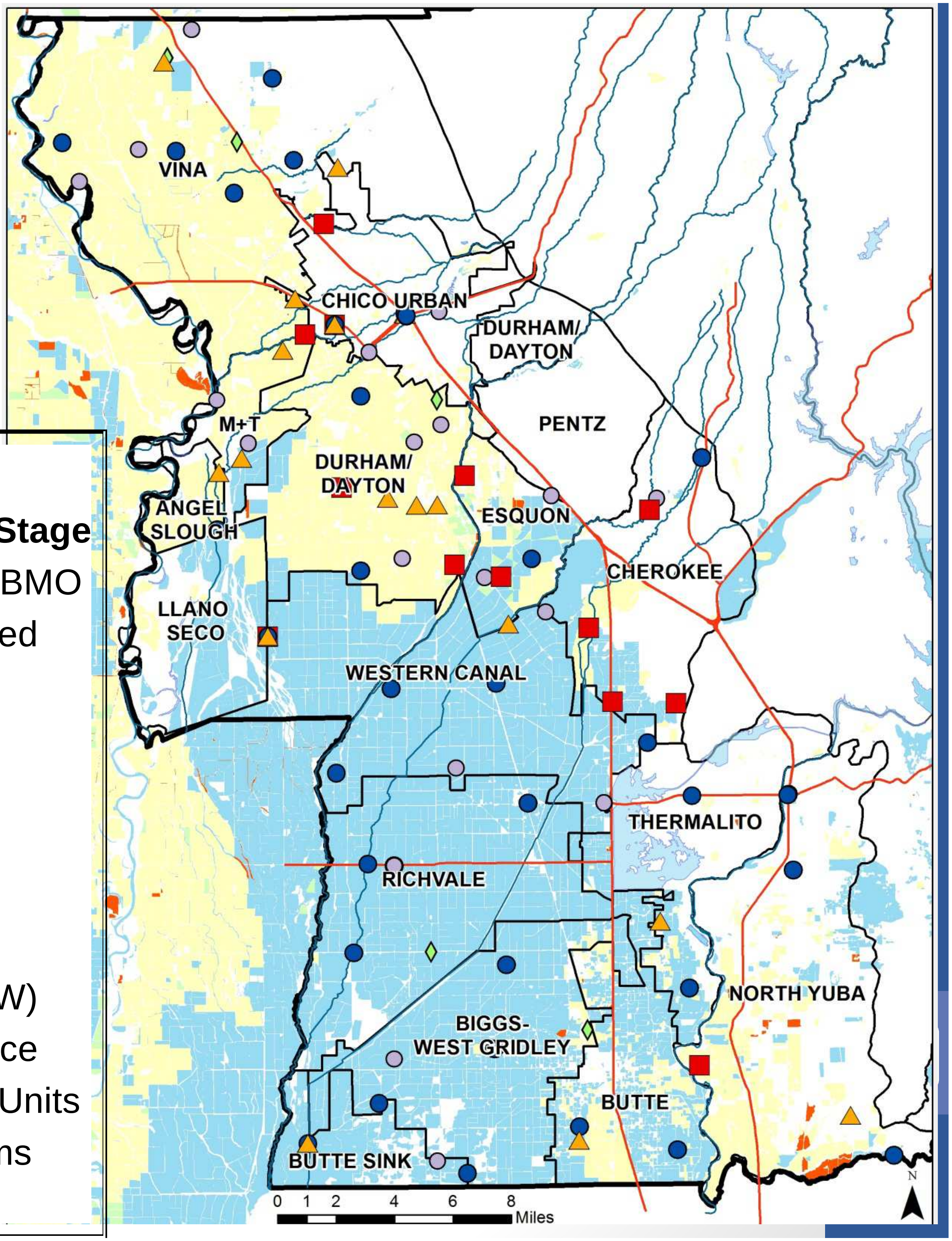
Fall: October 2013

	2008	2009	2010	2011	2012	2013
Alert 1	27	29	24	7	26	23
Alert 2	2	1	2	2	6	16

Spring 2013


Legend
Spring 2013 Alert Stage
○ Monitored, No BMO
● Alert not reached
▲ Alert 1
■ Alert 2
◆ Quest. Meas.
Highway
Primary Streams
Sub-Inventory Units
VINA
CHICO URBAN
DURHAM/ DAYTON
PENTZ
M+T
DURHAM/ DAYTON
ANGEL SLOUGH
ESQUON
CHEROKEE
LLANO SECO
WESTERN CANAL
THERMALITO
RICHVALE
NORTH YUBA
BIGGS-WEST GRIDLEY
BUTTE
BUTTE SINK
0 1 2 4 6 8 Miles
N

Spring 2013 with Water Source



Legend

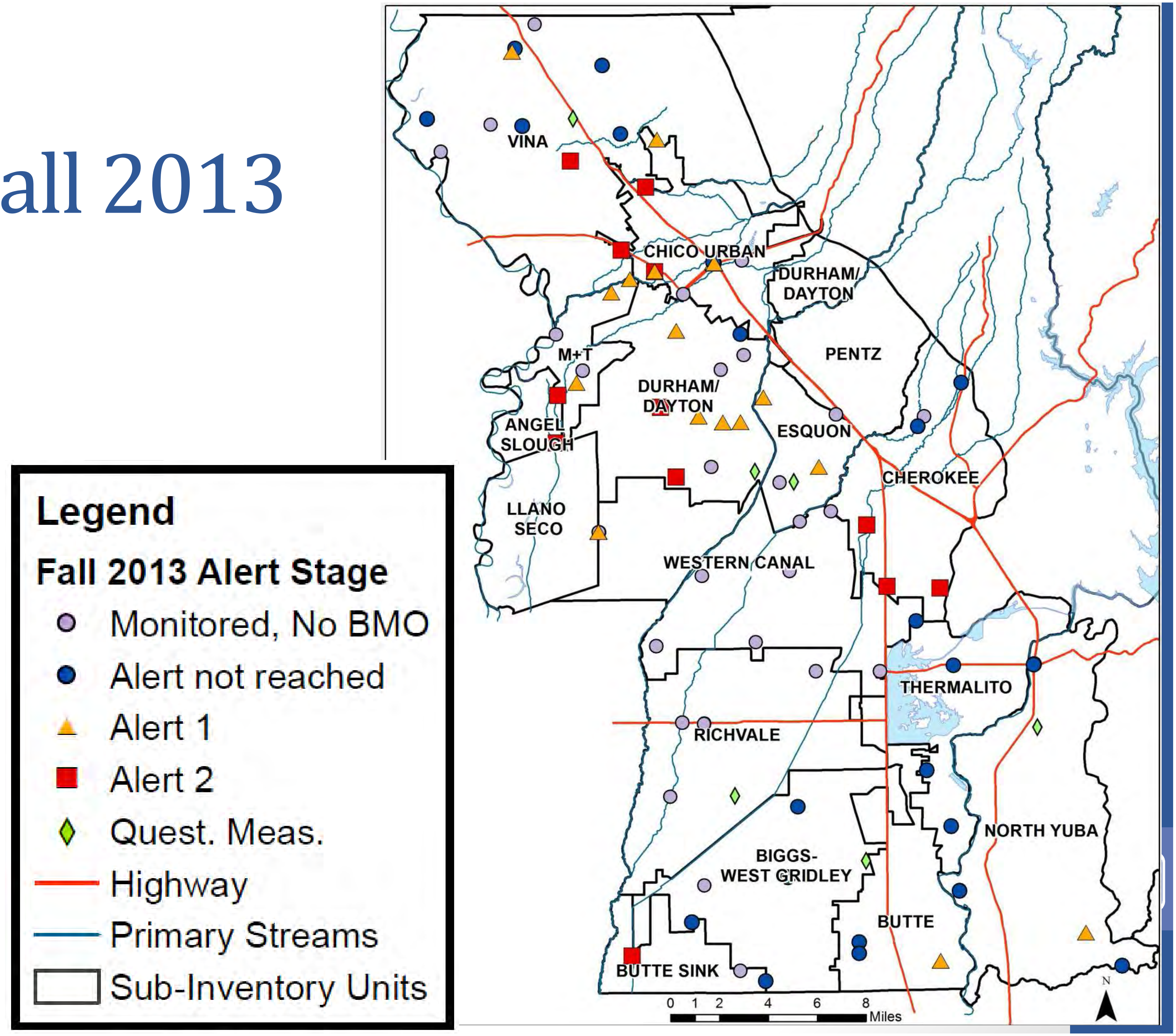
Spring 2013 Alert Stage

- ○ Monitored, No BMO
- ● Alert not reached
- △ Alert 1
- 🟥 Alert 2
- ◊ Quest. Meas.

Water Source

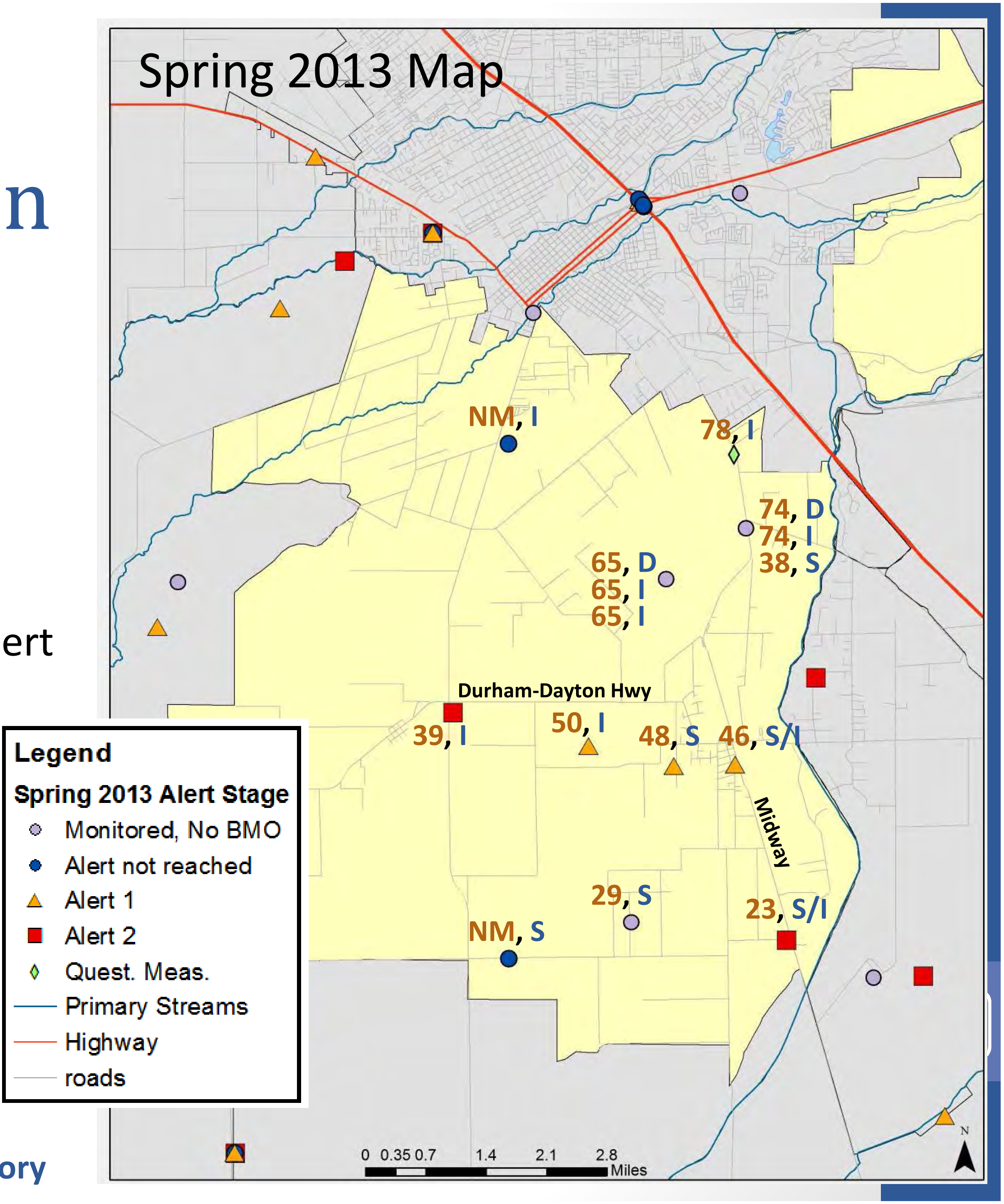
- 🟦 Surface Water
- 🟨 Groundwater
- 🟩 Mixed (SW&GW)
- 🟧 Unknown Source
- ☐ Sub-Inventory Units
- — Primary Streams
- — Highway

Fall 2013


Legend
Fall 2013 Alert Stage
○ Monitored, No BMO
● Alert not reached
▲ Alert 1
■ Alert 2
◆ Quest. Meas.
Highway
Primary Streams
Sub-Inventory Units
VINA
CHICO URBAN
DURHAM/ DAYTON
PENTZ
M+T
DURHAM/ DAYTON
ANGEL SLOUGH
ESQUON
CHEROKEE
LLANO SECO
WESTERN CANAL
THERMALITO
RICHVALE
NORTH YUBA
BIGGS-WEST GRIDLEY
BUTTE
BUTTE SINK
0 1 2 4 6 8
Miles
N

Durham Dayton Area

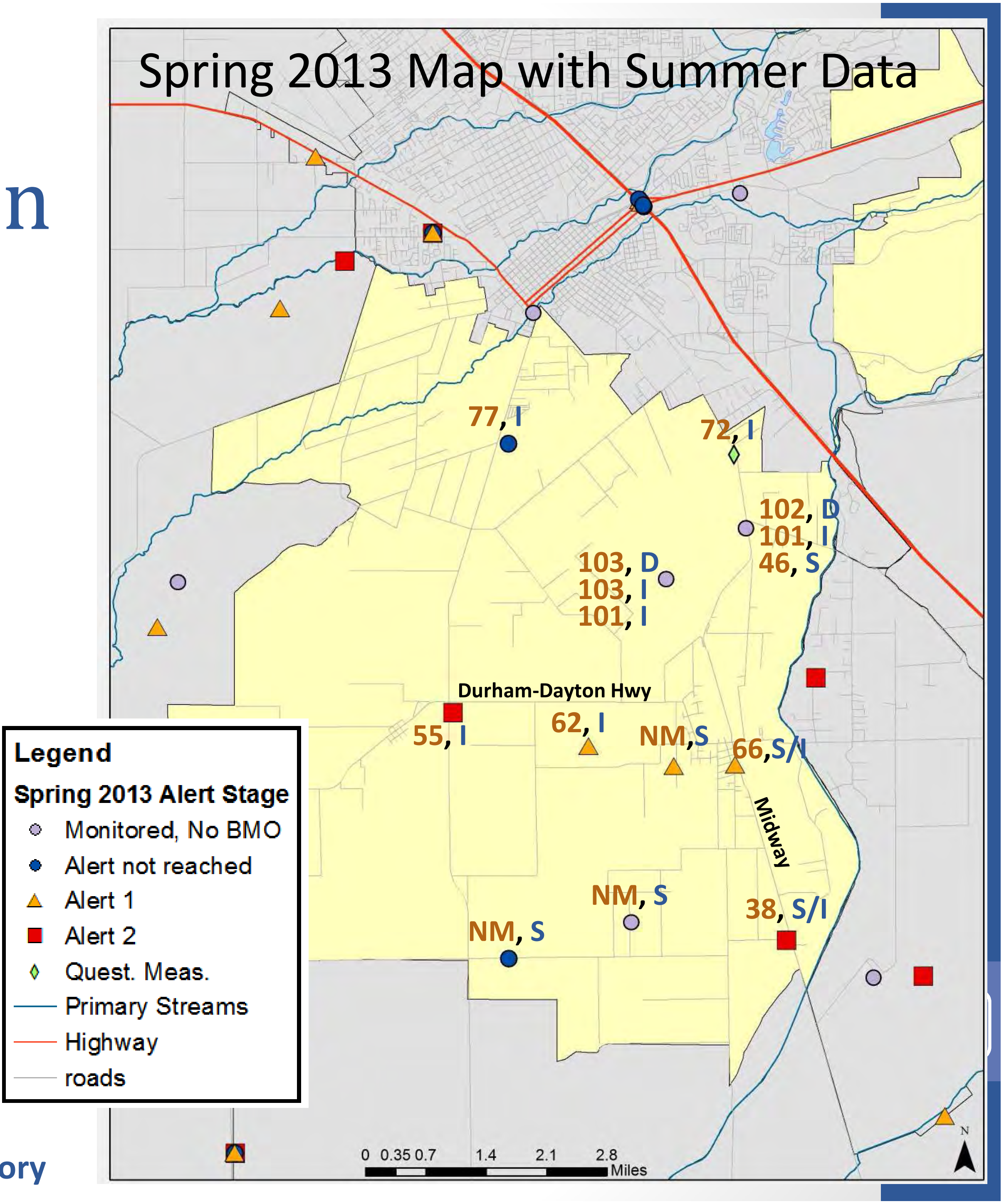
- 15 monitoring wells
  - 2 multi-completion wells
  - 8 wells with data loggers
  - 7 added since 2000, no alert stage set
- Spring 2013
  - 3 Alert 1; 2 Alert 2
- Fall 2013
  - 4 Alert 1; 2 Alert 2



Spring 2013 data
Depth to Water (ft), **Well Depth Category**

Durham Dayton Area

- 2013 Summer Depth to Water (feet)

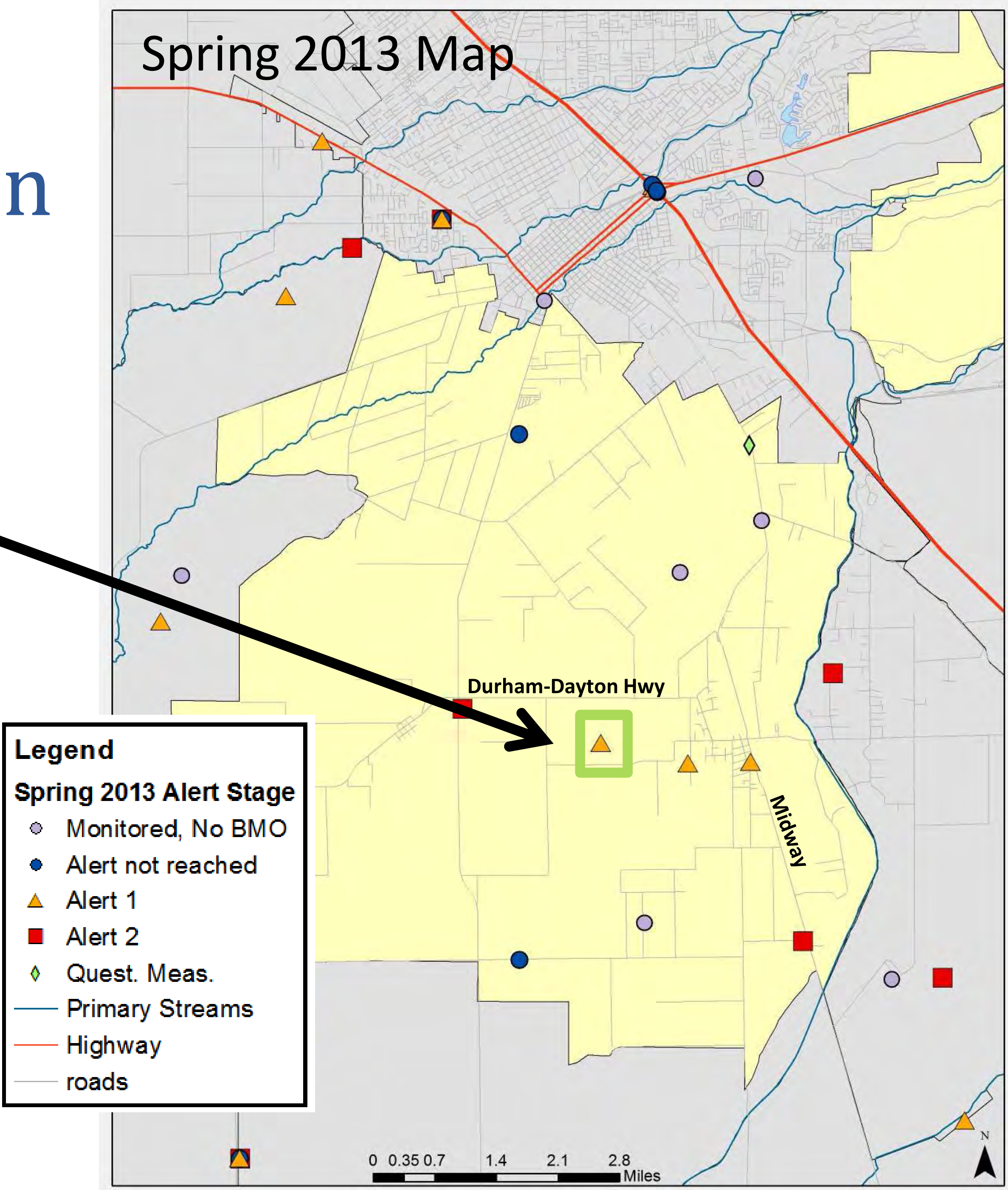


SUMMER 2013 data

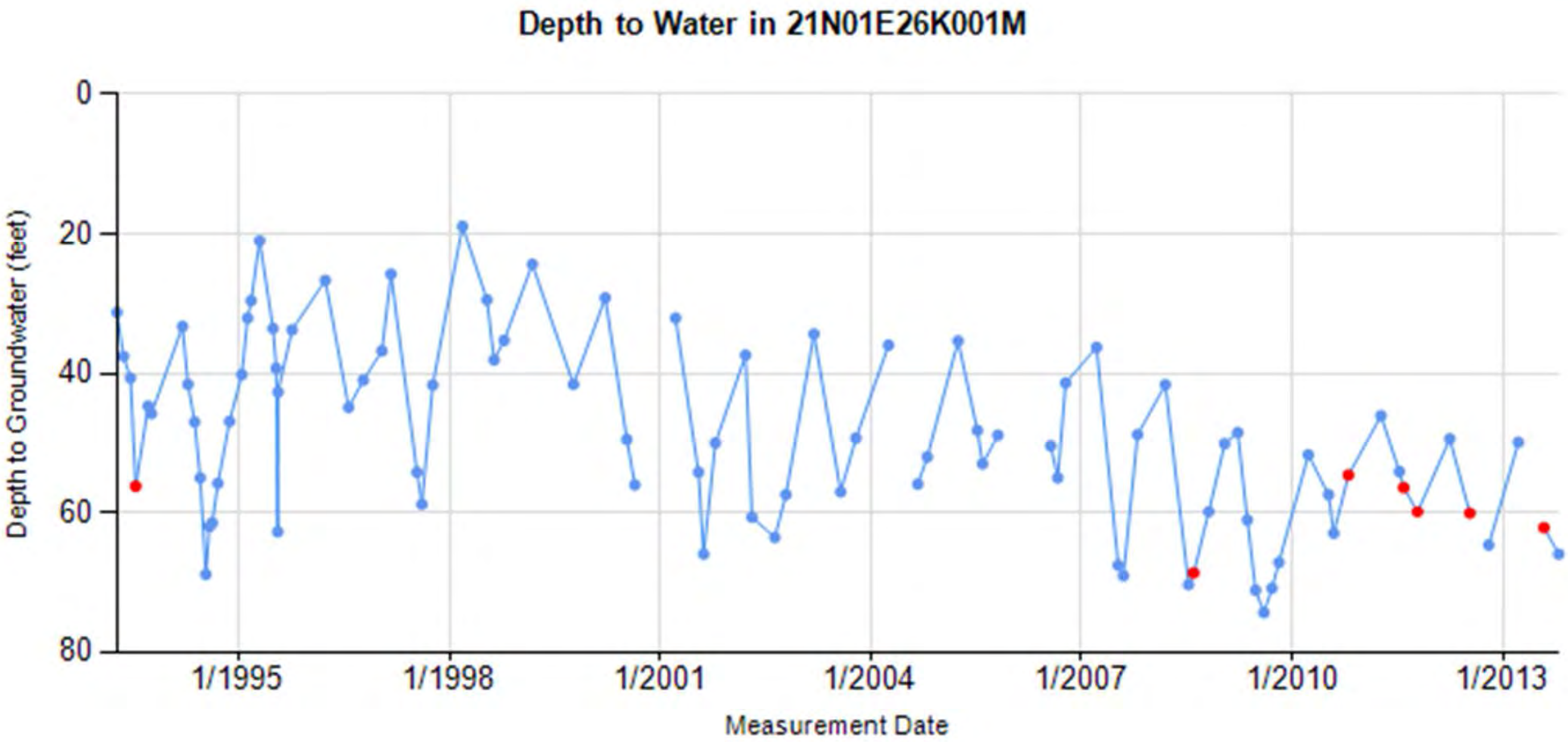
Depth to Water (ft), Well Depth Category

Durham Dayton Area

- A peek at the data….



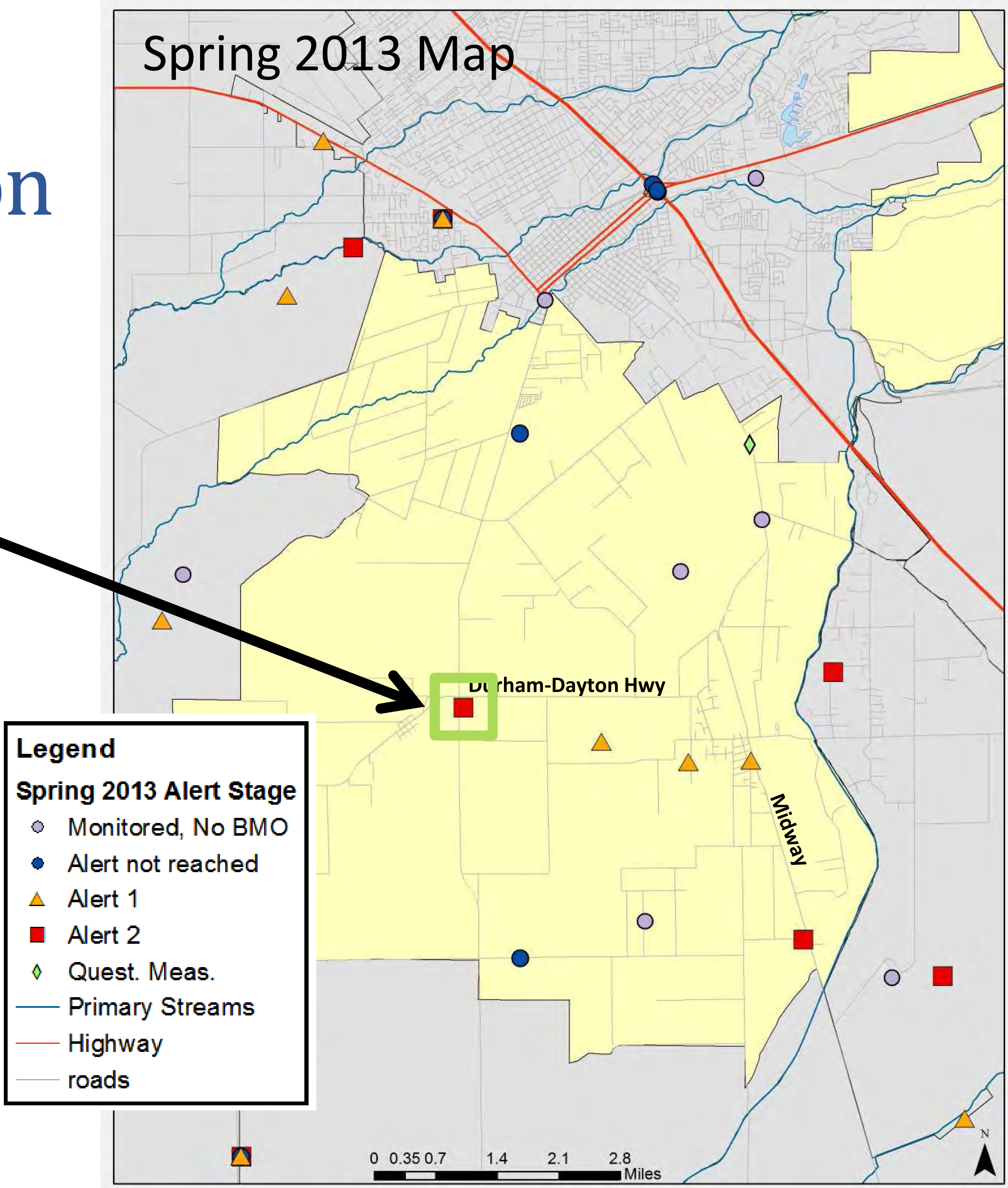
Groundwater Level Trends



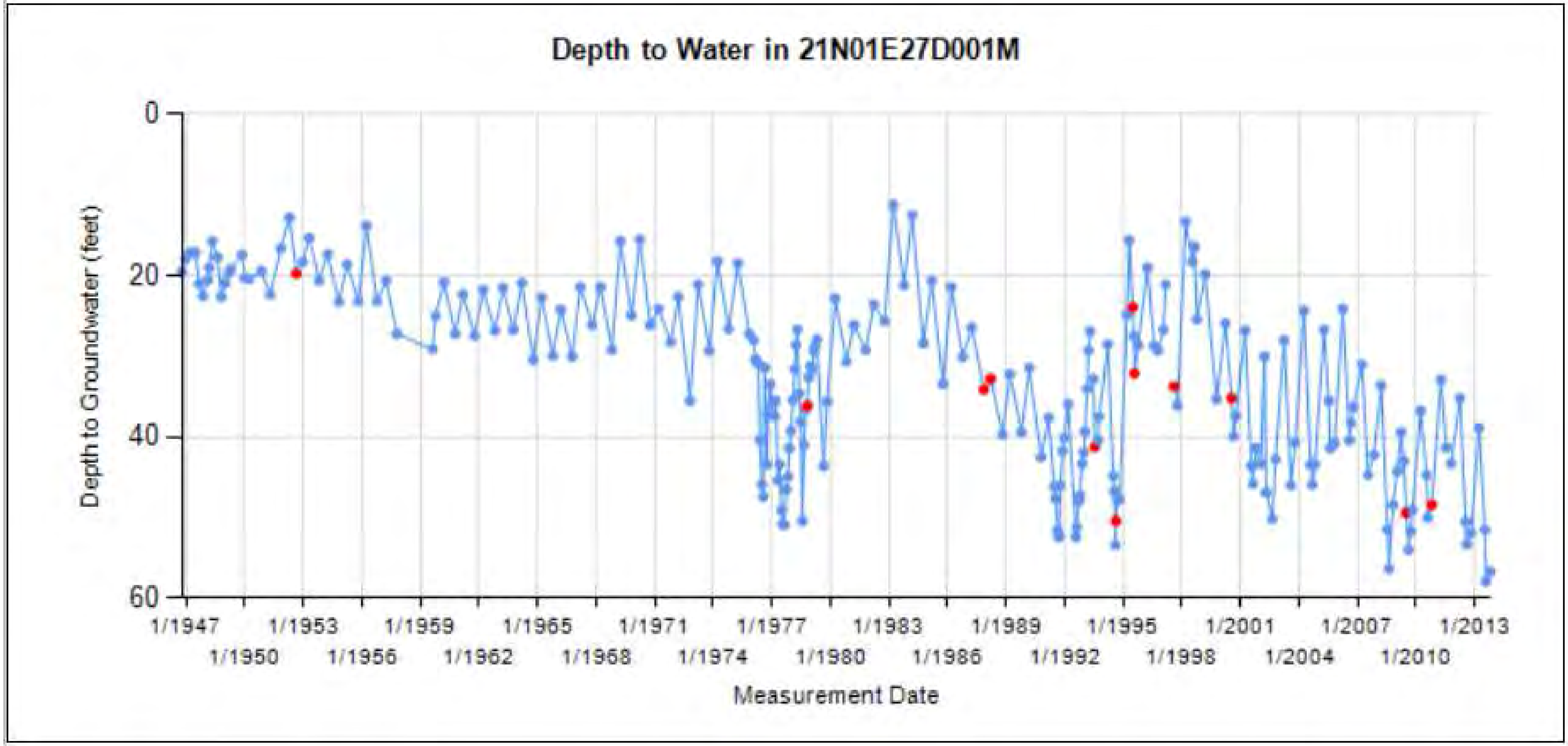
Irrigation, Intermediate (200-600 ft.) well in
Upper Tuscan Formation.
Record begins in 1993
Spring and Fall Alert 1

Durham Dayton Area

- A peek at the data….



Groundwater Level Trends



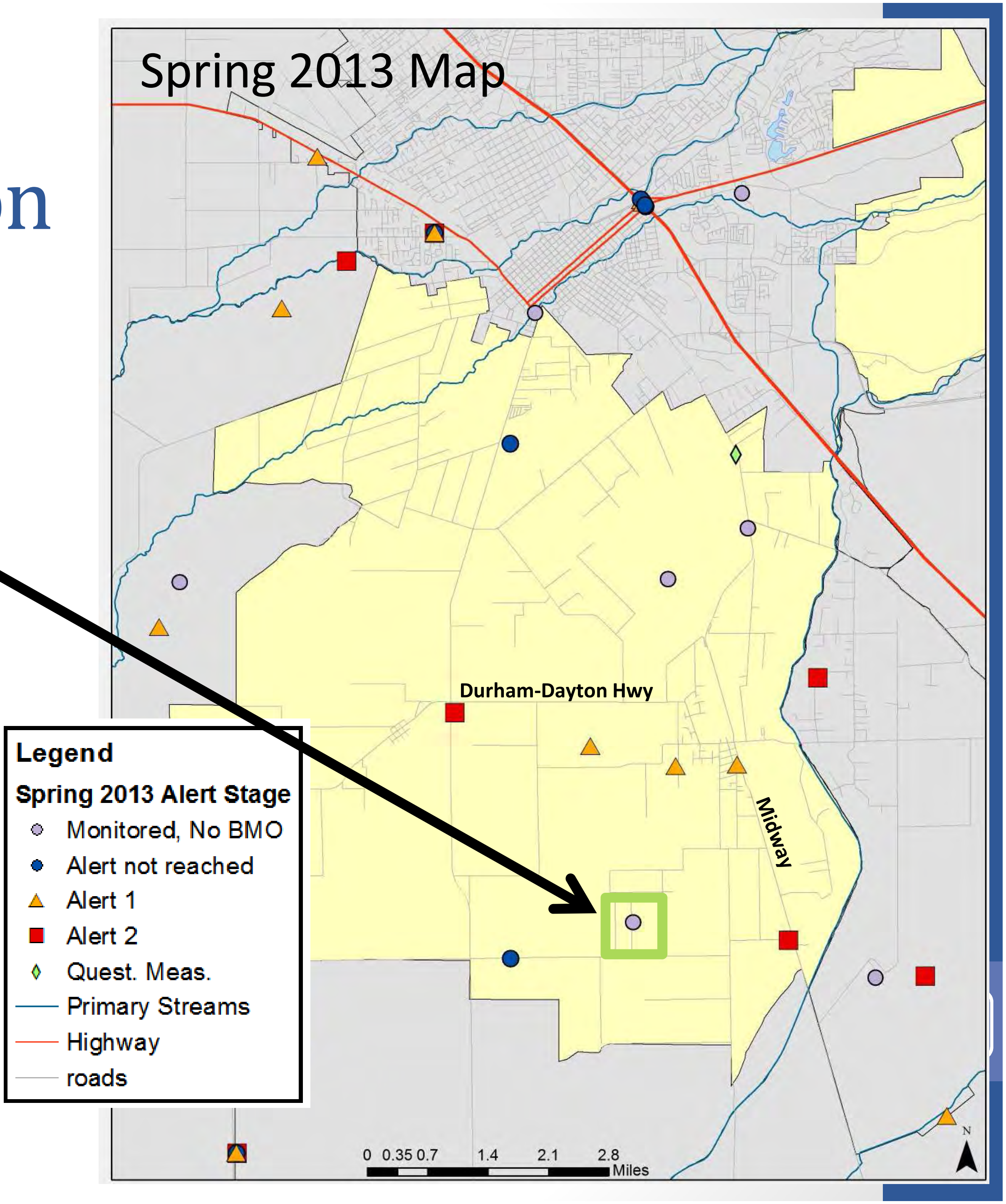
Domestic, shallow (<200 ft.) well in Modesto Formation.

Record begins in 1947

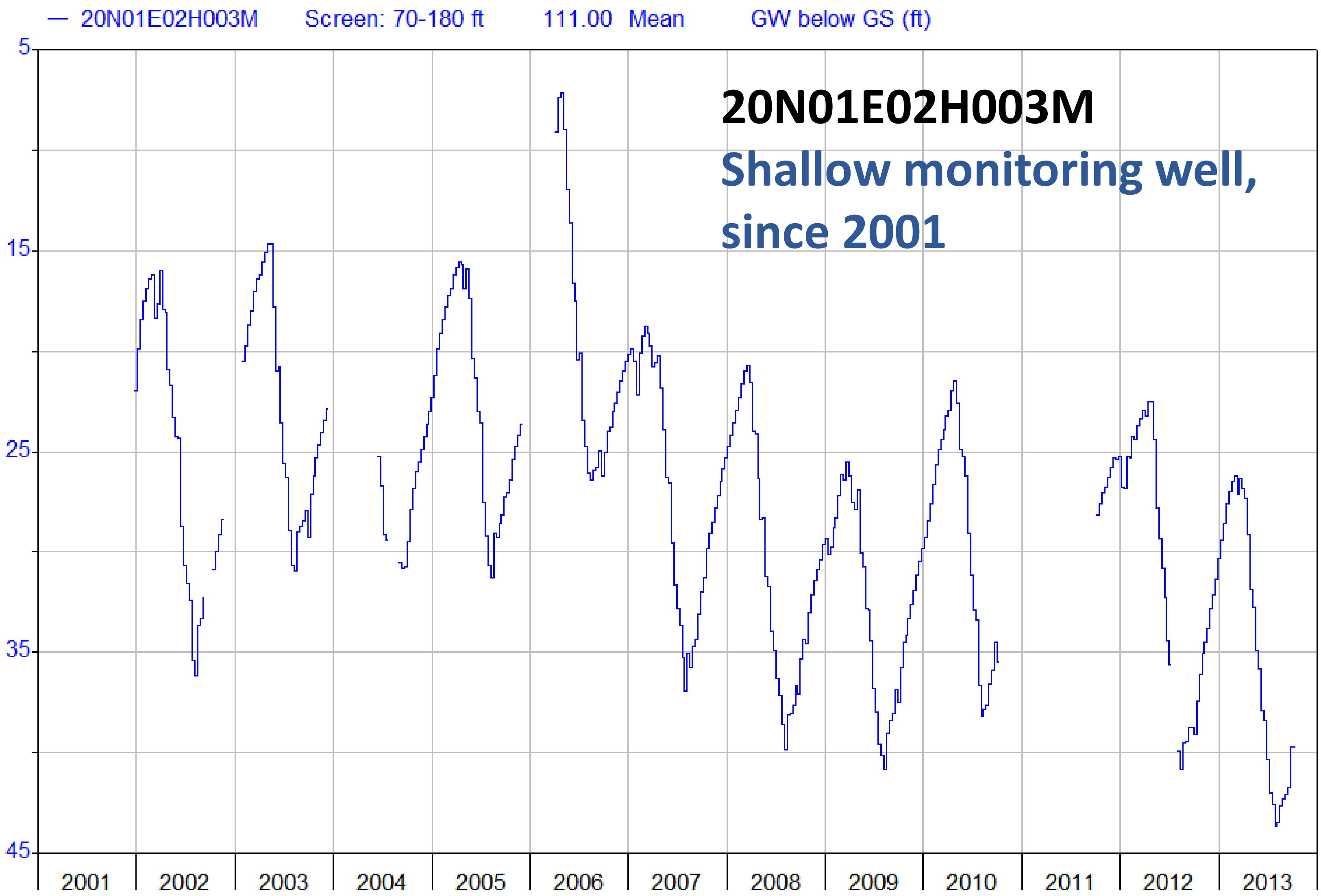
Spring and Fall Alert 2

Durham Dayton Area

- A peek at the data….



Logger Data

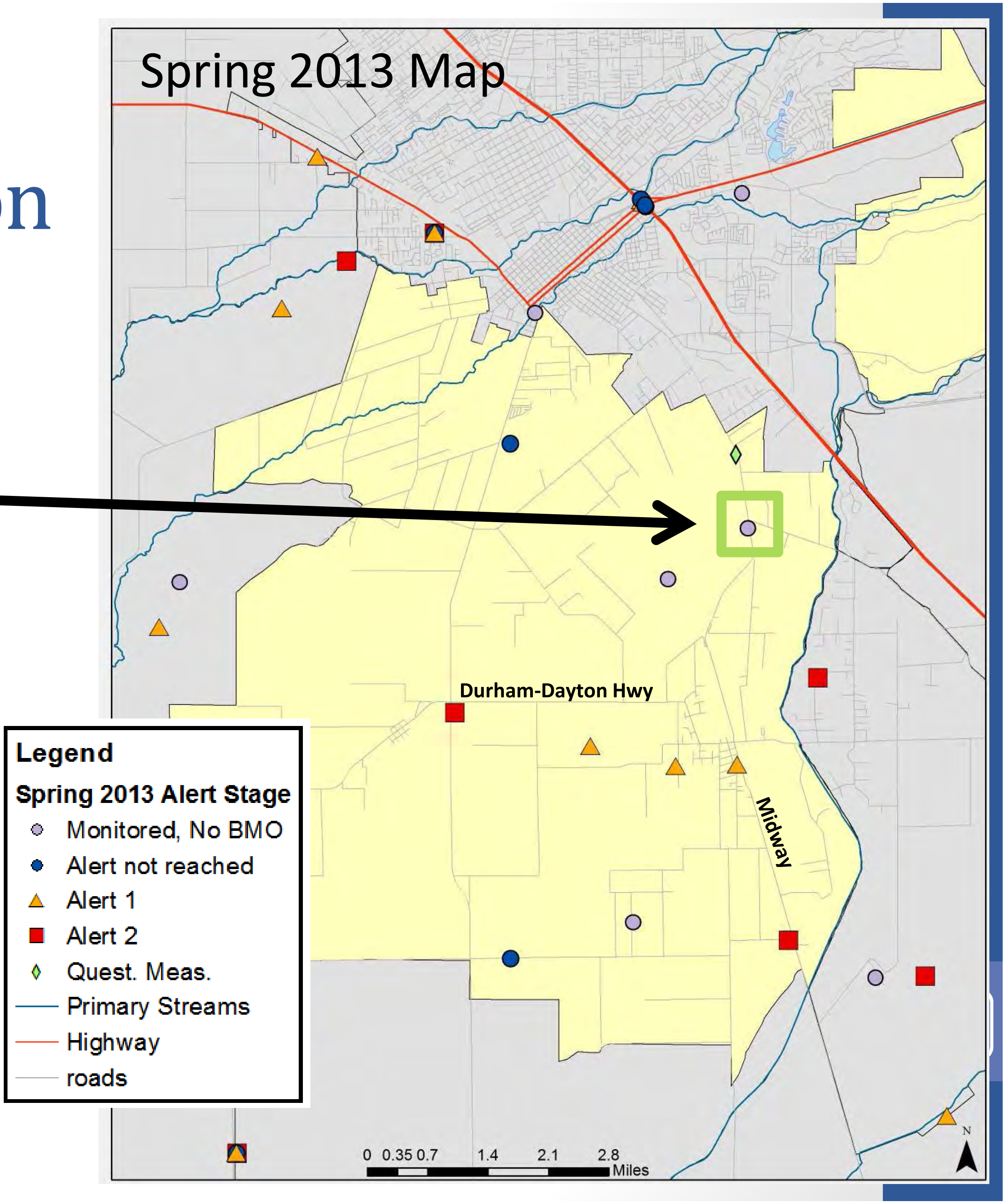


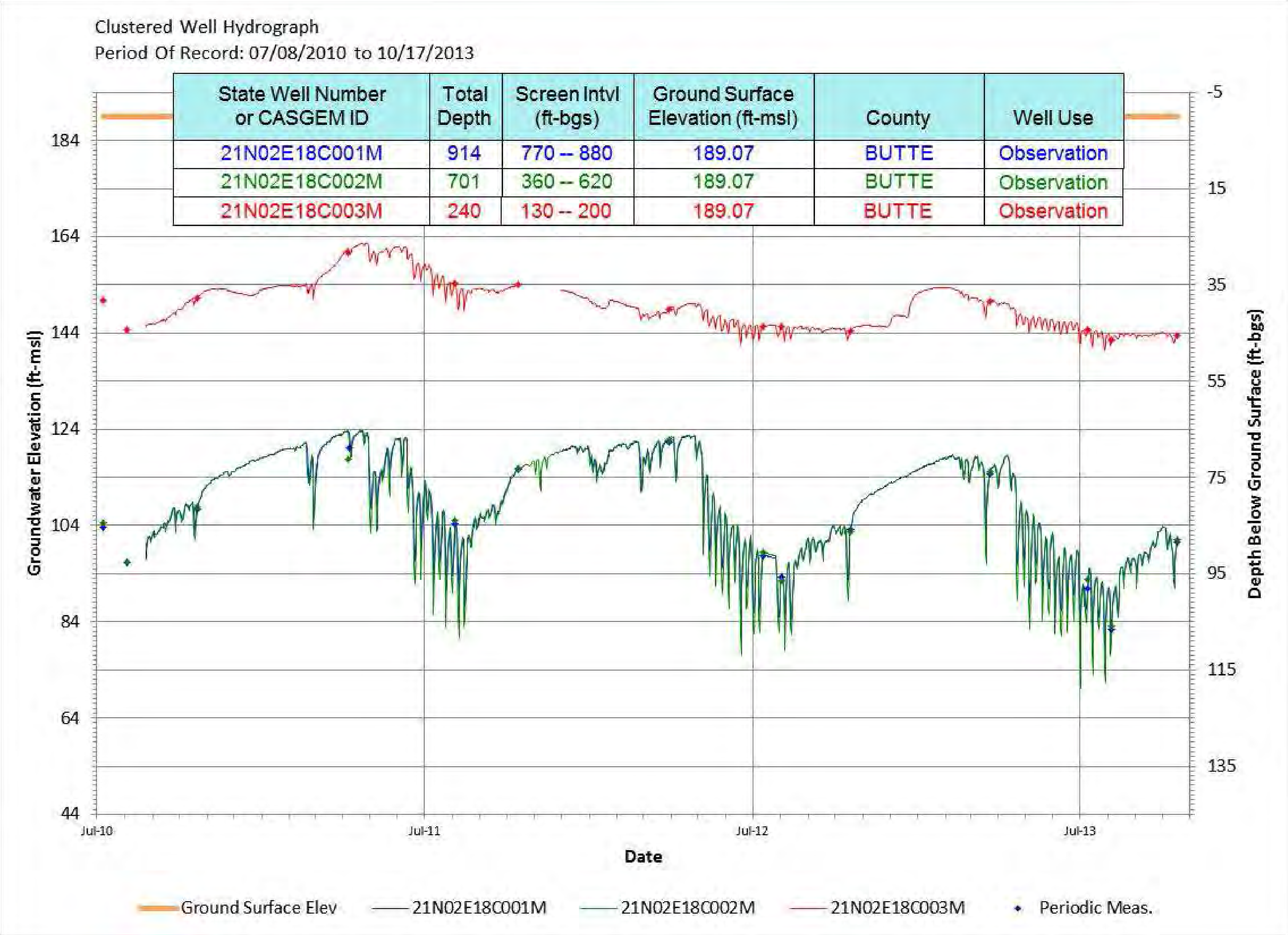
20N01E02H003M

Shallow monitoring well, since 2001

Durham Dayton Area

- A peek at the data….





Clustered Well Hydrograph
Period Of Record: 07/08/2010 to 10/17/2013

State Well Number or CASGEM ID	Total Depth	Screen Intvl (ft-bgs)	Ground Surface Elevation (ft-msl)	County	Well Use
21N02E18C001M	914	770 -- 880	189.07	BUTTE	Observation
21N02E18C002M	701	360 -- 620	189.07	BUTTE	Observation
21N02E18C003M	240	130 -- 200	189.07	BUTTE	Observation

Issued Well Permits

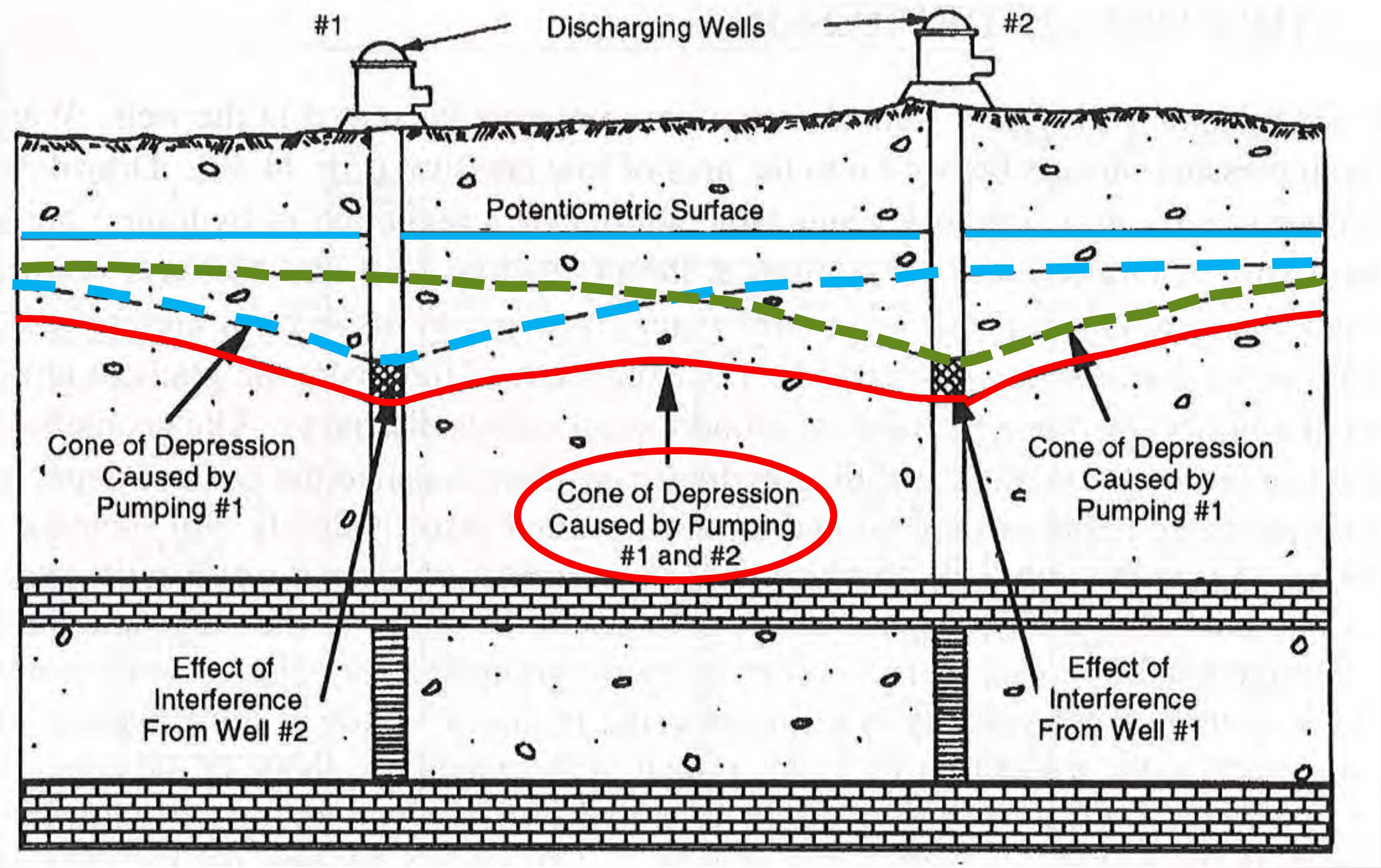
Well Type	2009	2010	2011	2012	2013
Small Diameter	97	82	53	63	125
Large Diameter	28	6	15	19	29
Well Deepening	16	8	5	12	8

- Number of well permits issued by Butte County Environmental Health, not necessarily wells actually drilled.
- Over 14,000 wells exist in the county
- 2009 was the last year of the last 3 year drought

Given the conditions….
What can I do?

What can I do?

1. Coordinate agricultural pumping with your neighbors



Credit: Kasenow 2010

What can I do?

2. Well Owners, Be Prepared
    - Have your well log on hand (a.k.a. well completion report). Available from Butte County Dept. of Environmental Health
    - Have a licensed well driller give your system an annual check up
    - **Wellowner.org** for basic groundwater information and well maintenance
        - Also has contractor locator tool

What can I do?

3. Be aware of groundwater conditions near you
    - Online Water Data Library for monitoring data
    - Come check out our table in the back
    - Know information about your well’s construction (total depth, screening intervals, depth of pump)

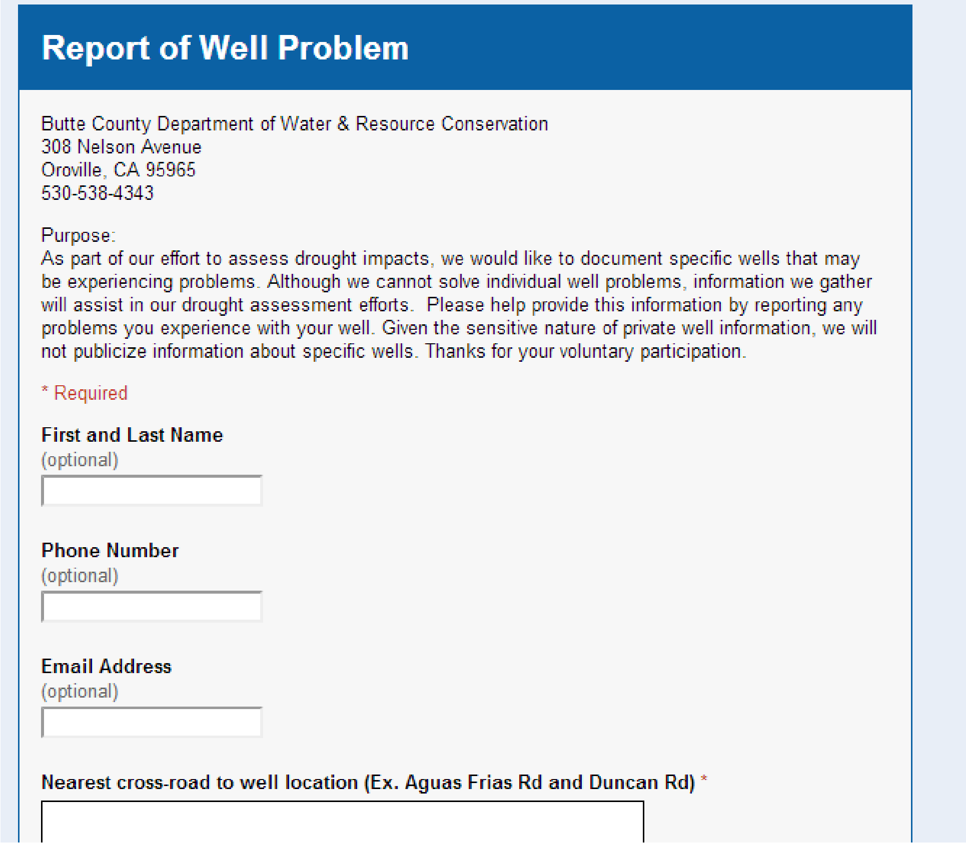
What can I do?

4. Use Water Wisely!
    - **SaveOurH2O.org**
    - Ways to save water Indoors and Outdoors

If you do run into trouble…

Help us document the impacts of the drought!

Fill out the online form. This will help us keep track of where and what the problems are.



Report of Well Problem

Butte County Department of Water & Resource Conservation
308 Nelson Avenue
Oroville, CA 95965
530-538-4343

Purpose:
As part of our effort to assess drought impacts, we would like to document specific wells that may be experiencing problems. Although we cannot solve individual well problems, information we gather will assist in our drought assessment efforts. Please help provide this information by reporting any problems you experience with your well. Given the sensitive nature of private well information, we will not publicize information about specific wells. Thanks for your voluntary participation.

* Required

First and Last Name
(optional)

Phone Number
(optional)

Email Address
(optional)

Nearest cross-road to well location (Ex. Aguas Frias Rd and Duncan Rd) *

Recap

- 2013 was a dry year in the Sacramento Valley and Statewide. Off to a very dry start for 2014.
- Groundwater levels generally declined over last several years, especially in groundwater dependent areas where they are at or near historical lows in many monitoring wells
- For local conditions, see spring/fall hydrographs in BMO reports or on Water Data Library
- Be prepared! Have your well log on hand and use water wisely

Questions?

Christina Buck
Water Resources Scientist
Butte County
Dept. of Water & Resource Conservation
cbuck@buttecounty.net
538-6265

State of California
State Water Resources Control Board
DIVISION OF WATER RIGHTS
P.O. BOX 2000, Sacramento, Ca. 95812-2000
Info: (916) 341-5300, FAX: (916) 341-5400, Web: http://www.waterrights.ca.gov
Rich.Satkowski@waterboards.ca.gov

PROTEST – (Petitions)
OBJECTION
PETITION FOR RECONSIDERATION
PETITION FOR HEARING

BASED ON ENVIRONMENTAL OR PUBLIC INTEREST CONSIDERATIONS

Temporary Urgency Change Petition and Responding Order for Permits 16478, 16479, 16481, 16482 and 16483 (Applications 5630, 14443, 14445A, 17512 and 17514A, respectively) of the Department of Water Resources for the State Water Project and License 1986 and Permits 11315, 11316, 11885, 11886, 11887, 11967, 11968, 11969, 11970, 11971, 11972, 11973, 12364, 12721, 12722, 12723, 12725, 12726, 12727, 12860, 15735, 16597, 20245, and 16600 (Applications 23, 234, 1465, 5638, 13370, 13371, 5628, 15374, 15375, 15376, 16767, 16768, 17374, 17376, 5626, 9363, 9364, 9366, 9367, 9368, 15764, 22316, 14858A, 14858B, and 19304, respectively) of the United States Bureau of Reclamation for the Central Valley Project.

We, Chris Shutes, Water Rights Advocate, California Sportfishing Protection Alliance (CSPA), 1608 Francisco St., Berkeley, CA 94703, blancapaloma@msn.com, (510) 421-2405; Bill Jennings, Executive Director, CSPA, 3536 Rainier Ave, Stockton CA 95204, deltakeep@me.com, (209) 464-5067; Barbara Vlamis, Executive Director, AquAlliance, P.O. Box 4024, Chico, CA 95927, barbarav@aqualliance.net, (530) 895-9420; Carolee Krieger, Executive Director, California Water Impact Network, 808 Romero Canyon Rd., Santa Barbara, CA 93108, caroleekrieger7@gmail.com, (805) 969-0824; and Michael Jackson, counsel to CSPA, CWIN and AquAlliance, P.O. Box 207, 429 W. Main St., Quincy, CA 95971, mjatty@sbcglobal.net (Protestants)

have read carefully a notice relative to a petition for Temporary Urgency Change (TUCP) of the Department of Water Resources (DWR) and the Bureau of Reclamation (Bureau), dated January 23, 2015. The Executive Director issued an Order granting this petition in part and denying it in part on February 3, 2015 entitled ***Order Approving in Part and Denying in Part a Petition for Temporary Urgency Changes in License and Permit Terms and Conditions Requiring Compliance with Delta Water Quality Objectives in Response to Drought Conditions*** (TUCO or “Order”).

The proposed petition for water and Order will:

(1) not be within the State Water Resources Control Board’s (SWRCB) jurisdiction
(2) not best serve the public interest

(3) be contrary to law
(4) have an adverse environmental impact

(All of the above)

We object to the TUCP and petition for reconsideration of the proposed Order for the reasons described below.

State Facts, which support the foregoing allegations:

Summary

The State and Federal water projects have again petitioned the State Water Board to relax Bay-Delta standards in February and March so that more water can be exported from the Delta during what appears to be a fourth consecutive year of drought. After twenty years of acquiescing to the water interests, consistently leaving Delta standards unenforced in dry years, Board staff has issued an Order that would reduce Delta outflow requirements, allow additional operation of the Delta Cross Channel gates, and reduce Vernalis flows with no mitigation, but would not allow the requested higher exports when D-1641 standards are not being met, despite acquiescence of the fisheries agencies to what these agencies appear to have assumed was a foregone conclusion. However, the Order leaves open the option for the Board to change its mind on the request in the future, and will discuss the matter with those involved at a February 18, 2015 public workshop.

Recognizing the failure of the fisheries agencies to address the appropriate legal standard (whether the requested actions will have unreasonable effects on fish and wildlife), Board staff at least refuses in the Order the request of DWR and the Bureau to weaken export requirements even more than last year.[1] In what we would like to think is responsive to our comments last September,[2] the Order cites to objective evidence and highlights key biological considerations.[3] The discussion portion of the Order describes how it is necessary to consider the condition of affected fisheries over the past several years and over the past few months. However, despite the acknowledgment of such required analysis, the Order incredibly draws exactly the same conclusions and requires the same weakened Delta outflow and export conditions that similar

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[1] See Order, p. 17:

> It should be noted that while the fisheries agencies indicated that the changes proposed in the TUCP could be made in compliance with ESA and CESA requirements, those letters did not determine whether the potential impacts of the changes would unreasonably affect fish and wildlife. The ESA and CESA standard of avoiding jeopardy to the continued existence of a threatened or endangered species is a minimal standard, and as such may differ from the Water Code requirement that the changes must not unreasonably affect fish and wildlife, especially when many species have already experienced extreme impacts from the drought for several years.

[2] See CSPA et al Comments on *Draft Order Denying Petitions for Reconsideration and Addressing Objections regarding the Temporary Urgency Change Petitions and Orders for the operation of the Central Valley Project and the State Water Project*, September 16, 2014, p. 2: "Rather than citing objective evidence, the Board has relied on concurrence from the fisheries agencies to support its decisions."

[3] See Order, Section 2.6.

orders required last year. These are the conditions that led, as CSPA predicted in 2014, to all-time lows in Delta smelt abundance and the population collapse of winter-run Chinook salmon.

The Order recognizes that the main beneficiaries of water held in storage rather than released to meet D-1641 outflow and salinity requirements are water users. In light of the failure of 2014's efforts to maintain temperature control, and the loss of ~95% of the 2014 winter-run cohort and the loss of virtually all of the 2014 spring-run cohort (of fish that spawn in the Sacramento River), the statement is indisputable. The solution in 2015 is to require lower deliveries to CVP Settlement Contractors north of Delta and/or lower deliveries of CVP Settlement Contractors' water in the form of transfers south of Delta. With 75% of deliveries in 2014 allowed to CVP Settlement Contractors north of Delta, and likely identical deliveries in 2015, this represents real water, far greater than the savings achievable by starving Delta outflow and water quality requirements. The glib statement in the TUCP cover letter that requested "… changes would allow management of reservoir releases on a pattern that conserves upstream storage for fish and wildlife protection" offers no assurance that such management will occur or will be effective.[4] This year, the Board should exercise strict independent oversight of efforts to manage water temperature in the Sacramento River downstream of Keswick, using its water rights authority to limit north of Delta CVP deliveries if necessary, and not rely on the irresolute federal fisheries agencies who failed in 2014. This option should be considered in the water temperature modeling that is required under Order ¶6(b), alterative (c).

The Order appears to make an improvement over last year's orders in that it does not allow transfers of water from SWP and CVP contractors north of Delta to SWP and CVP contractors south of Delta unless D-1641 requirements are being met. This appears to respond affirmatively to our criticism in our September 16, 2014 comments: "the transferred water [in 2014] was largely sourced from Project reservoirs, sold by settlement contractors who in water year 2014 got most of the available water."[5] One does not conserve project water in storage for any purposes by allowing it to be called on from Lake Shasta by Settlement Contractors and then transferred south of Delta.

However, the Order continues to exempt from limitations transfers of water that are made where the transferred water is sold by an entity with non-project water rights.[6] It makes no difference to fish if the increased risk of entrainment or other causes of mortality in the central and south Delta is caused by export of transferred water rather than export of project water. The Board should not only disallow transfers of *any* water through project facilities when D-1641 standards are not being met, it should require the same import-export mitigations it requires of the projects. What is unreasonable for project water is no less unreasonable for anyone else's water.

Storage conditions in the San Joaquin tributary reservoirs are particularly severe. However, the Order does nothing to reduce the severe risks to lower San Joaquin River and San Joaquin tributary fisheries. The Board should order the Bureau of Reclamation to immediately develop and, as soon as practicable, implement a plan in conjunction with the Department of Fish and Wildlife to capture Stanislaus River salmonid outmigrants at the fish weir on the Stanislaus River

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[4] See TUCP cover letter, p. 1 of TUCP.

[5] CSPA et al September 16, 2014 comments, op cit, p. 5.

[6] See Order at ¶1(e), p. 22.

and transport them to barges at the upstream-most point this is reasonably feasible, for barge transport to Suisun or San Pablo Bay. In addition, the Bureau should capture and transport juvenile salmon migrants from the San Joaquin River downstream of Friant Dam to the same barges, rather than dumping them at the confluence of the lower San Joaquin River with the Merced River, as the Bureau did in 2014. In the absence of such a program, allowing exports at D-1641 levels under flow conditions in the lower San Joaquin River will have severe impacts on San Joaquin River and tributary salmon and steelhead, to a level that will have unreasonable effects to fish and wildlife.[7]

In sum, the TUCO, if adopted, would allow measures that would have unreasonable effects on fish and wildlife. The protective measures in the TUCO should be retained. The variances requested in the TUCP should be denied, especially considering that rainfall in the Sacramento Valley has been near or above normal and Shasta and Oroville have almost a million acre-feet more water in storage than this time last year. In addition, we recommend adding protections and a strong array of mitigation actions rather than relaxing standards. In the long run it makes no sense to destroy public trust fishery resources for a minute augmentation of water supply.

TUCP Proposed Changes

The Temporary Urgent Change Petition (TUCP) requests temporary modification of requirements included in Water Board's Decision 1641 (D-1641) to meet water quality objectives in the Water Quality Control Plan (Plan) for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Specifically, the TUCP requests modifications to water right requirements to meet the Delta outflow, San Joaquin River flow, Delta Cross Channel (DCC) Gate closure, and Delta export limits objectives. Reclamation and DWR are requesting these temporary modifications in February and March in order to respond to unprecedented critically dry hydrological conditions as California enters its fourth straight year of below average rainfall and snowmelt runoff. The TUCP also identifies possible future requests for further modifications to operating standards for the period from April to September.

The following are the proposed changes in standards:

1. The Delta Standard for the minimum net daily Delta outflow index (NDOI) during February through June is 7,100 cfs calculated as a 3-day running average. This requirement may also be met by achieving either a daily average or 14-day running average EC at the confluence of the Sacramento and San Joaquin Rivers of less than or equal to 2.64 millimhos per centimeter (mmhos/cm) (Collinsville station C2). **Proposed Change:** reduce minimum to 4000 cfs in February and March.
2. The San Joaquin River Delta inflow requirement for February and March is 710 or 1,140 cfs. **Proposed Change:** reduce to 500 cfs in February and March.
3. X2 Days at Port Chicago (days EC is to be 2.64 millimhos per centimeter at Port Chicago - station C2 – 9 days according to Table 4 D-1641. **Proposed Change:** no requirement.
4. The Delta Cross Channel (DCC) is to remain closed in winter. **Proposed Change:** Opening DCC as necessary to protect water quality.

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[7] Of the juvenile salmon transported from the San Joaquin River downstream of Friant to confluence of San Joaquin and Merced rivers, 2 were captured in the Mossdale trawl and none were detected at Chipps Island.

5. Delta Exports are not to exceed 1500 cfs when NDOI is less than 7100 cfs or 45% of Delta Inflow. **<u>Proposed Change:</u>** Allow exports when NDOI is less than 7100 cfs up to 45% of Delta Inflow.

Possible Future Change Requests

According to the TUCP, potential future requests to modify D-1641 requirements include: (1) additional requests to modify Delta outflows to balance upstream storage and fish protection, (2) requests to move the compliance point for the Western Delta agriculture salinity objective from Emmaton to Three-Mile Slough, (3) additional requests to modify San Joaquin flows at Vernalis, and (4) requests to modify Rio Vista flow requirements. Additionally, the Petitioners may request flexibility provided in D-1641 to adjust the export limits to modify required averaging periods for sporadic storm events. There will also likely be a request to place salinity barriers in the Delta to minimize salt water intrusion into the Delta (so that the "last drop" of freshwater can be exported). Other water project funded actions may include preferential pumping at one or the other SWP and CVP export facilities in the South Delta to reduce fisheries impacts (which serves to mask true fish losses) and increasing hatchery production to mitigate for drought impacts.

These potential future requests, while not presently under consideration, will individually and collectively result in serious biological harm to beleaguered pelagic and salmon fishery populations that are already at or near historically low abundance levels. The parties filing this Object and Petition for Reconsideration will provide comprehensive comments on the consequences of these potential actions when DWR and the Bureau formally request them.

Order in Response to TUCP

The Order in response to the TUCP would make the following temporary modifications to D-1641 requirements during February and March:

- Modify minimum monthly Delta outflows to 4,000 cfs;
- Modifies minimum monthly San Joaquin River flows at Vernalis to 500 cfs;
- Allow the DCC Gates to be opened consistent with triggers to protect fish species;
- Adds export constraints to allow exports of 1,500 cfs when Delta outflows are below 7,100 cfs regardless of DCC Gate status and allows exports up to D-1641 limits when Delta outflows are above 7,100 cfs and the DCC Gates are closed. (Note this is not consistent with the TUCP, which requests higher exports.)
- The Order appears to drop the requirements for D-1641 Table 4 minimum X2 requirements, though it leaves open the option of a flow pulse for the estuary.

The Order also includes additional requirements to assure that the changes: do not impact other legal users of water, do not have unreasonable impacts of fish and wildlife and other beneficial uses; and are in the public interest. The Order also provides for a higher pulse flow to be scheduled to benefit fish species (possibly to satisfy Table 4 requirements in D-1641). The magnitude, timing, and duration of this pulse flow will be determined through the upcoming consultation process.

The Order would allow the DCC gates to be opened during February and March as needed to reduce upstream releases to maintain salinity conditions in the interior Delta. To ensure that gate opening avoids impacts to fish, the Order would require the gates to be operated in compliance with the DCC Gate Triggers Matrix in the April 2014 Drought Operations Plan and Operational Forecast. The opening would only occur when exports are less than 1500 cfs.

The Order does not approve the requested interim export level of 3,500 cfs when NDOI is at least 5,500 cfs. This request may be allowed in subsequent orders.

The Order would reserve the Executive Director's authority to require modifications to the Order to protect fish and wildlife or other uses of water based on additional information, including information that may be presented during the State Water Board workshop on February 18, 2015, concerning the Order and the Drought Contingency Plan.

Given the present condition of fisheries, the Order's modification of D-1641 standards developed and implemented through extensive evidentiary proceedings will unreasonably affect fish and wildlife. The standards themselves have proven to be seriously inadequate and fishery populations have continued to decline. To further weaken these inadequate standards will cause grievous irrevocable harm and potential extinction.

Status of the Fish Populations

The populations of fish species that depend on the Delta including Chinook salmon, steelhead, sturgeon, American and threadfin shad, striped bass, and delta and longfin smelt have all declined over the past eight years that included six years of drought (2007-09; 2012-14). The latest indicators show near historic or historic low levels of abundance for all of the Delta's pelagic species. All indications are that the populations that depend on the Delta are at extreme risk of added mortality under the present winter 2015 conditions. According to the Order most of the limited production of wild winter run salmon smolts moved into the Delta during the December storms and have yet to leave to the Bay and Ocean. In addition, the spawning runs of adult delta and longfin smelt moved upstream from the Bay into the Delta during the December flow events. They have begun spawning in areas where hatched larvae are highly vulnerable to South Delta exports.

If we have learned anything from decades of relentlessly declining fisheries, it is that the present D-1641 standards, as well as the current biological opinions, are not protective of listed species or the Bay-Delta ecosystem. Given this irrefutable fact, species that are hovering on the precipice of extinction should not have to assume an additional burden of further sacrifices to benefit water exports and deliveries. Any "balancing" of the public trust or beneficial uses must take the present jeopardy of these fisheries into consideration.

Over the last several years, CSPA has appeared before the State Water Board on a number of occasions and described the consequences of weakening already inadequate standards protecting fisheries and water quality. Unfortunately, our predictions came true. In August 2013, we prepared a report that documented the adverse impacts to Delta smelt from the Board's relaxation of standards (Attachment 1, *Summer of 2013*). Again, in October 2014, we prepared a report chronicling the impacts from the relaxation of standards on Delta smelt (Attachment 2, *Summer of 2014*). As we predicted, the population abundance of Delta smelt, as well as all pelagic species, again declined (Attachment 3, Fall Midwater Trawl 2014 Annual Fish Abundance Summary). In January 2015, the California Department of Fish and Wildlife's initial Spring Kodiak Trawl revealed that abundance of spawning Delta smelt had declined 84% from the last year's abysmal low.[8] With Delta smelt abundances at a historical low, the State Water Board inexplicably proposes to again relax critical standards established to protect these species in drought conditions. We further advised the Board in 2014 that efforts to reserve cold water in Shasta Reservoir to protect fisheries would come to naught if the reservoir was drained to provide water to CVP contractors. That too came to pass, as deliveries to Sacramento River contractors depleted the reservoir leaving insufficient water to maintain temperatures and protect spawning beds (Attachment 4, Demise of Winter Run in Summer 2014). Consequently, Winter-run salmon losses approached 95%.

Winter 2015 Risk Factors

Following a respite from drought in a wet December, there was record low January precipitation that brought back drought conditions to the Central Valley and the Bay-Delta. With limited restrictions in the Delta Standards for January[9], moderate exports brought salvage events at the south Delta fish facilities of winter run Chinook salmon smolts and adult delta smelt. Surveys indicate that most of the 2014-year class of winter-run salmon have yet to move out of the Delta on their emigration from the Sacramento River to the Bay and Ocean. Early warning trawl surveys in January indicate the presence of adult longfin and delta smelt in the lower San Joaquin River near Jersey Point and Prisoners Point, a sign that the smelt may likely spawn in the Central and South Delta where newly hatched larvae will be highly vulnerable to South Delta exports. The January Larval Smelt Survey indicates recently hatched longfin smelt larvae are concentrating in the low salinity zone in the Western Delta[10]. Gages measuring salinity indicate that as Delta outflow has fallen in January, the low salinity zone has moved upstream into the central Delta. With each high tide, large amounts of the low salinity zone water are "pumped" into Franks Tract and Old River where water and planktonic fish like the smelt are likely to be entrained into the flow to the south Delta export pumps. Little remains of the fresh water in the Delta left over from the December storms. This pool of fresh water has been diverted from the Delta by high January exports. Any benefits to Delta conditions accruing from the February storms will likely dissipate if not followed by subsequent rain events. No one really believed the Delta needed protection in January when D-1641 standards were originally being developed in 1995. What has happened this January is already a demonstration that this lack of concern was a grave mistake.

The Smelt Working Group has met weekly in January and has carefully documented these risks and what may be in store for the fish[11]. Each week, it indicates that "some of its members" are worried, but the conclusion is often "*distribution information does not indicate advice is*

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[8] http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SKT

[9] 4500 cfs minimum Delta outflow; export allowed up to 65% of Delta inflow.

[10] http://www.dfg.ca.gov/delta/data/sls/CPUE_Map.asp

[11] http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm

warranted". We believe the level of concern is greater than expressed, and recommend that the Board hear from individual members of the Smelt Working Group at the upcoming workshop.

In early February of this year, 600,000 hatchery winter-run Chinook juveniles were released from the Livingston Stone fish hatchery into the Sacramento River near Redding. Although flows downstream at Bend Bridge reached 50,000 cfs on February 7 and was as high as 20,000 cfs two days later, the pulse downstream of Keswick was less than 5000 cfs, and was back to a the minimum release of just of 3000 in two days. Salmon and steelhead immediately downstream of valley rim dams, the major spawning areas on regulated rivers, receive no direct flow benefit from storms when reservoirs are storing all inflow possible. The absence of designed flow releases from Sacramento Valley rim dams timed to take advantage of the natural flow increases due to accretion further downstream leaves salmonids without benefit from natural events. In the Sacramento system, this can be partially mitigated by trucking hatchery fish downstream to points where tributary inflow is substantial.

In the San Joaquin system, there is little significant tributary inflow downstream of rim dams; peak flow at Vernalis increased to just over 1260 cfs after on February 10 while flows at in the Sacramento were over 30,000 cfs. More extensive transport of salmon juveniles from the Merced River Fish Hatchery and the upper San Joaquin program to Suisun or San Pablo bays may be needed this year, and capture of wild fish may need to be considered.[12] Delta pumping during outmigration of the remaining San Joaquin system salmon will be particularly harmful this year, particularly if pulses are exported, as they were in 2014.

In fact, exporting storm-fed pulse flows have already been permitted twice this winter, once in early December and once in early February, to the detriment of Delta smelt and Winter-run and Spring-run salmon. Each of these events had major consequences to the Delta and its low salinity zone. The two storm events brought considerable freshwater inflow to the West Delta at Jersey Point. However, the salinity response at Jersey Point lagged and salinity actually increased slightly on he ascending limb of the flow pulse. The reason is that, on the ascending limb of the flow pulse, a precipitous increase in exports drew water from the West and Central Delta. The low salinity zone, which had been located between Antioch and Jersey Point on the lower San Joaquin River was drawn eastward (upstream) into Old River. Flow across the Northern to the Central Delta is limited because the Delta Cross Channel is closed during winter to protect Sacramento River salmon from being diverted into the Central Delta. There was a lag in salinity response to the increased freshwater flows. The expected EC response at Collinsville didn't show up until 10 February, several days after the storm pulse reached Freeport. Unfortunately, Delta exports were allowed to increase prior to the flushing of the low salinity zone west of the Delta. Increases in Delta exports following storm events should not be allowed until storm pulses have pushed the low salinity zone into the West Delta.

D-1641 Delta Outflow Standards Do Not Comport With Actual Measured Outflow

The Net Delta Outflow Index (NDOI) relied upon by the State Water Board in establishing outflow standards protecting fish is based upon flawed calculations and is significantly different that the measured outflow at United States Geological Survey (USGS) gages that record

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[12] Escapement to the Merced and Tuolumne rivers in 2014 was in the hundreds; to the Stanislaus less than 3000.

cumulative Delta outflow (Attachment 4, *Delta Smelt on the Scaffold*, pp. 3-7). At times, particularly during periods of low flow, this discrepancy is substantial. For example, during May 2014, the NDOI calculated Delta outflow at 3,805 cfs while the measured outflow as a minus 45 cfs. The agencies have long known that the NDOI does not reflect actual outflow.[13] Relaxing standards and reducing Delta outflow requirements to levels that are likely to result in negative outflow will lead to unreasonable and potentially irreversible affects upon fisheries and cannot serve the public interest. The State Water Board must develop Delta outflow standards that accurately reflect actual Delta outflow.

Continuing Violations of Interior Delta Salinity Standards are Ignored in the Order

The Order is strangely silent regarding the chronic violations of D-1641 interior Delta salinity standards. For example, between 13 January and 11 February 2015, salinity continually exceeded the salinity standard of 1.0 mmhos/cm at Brandt Bridge and Old River Near Tracy. There were frequent violations of standards at Vernalis and Old River Near Middle River. DWR and the Bureau are under a Cease & Desist Order issued by the State Water Board that requires notification of exceedences and a description of measures that are being taken to alleviate violations. However, the relaxation of flow requirements requested in the TUCP and provided in the Order will only exacerbate salinity levels and increase violations. As the temporary increase in streamflow from recent rains subsides, salinity concentrations are likely to significantly increase. Salinity standards protect numerous beneficial uses including agriculture and aquatic life, and simply ignoring these long-established standards is contrary to law, cannot be in the public interest, and represents an unreasonable adverse impact to fisheries and Delta agriculture.

Chronic Relaxation of Promulgated Standards Because Water Agencies Refuse to Pursue Reasonable Measures to Address Drought Emergencies that Occur 40% of the Time Cannot be in the Public Interest

The State Water Board has now relaxed Bay-Delta standards established to protect fisheries and water quality in each of he last three years. In March 2014, CSPA chronicled the habitual pattern of mismanagement by the state and federal water project operators at a Board workshop (Attachment 4, *CSPA Presentation*). We pointed out that California experiences drought conditions 40% of the time, yet the state and federal projects continue to operate and deliver water as if there is no tomorrow. The projects draw down reservoir storage under the assumption that the coming year will be wet, providing little reserve storage in the event the following year is dry. In the event of another dry year, they endeavor to maximize deliveries in the hope that it will rain next year. This pattern has repeated itself for decades, most recently during the 2007-2000 and 2013-2015 droughts. Project operators have refused to adjust to the state's Mediterranean climate and over-subscribed water delivery system. They count on the Board to bail them out by relaxing standards and reducing water flows crucial to healthy and reproducible fisheries. And the Board has obliged the projects by relaxing standards thereby encouraging them to continue to operate on the edge of crisis while fisheries, hanging on the lip of extinction, pay the price.

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[13] http://www.water.ca.gov/dayflow/docs/2014_comments.pdf

The Bay-Delta ecosystem is a national treasure similar to the Everglades, Chesapeake Bay, Great Lakes or Puget Sound. It is a public trust resource – a property right - owned by all of the citizens of the state and nation. Since the State Water Project became operational, population abundances of the estuary's native pelagic and salmonid fisheries and associated lower trophic orders have declined by one to two magnitude. Listed Delta smelt abundance has plunged to historic lows each of the last two years. The continuing collapse of fisheries is a continuing indictment of the Board and fishery agencies to fulfill their public trust mandates. Yet, the State Water Board has again relaxed minimal standards developed for drought conditions even as Sacramento Valley rainfall is near or above normal and Sacramento Valley Reservoirs contain more than a million acre-feet more water than they did last year.

It cannot serve the public interest to sacrifice species that evolved over millennia in one of the great natural ecosystems on the planet simply to provide a marginal increase in water delivery to projects that have repeatedly refused to adjust an over-subscribed water delivery system to the reality of available water supply. It cannot serve the public interest to continue to encourage water project operators to take reckless risks under the assumption that the Board can be counted upon to waive standards and bail them out from the consequences of their mismanagement. It cannot serve the public interest to choose almonds over salmon and exports to junior water rights holders over sustainable Delta agriculture.

The TUCP and the Responding Order are Contrary to Law

While the State Water Board has been granted water quality permitting authority pursuant to the federal Clean Water Act, establishment and modification of water quality criteria must be approved the U.S. EPA. The Board has said on several occasions that it does not necessarily agree with this requirement but petitioners believe the Board to be in error and a failure to seek approval for the present waiver of standards would represent a serious violation of the Clean Water Act. In any case, the Order violates the federally promulgated Estuarine Habitat Criteria for the Bay/Delta estuary at CFR 131.37.[14] This federal criteria requires that salinity shall not exceed 2640 micromhos/cm specific conductance at 25 degrees Centigrade (measured as a 14-day moving average) at the confluence of the Sacramento and San Joaquin Rivers at specific locations near Roe and Chipps Islands for a specified number of days each month between 1 February and 20 June depending on the 8-River Index. Specifically, for February, the 2650 micromhos/cm standard at Chipps Island must be maintained throughout the month under all historical 8-River Index values for January. Other federal criteria include Stripped Bass spawning criteria between 1 April and 31 May and Suisun marsh criteria. The Board has consistently ignored these federally issued criteria and we believe failure to enforce these criteria has contributed to plummeting fish populations.

For all of the reasons herein, we believe the evidence would show that the proposed TUCP, and the Order to the degree that it grants the measures requested in the TUCP, violate state and federal laws, including but not limited to:

The California public trust case law;

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[14] http://www.ecfr.gov/cgi-bin/text-idx?node=pt40.22.131&rgn=div5#se40.22.131_137

Article 10, Section 2 of the California Constitution;
The California Water Code;
SWRCB D-1641;
SWRCB D-990;
The California Endangered Species Act;
Section 5937 of the California Fish and Game Code;
Section 7 of the Federal Endangered Species Act;
The Federal Clean Water Act;
The Federal CVPIA doubling standard for salmon and steelhead; and
The Governor's 2014 Declaration of Drought Emergency.

As the Board knows from previous drought proceedings, petitioners believe the overwhelming evidence of violation of these statutes by the Bureau and DWR is arbitrary and capricious, and the Board's refusal to hold evidentiary hearings violates our due process rights under both the state and federal constitutions.

Specific Comments on the Responding Order

We present below a point-by-point response to sections of the Order Approving in Part and Denying in Part DWR and the Bureau's January 23, 2015 Temporary Urgency Change Petition.

The allowance of continued exports of 1,500 cfs when outflows are below 7,100 cfs and exports up to D-1641 limits when outflows of 7,100 cfs are maintained (but not additional Table 4 requirements) was made to mitigate to some extent the significant water supply reductions to municipal, industrial, and agricultural water users that are likely to occur due to the drought. The water supply considerations discussed above are considered urgent due to the significant impacts to water supplies that occurred last year and the associated severe economic impacts in some communities, especially given that foregone opportunities to conserve storage for later use cannot be regained. (Order, p. 16)

Comment: We recognize the urgency, but the urgency for the fish is just as important and needs to be discussed on an equal level by the Board. The water that would be delivered or temporarily stored pursuant to TUCP, while needed for other beneficial uses, but it is absolutely essential for the survival of fish and other Bay-Delta public trust resources.

As discussed above, dry conditions during this winter are expected to adversely affect spawning and rearing conditions for delta smelt and longfin smelt, and migration conditions for winter-run Chinook salmon, spring-run Chinook salmon, steelhead trout, and North American green sturgeon. While maintaining the D-1641 Delta outflows and San Joaquin River flow requirements would provide some short term benefits to these species, the overriding effects of the drought would persist. (Order, p. 17)

Comment: We disagree that the benefits of maintaining standards are "short term benefits;" failure to survive is not a short-term issue. Relaxing standards would add further to the burden on fish by taking away what little is left of the freshwater essential to the Bay-Delta Estuary. The effects of drought were greatly exacerbated in January when the Low Salinity Zone was pulled upstream into the Delta because of a combination of high volume January exports and inflow diminishing to very low levels.[15] This already created a prolonged period of high mortality. The augmented exports requested in the TUCP (though so far denied in the Order) would allow a repeat of these conditions, which are not allowed in February and March under D-1641.

With respect to the DCC Gates, the Petitioners propose to open the gates as necessary to reduce intrusion of high salinity water into the Delta while preserving limited storage in upstream reservoirs and reducing impacts to migrating Chinook salmon through use of the DCC Gate triggers and consultation with the RTDOMT. The principal benefit of opening the DCC Gates in February and March is to move more fresh water to the interior Delta, using less storage releases than would be needed to achieve the same salinity with the gates closed. This freshening of the Delta will maintain water quality at the CVP and SWP export pumps and the intakes of Contra Costa Water District that are needed for the protection of public health and safety. (Order, p.18)

Comment: The reality is that opening the DCC gates as requested would not save reservoir storage, but would be required to enable higher exports without at the same time pulling saltwater into the West Delta. Higher storage releases would be necessary to control salinity intrusion with the higher exports requested in the TUCP. Maintaining minimum exports will alleviate the need to open the DCC.

With the DCC Gates open, there is potential for decreased survival of Sacramento River-origin species as they move through the central Delta. Potential hazards include increased entrainment, predation, and salvage. These impacts will be reduced by implementing the DCC Gate closure criteria proposed in the TUCP. Further, the tradeoff with maintaining upstream storage will also reduce impacts to other uses as discussed above. The State Water Board concludes that the potential for impairment to instream beneficial uses from this temporary change is not unreasonable considering the potential impacts to agricultural and municipal water supplies and potentially fish and wildlife that could occur if the temporary change is not approved. (Order, p. 18)

Comment: The impacts of DCC gate opening will not be mitigated by implementing gate closure criteria (e.g., temporary gate openings and the following closures). Fish that have already moved through the gates will be trapped in the interior Delta. Monitoring is insufficient to assess any real risks to the populations from DCC openings. Sudden opening and closure of the gates causes large scale shifts in Delta hydrodynamics that affect fish survival and migration success.

With respect to the export limits, as stated in the TUCP and discussed above, unlike Water Year 2014, winter-run Chinook salmon and delta smelt are currently at an elevated risk of entrainment impacts due to their spatial distribution, abundance, and productivity, as well as

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[15] Standards for February and March call for the LSZ to be centered around Collinsville in eastern Suisun Bay and not upstream in the Delta.
http://cdec.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=8873&end=02%2F09%2F2015+10%3A52&geom=huge&interval=120&cookies=cdec01

predicted storm events later in the week. Spring-run Chinook and steelhead are also predicted to have an increased risk of entrainment in the south Delta as their migration increases through February and March. Given this heightened concern, this Order does not approve the requested interim pumping level of 3,500 cfs when NDOI is at least 5,500 cfs. This Order does allow for exports of 1,500 cfs when NDOI is at least 4,000 cfs, regardless of whether the DCC Gates are open. This Order also allows for exports of natural and abandoned flows above Flow and salinity objectives in the Bay-Delta Plan and D-1641 were developed based on historic hydrologic conditions. Provisions for the extreme dry conditions currently being experienced were therefore not considered in either the Bay-Delta Plan or D-1641. (Order, p. 18)

Comment: The situations for fish are surprisingly similar between winters 2014 and 2015. We appreciate the Board's greater awareness of these conditions following what happened in 2014. We are astounded that the fisheries agencies do not appear to share the Board's "heightened concern." Despite last year's lessons, NMFS appears to believe that the TUCP will conserve Shasta storage. The 2014-year class of winter-run and spring-run was lost because of storage releases for water supply and not for releases to maintain Delta standards. A real benefit to winter-run would accrue from keeping exports to a minimum and not dropping outflow to 4000 cfs; thus enabling more winter-run to the Bay and Ocean. Finally, there is nothing in any record that supports the contention by Executive Director Howard, made in a workshop last year and now repeated in the Order, that provisions for extreme conditions were not considered in the Bay-Delta Plan or D-1641.

These approvals are consistent with export levels approved in 2014, which balanced water supply needs with the need to protect of fish and wildlife. While there may be impacts to fish and wildlife from entrainment and associated effects associated with the approved export levels, these changes are reasonable given the extremely limited water supply conditions that water supply contractors and wildlife refuges are likely to face this year and the prolonged depletions of groundwater resources that have occurred associated with the drought. (Order, p. 19)

Comment: The "approvals" and "changes" are not balanced. They are one-sided, even when unchanged from 2014 or D-1641. The fish and the Bay-Delta ecosystem are again being asked to bear the burden of drought with little consideration or benefit in order to add a very small increment of water for water supply (less than the amount of added water stored in Shasta in one day from the recent storms). These changes are not "reasonable." Allocating some of the added Shasta storage for fish would be reasonable**.**

With respect to the interim export level, there is not currently adequate information to indicate that this export level is reasonable given the current status of species and their distribution in the Delta and the potential additional risk of entrainment from the interim pumping level on various species, especially given the precipitation events that are projected this week, which may increase turbidity and associated entrainment risks as discussed above and in the Biological Reviews. While the TUCP and Biological Reviews state that additional monitoring will be conducted to evaluate this issue, it is not clear if that monitoring would be adequate to avoid entrainment impacts given the concerns with the accuracy of entrainment estimates due to the extensive amount of water hyacinth in the vicinity of the export facilities, especially for eggs and larvae. Further, the water supply tradeoffs are not clear given the unknown water contract *allocations that will occur this year. This matter will be further discussed at the Board's workshop on February 18, 2015. If adequate information is developed to determine that the interim pumping level could be allowed in a way that would not have unreasonable impacts on fish and wildlife, this Order may be amended to allow for the interim pumping level.* (Order, p. 19)

Comment: The export levels of 2500-3500 cfs to date in February and the export of 4000-6000 cfs in January were entirely "unreasonable" given current conditions. Not only is monitoring "unclear" but it is also after–the-fact. As to "adequate information," we present what we believe is adequate in our attachments to these comments. We fear that the Board will receive a chorus of arguments and counter-arguments at the workshop on subjects that have been argued in many forums over the past several decades to no avail. There is no "adequate information" that will change the consequences of last year's actions and the fisheries disasters of the last twenty years: the listed species and many other species are at record lows even under full D-1641 protections. Now is not the time to reduce even these minimal protections.

Based on the above, the State Water Board concludes that the potential for impairment to instream beneficial uses from the approved temporary changes is not unreasonable considering the impacts to agricultural, municipal and wildlife refuge supplies or fish and wildlife that could occur if the temporary changes are not approved. (Order, p. 19).

Comment: We disagree with the conclusion that the approved changes are "not unreasonable". The impacts to fish of reduced outflow and opening the DCC gates is not a reasonable burden to place on the fish populations and the Bay-Delta ecosystem. On the contrary, further actions are necessary to protect these public trust resources.

The population of delta smelt, which is listed as threatened under both ESA and CESA, has reached record low numbers, as measured by the Fall Midwater Trawl (FMWT), which began in 1967, and the first survey of the Spring Kodiak Trawl (SKT). (Order, p. 9)

Comment: The Board recognizes that the FMWT 2014 index of delta smelt is at a record low, as is the catch level in the January 2015 SKT survey. Equally relevant are the record low index from 2014 Summer Townet Survey and previous record low indices from these surveys from the 2007-2009 and 2012-2013 drought years.

Further, according to the Biological Reviews submitted with the TUCP, monitoring has not detected any delta smelt in the Cache Slough and Liberty Island complex, a location that in previous years has been considered a spatial refuge for delta smelt, especially from the effects of entrainment and the Project pumping facilities. According to the Biological Reviews, this has shifted the centroid of the delta smelt population distribution south and closer to the Project export facilities, making the condition of and risks to the delta smelt in the lower Sacramento River and San Joaquin River of greater importance to the overall status of the species. (Order, p. 9)

Comment: Adult delta smelt were found in the north Delta in the Ship Channel. Since the January SKT survey, "early warning monitoring" with Kodiak trawls has only occurred in the

Lower San Joaquin River from Jersey Point and Prisoners Point, with adult delta smelt collected at both locations, thus indicating the potential for substantial smelt spawning in the Central and South Delta. Regardless, larval smelt spawned in north Delta remain vulnerable to south Delta exports via Three Mile Slough and False River.

Storm events in December are thought to have stimulated a pre-spawning migration of delta smelt that has expanded the population west and east of its centroid, which led to increased entrainment at Project facilities this water year that was not observed last water year. Further, delta smelt captured in trawl surveys during 2014 were reported to have been in relatively poor condition and of smaller size than in previous years, which indicates a potential for lower fecundity and survival of offspring in 2015. (Order, p. 9)

Comment: Spawning in the central Delta, subsequent poor condition, and smaller size are just some of the risk factors facing the fish during drought conditions. Contributing to such risk by reducing outflow and allowing exports is not reasonable.

Because of elevated water temperatures from the drought and the pre-spawn migration that has occurred, an early spawning event is expected this year, which will expose both adult delta smelt and eggs to the changes considered under the TUCP. (Order, p. 9)

Comment: This is equally true for larval and juvenile smelt.

The Smelt Working Group (SWG) expects that delta smelt will remain in the central and south Delta in preparation for spawning as long as conditions remain turbid during February and March (SWG notes, January 5, 2015). (Order, p. 9)

Comment: Adult smelt will spawn upstream of the Low Salinity Zone in freshwater. Exports (pulling freshwater from the north Delta toward the south Delta export pumps), opening the DCC, and the salinity barriers under consideration will if allowed freshen the central and south Delta, stimulating spawning in these extremely dangerous locations.

Continued minimal reservoir releases proposed in the TUCP are expected to cause the centroid of the delta smelt population to shift inland, exposing a greater proportion of the population to entrainment if the distribution does not shift back into the Sacramento River in response to lower outflow and higher water transparency. Potential impacts from entrainment are expected to be higher in February than March because more delta smelt will be spawning in February than in March. (Order, p. 9)

Comment: January and February exports, not minimal reservoir releases, have moved the Low Salinity Zone upstream into the Delta. The pool of freshwater from the December storms has been removed by exports. It will take time for the new storm water to flush the Delta again, although increased exports will now limit such flushing[16], because exports are allowed based on

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[16] Exports as of February 11, 2015 are greater than 6000 cfs. http://cdec.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=8873&end=02%2F09%2F2015+10%3A52&geom=huge&interval=120&cookies=cdec01

inflow, not on real outflow, X2, or EC at Collinsville, Emmaton, or Jersey Point. Entrainment risks to delta smelt will be high into the summer.

According to the Biological Reviews, with the DCC Gates closed it is expected that adult delta smelt entrainment will be low if NDOI is between 4,000 cfs and 5,500 cfs and pumping remains at 1500 cfs. However, under turbid conditions, if pumping increases on the ascending limb of the hydrograph in response to increased NDOI between 5,500 and 7,100 cfs, model results indicate that if delta smelt are east of Franks Tract, upward of 70 percent of adults are at risk of entrainment. **(**Order, p. 10)

Comment: Any adult or juvenile smelt unlucky enough to find itself in Frank's Tract or other areas of the central and south Delta will likely not survive.

However, according to the Biological Reviews, the December and January SKT surveys showed that the majority of Delta smelt were distributed around Decker Island and the confluence of the Sacramento and San Joaquin Rivers. (Order, p. 10)

Comment: Delta outflow was near 15,000 cfs or higher during these surveys. Saltwater subsequently intruded upstream of these areas as outflows fell to 5000 cfs or below by mid–January, when adult smelt were detected at Prisoners Point well upstream in the central Delta.

As such the Biological Reviews conclude that adult delta smelt would only be expected to shift their distribution towards the south Delta if another rain event occurs and turbidity is dispersed again into the southern Delta. The Biological Reviews conclude that as long as the proposed operations do not draw delta smelt into the San Joaquin River in the vicinity of Prisoner's Point, it is unlikely that delta smelt distribution will change in a way that increases their entrainment risk. The Biological Reviews call for continued monitoring and evaluation to inform real-time operations. As discussed above, rain events are expected later this week that may increase turbidity in the Delta. (Order, p. 10)

Comment: With outflow at 7000 cfs and exports at 2500 cfs, any increase in Delta inflow unless very substantial would be exported, since the limit is 45% of Delta inflow. If inflow increases to 15,000 cfs from the present 10,000 cfs, exports would increase to 6750 cfs, while outflow would increase to only 8250 cfs. Such conditions in February would be dire for delta smelt, longfin smelt, and Chinook salmon, as they were in December and early January. A strengthening of D-1641 standards is needed to protect fish; relaxation of the existing protections will make things worse.

Longfin smelt, which is listed as threatened under CESA and is a candidate for listing as threatened or endangered under ESA, experienced its second lowest FMWT index in 2014. According to the Biological Reviews, reductions in flows associated with the TUCP are expected to shift the centroid of the longfin smelt population inland, which will expose a greater proportion of the adult population to entrainment at the Project facilities. The primary concern for entrainment however is for larval and juvenile longfin smelt. Based on the current longfin smelt distributions, a reduction in outflows is expected to result in an elevated risk of entrainment of larvals and juveniles during February and March.

Comment: The same risks occur for delta smelt larvae and juveniles in February and March, but were not mentioned in the section of the Order that discusses delta smelt.

The strong and consistent relationship between outflows and survival of juvenile to age-1 longfin smelt, also supports the conclusion that reductions in outflows this year will reduce the survival of these fish (Jassby et al. 1995, Kimmerer 2002, McNally et al. 2010). However, detection of larval longfin smelt in the Cache Slough Complex and the current distribution of adults indicate that the larval population is likely to be widely dispersed during February and March. (Order, p. 10)

Comment: the first Larval Smelt Survey (early January) shows larval longfin smelt were concentrated in the Low Salinity Zone in the west Delta. Subsequent reductions of outflow have moved this zone into the central Delta, where longfin larvae are at high risk of entrainment due to export operations.

Therefore, operations are not expected to affect the species population as heavily as may be the case with delta smelt unless a greater percentage of the population migrates into the lower San Joaquin River. (Order, p. 10)

Comment: Significant numbers of longfin smelt larvae were already identified in the January Larval Smelt Survey in the Lower San Joaquin River portion of the western Delta.

The Biological Reviews conclude that entrainment risk of adult longfin smelt is likely to be low unless their distribution narrows and shifts further into the interior and south Delta, which may occur as a result of the expected precipitation. (Order, p. 10)

Comment: This risk factor was already apparent in late January and early February. Expected precipitation and associated higher exports will only worsen the risk.

The endangered winter-run Chinook salmon is of particular concern during dry years. Winter-run inhabit the upper reaches of the Sacramento River below Keswick Dam and are entirely dependent on adequate temperature and flow conditions below the dam for their survival. Despite temperature modeling that indicated that temperatures could be maintained below 56 degrees throughout the 2014 temperature control season immediately below the dam under the conditions that existed last year, temperature control was lost several weeks before the end of the egg incubation life stage last year. As a result, the 2014 winter-run brood year (BY) is estimated to have experienced 95 percent mortality. This is of particular concern given winter-run's endangered status and extremely limited distribution, reducing the resilience of this species to withstand impacts, especially during a prolonged drought. **(**Order, p. 10)

Comment: Absent substantial increase in storage levels at Lake Shasta and/or dedication of adequate storage to instream uses, conditions and risks will be no different this year.

According to the Biological Reviews, it is currently estimated that 95 percent of the surviving winter-run are in the Delta and rearing extensively in the lower Sacramento River and Delta with some fish in the south Delta waterways.

Comment: If 95% of the year class already perished, and 95% of the remaining 5% is now in the Delta, what is the possible justification for cutting outflow, opening the DCC, and (as requested) increasing exports?

The 2014 spawning run of spring-run Chinook salmon returning to the upper Sacramento River also experienced significant impacts due to drought conditions as well as from sedimentation resulting from rain events in late October through December that covered eggs leading to mortality. According to the Biological Reviews, the run was lower in four of seven locations compared to the 2013 escapement,8 with considerably lower escapement observed in the Butte Creek and Feather River Hatchery. Spring-run eggs in the Sacramento River underwent significant, and potentially complete, mortality due to high water temperature downstream of Keswick Dam starting in early September when water temperatures exceeded 56 degrees Fahrenheit. Extremely few juvenile spring-run Chinook salmon have been observed this year migrating downstream on the Sacramento River during high winter flows, when spring-run originating from the upper Sacramento River, Clear Creek, and other northern tributaries are typically observed, which presents a significant concern for the population. Based on the currently available data, the majority (80-90 percent) of yearling spring-run are estimated to be in the Delta, while less than 5 percent remain upstream of Knights Landing on the upper Sacramento River and less than 15 percent have already exited the Delta. Up to half (25-50 percent) of young of the year spring-run are estimated to be in the Delta, while 50-75 percent remain upstream, and less than 5 percent are estimated to have already exited the Delta. **(**Order, p. 11)

Comment: The Delta is an important rearing area. If many salmon move with the storm flows into the Delta under conditions of higher exports and negative flows at cross Delta sloughs, they will die at the pumps or on their way to the pumps. The excellent pool of fresh and low salinity water provided by the December storms is now gone. If anything, some young salmon have likely moved upstream from Suisun Bay into the Delta during January. If 100% of the Sacramento River year class of spring-run have already perished, and 50-75% of the surviving juveniles from the few remaining tributaries are now in the Delta, what is the possible justification for cutting outflow, opening the DCC, and (as requested) increasing exports?

Steelhead and green sturgeon have also likely been affected by the drought, but given the difficulty in sampling for these fish it is problematic to determine exactly how the species have been affected. Impacts to other species, including commercially important fall-run are also expected to be realized as a result of the drought. If these impacts are severe enough they could result in significant impacts to the commercial and recreational fishing industry." (Order, p. 11)

Comment: Adult and juvenile abundance of these listed species is monitored. Runs are down. Hatchery returns of steelhead are very low this year. Budgets for the hatchery programs have been decimated. Funds are needed to continue trucking hatchery fall-run smolts to the Bay; otherwise hatchery production will simply be dumped into the rivers to experience low drought flow to and through the Delta. The prognosis for commercial and sport fishing for salmon, steelhead, sturgeon, shad, striped bass, and other Central Valley fish is indeed poor.

According to the Biological Reviews, both positive and negative effects of the TUCP are expected on salmonids and green sturgeon during February and March. The TUCP changes are expected to affect the abundance and spatial distribution of juvenile winter-run and spring-run Chinook salmon, steelhead, and green sturgeon. The modifications to outflows and DCC Gate operations may affect the spatial distribution and abundance of adult winter-run Chinook salmon and green sturgeon. Life history diversity of steelhead may be affected due to reduced survival through the San Joaquin River migration corridor. The modification of outflow, exports, and Vernalis flows may reduce survival of juvenile listed salmonids, steelhead and green sturgeon, and may modify their designated critical habitat. The modification of juvenile winter-run and spring-run Chinook salmon and steelhead survival due to changes in outflow would occur primarily in migratory corridors in the north Delta due to increased entrainment into the interior Delta. Steelhead survival may also be reduced along the mainstem of the San Joaquin River downstream of the Stanislaus River leading to increased entrainment of steelhead toward the Project pumping facilities. (Order, p. 11)

Comment: The Order correctly notes that the conservation of water in storage is essentially a water supply benefit. We see no "positive effects" to fish of the variances allowed in the Order. The lower San Joaquin River flows (from 700 cfs to 500 cfs) will cause lower tributary flows and lower survival to and through the Delta for San Joaquin salmon and steelhead.

There may be impacts from opening the DCC Gates on Sacramento River origin salmonids from straying and entrainment. However, the Biological Reviews conclude that those effects will be minimized due to compliance with the DCC Gate operations matrix which limits opening of the DCC when migrating ESA-listed salmonids are present in the lower Sacramento River region. Further, during the period the gates are open, exports are proposed to be limited to 1,500 cfs. This export limit along with the implementation of the DCC Gate Triggers Matrix is expected to minimize entrainment of existing rearing fish in the interior and south Delta. (Order, p. 12)

Comment: The Delta is a significant rearing habitat under low inflow/outflow and low exports. Opening the DCC will move more young salmon into the interior Delta to rear. They will be more likely to survive if exports are kept low. However, if the projects subsequently close the DCC and increase exports when inflows increase (usually at Freeport on the Sacramento River), the fish rearing in the interior Delta will not survive in the absence of a positive QWEST (positive San Joaquin River outflow). USFWS studies have shown very poor survival of salmon rearing in the interior Delta following closure of the DCC.

While there may be impacts from modifications to outflows, San Joaquin River flows and opening of the DCC on salmonids and other species, the Biological Reviews conclude that these effects would be offset by increased storage in Project reservoirs which will help to maintain water temperatures necessary for Chinook salmon, steelhead, and green sturgeon over the summer and fall of 2015. (Order, p. 12)

Comment: There is need for storage releases only to meet the requested higher exports that the Order does not allow. Storage releases are and can remain at the minimums required by tailwater requirements, which include spring-summer water temperature maintenance in the Sacramento River. Low storage last summer was a direct consequence of downstream export/diversion requirements for water supply, not water released to meet Delta standards. Increased storage must come from limiting exports, transfers of stored water and in-basin diversions. Trading between one and the other doesn't help. For example, last year summer water transfers via south Delta exports were exempt from Delta standards. Water released from Shasta to maintain water temperature in the Sacramento River for salmon went eventually to water contractors not the Bay. The only way to save the cold water pool in Shasta is to reduce allocations for exports to water contractors. Reducing requirements for Delta outflow provides little water, saves little or none of the coldwater pool in Shasta, and causes severe stresses to the Bay-Delta ecosystem and all the listed fish species.

The Biological Reviews conclude that without the changes to outflows, the low reservoir storage conditions are likely to result in extremely high egg mortality or even complete failure of natural BY 2015 spring-run Chinook and winter-run Chinook below Keswick Dam due to high water temperatures. Relaxation of Delta outflow requirements and San Joaquin River flow requirements, while still continuing to meet required tributary releases from Oroville, Folsom, and New Melones, is projected to enhance the opportunities for summertime cold water management across Project reservoirs in 2015." (Order, p. 12)

Comment: The D-1641 standards allow for relaxation of Delta outflow standard of 7100 cfs for February and March to conserve reservoir storage. Reducing this outflow standard in February and March will not improve Shasta reservoir storage absent subsequent reductions in water supply deliveries. So far in February, no added reservoir releases have been necessary to meet this outflow standard. However, allowing the full 45% export limit under the standard could require additional reservoir releases, which would affect Shasta storage. .

With respect to the proposed modifications to exports, the Biological Reviews find that unmeasured mortality of salmonids in the south Delta region may increase as a result of increased entrainment towards the Project facilities under the proposed intermediate export rate of 3,500 cfs when NDOI is between 5,500 and 7,100 cfs. (Order, p. 12)

Comment: The Water Board concedes that operations since mid-January of 5000 cfs exports with only 5000 cfs outflow resulted in unnecessary increased mortality of juvenile salmonids that had moved into the Delta during the December storms. Given present salmonid population levels, increased though not precisely quantifiable mortality provides ample justification to conclude that higher exports and reduced outflow results in unreasonable effects to salmon and smelt.

The Biological Reviews also find that mortality may increase due to long transit times on the San Joaquin River where exposure to degraded habitat and predaceous species is constant. The Biological Reviews conclude that under exports of 1,500 cfs with NDOI of 5,500 or less, reduced entrainment and salvage of listed species at the Project fish collection facilities adjacent to the

South Delta export facilities would be expected due to increased positive flows in the south and central Delta. (Order, pp. 12-13)

Comment: Exports of 1500 cfs would lead to "reduced entrainment and salvage" as compared to greater exports, but to increased entrainment and salvage as compared to D-1641 required outflow, because flows in the south and central Delta would continue to be negative, not "increased positive". Exports of 1500 cfs and with outflow of 4000 cfs would continue to put salmonids and other fish populations at risk in the Delta.

In determining whether the impact of the proposed changes on fish and wildlife is reasonable, the short-term impact to fish and wildlife must be weighed against the long-term impact to all beneficial uses of water, including irrigated agriculture, municipal and industrial use, use by wildlife refuges, salinity control in the Delta, and other fish and wildlife uses, if the changes are not approved. Further, the effects that have occurred to the species over several years must be considered." (Order, p. 17)

Comment: The key question that the State Water Board must address is whether the Order is reasonable. The fisheries agencies submitted concurrence letters on January 29 (NOAA) and January 30 (USFWS and DFW) indicating that the changes proposed in the TUCP are in compliance with ESA and CESA requirements; however, as the Order states, these concurrences did not address the question of whether impacts to fish and wildlife would be unreasonable. In addition, the fisheries agencies concurred with the TUCP based on the unfounded assumption that the following statement from the TUCP was true: "*While maintaining flows consistent with unmodified D-1641 outflow requirements would provide some short-term support for these species, the reduced storage concomitant with these outflows would lead to substantially worse impacts later in the year. Conversely, while a modified D-1641 which reduces outflows may decrease Delta survival of the salmonids during winter, it will conserve reservoir storage which will lead to increased cold water pool available later in the year to provide upstream fishery benefits*." (Attachment 1 of TUCP, p. 10). In 2014, D-1641 flows were reduced, but the assumed benefits of increased storage were undermined by exports and deliveries to settlement contractors. The resulting insufficient storage in Lake Shasta led to a 95% population loss of endangered winter-run salmon and a historic low for Delta smelt. Given the present population levels of both pelagic and anadromous species, increased reservoir storage must come from reduced exports and water deliveries, and not at the expense of eliminating fundamental biological requirements for fish.

Specific Comments on the January 23, 2015 TUCP

The following are CSPA's comments on details of the proposed changes and supporting rationale presented in Attachment 1 of DWR and the Bureau's January 23, 2015 Temporary Urgency Change Petition.

Comments on Proposed Changes:

1. *DWR and Reclamation request a Delta outflow of 4,000 cubic feet per*

second (cfs),

Comment: February and March Delta outflow requirements are provided to protect many aspects of the Delta environment not the least winter run Chinook passage through the Delta, upstream adult winter and spring run Chinook on their spawning runs, steelhead smolt emigration through the Delta, adult steelhead spawning runs, and longfin and delta smelt spawning and early rearing. One critically important function of outflow is estuary productivity including the pelagic organism food web concentrated in the Low Salinity Zone (LSZ). An outflow of 4000 cfs greatly reduces estuary productivity from San Francisco Bay into the Delta. With proposed moderate exports the LSZ will be subject to direct exports from the South Delta and general degradation by high inflows of reservoir water needed to meet the export demands. The proposed outflow of 4000 cfs is to be measured by the standard NDOI, a notoriously poor predictor of true Delta outflow, particularly at low outflow levels. Such a low and unpredictable outflow will put Delta and longfin smelt at added risk of extinction by greatly increasing their vulnerability to south Delta exports and degrading their pelagic habitat within the Delta. Such low outflows and proposed exports may cause more smelt to spawn in the central and south Delta, essentially sacrificing this production to the south Delta exports (Smelt Working Group discussions[17]). Both species are already at record low levels from three years of drought and previous TUCs. Adding this new and unprecedented combination of changes would put these species at extreme risk of extinction. Winter-run Chinook have been devastated by these same three years of drought, causing Interior to raise and release more hatchery smolts at Redding to replace lost production. Reducing smolt survival through the Delta will put the population at further unnecessary risk Last year, deliveries to water contractors diminished critically needed outflow and at the same time depleted the Shasta cold-water pool. The State Board should require that Shasta water releases first meet outflow and achievable temperature requirements and meet water delivery requirements as a benefit of meeting temperature requirements; not the other way around. Providing winter storage releases to provide higher survival for downstream migrating young winter run may be, on balance, just as important as maintaining summer water temperatures. Regardless, given the state of fisheries, both of these needs should have priority over demands for water contractors from Shasta in spring and summer.

2. *San Joaquin River at Airport Way Bridge, Vernalis river flow of 500 cfs*

Comment: Reducing the winter flow requirement of the San Joaquin from an already low level of 700 cfs to 500 cfs will simply further burden the San Joaquin salmon and steelhead populations by reducing tributary flows needed for spawning and rearing, as well as survival of smolts through the Delta. All the efforts toward salmon recovery in the San Joaquin system will simply go for naught if winter flows continue to be reduced.

3. *Modify the closure requirement of the Delta Cross Channel gates (DCC) to address Delta water quality concerns consistent with fish protections necessary as determined by the RTDOT,*

Comment: Allowing the opening of the DCC during February and March to reduce salinity levels in the South Delta will simply allow higher export levels while increasing the probability

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[17] http://www.fws.gov/sfbaydelta/cvp-swp/smelt_working_group.cfm

that emigrating winter and spring run Chinook salmon and steelhead will be diverted into the Central and South Delta to die. These fish will not be able to complete their emigration as they will succumb to the many forms of mortality in the Delta including loss to the export pumps. The closure of the DCC in winter has long been a key element of the salmon and steelhead recovery plans as well as being an essential element of the historic 1995 Delta Agreement and D-1641 Standards.

4. *Allow higher export rate that reflects an appropriate balance between competing beneficial needs in light of the drought.*

Comment: The existing requirement that no more than 35% of Delta inflow may be exported from the Delta in February and March is a key provision of D-1641. A January limit of 65% has devastated the Delta in many dry years, showing clearly that not including January in the 35% criteria was a mistake. D-1641 already allows the standard to be increased to 45% in droughts. Allowing the exports to reach 50% or higher of total Delta inflow puts all the listed species at further increased risk and would further degrade the pelagic organism habitat of the LSZ and other zones of the estuary. Not only does it encourage higher exports, but it also releases of what little reservoir storage that remains upstream, because higher allowed exports would increase demands on Shasta reservoir storage by water contractors south of the Delta.

Comments on Supporting Rationale

"These changes will allow management of reservoir releases on a pattern that will conserve upstream storage for fish and wildlife protection and Delta salinity control while allowing for critical water supply needs exports." (Attachment 1, p. 1)

Comment: The proposed changes will increase Central Valley reservoir releases and Delta exports, while devastating already stressed Central Valley and Bay-Delta ecosystems and populations of listed fish species.

"As set forth in the 2015 DCP, critical operational considerations for these and other changes includes providing essential human health and safety needs to CVP and SWP service areas throughout 2015 and 2016 if drought conditions continue, reducing critical economic losses to agriculture, municipal and industrial uses, maintaining protections for endangered species and other fish and wildlife resources, providing water for state, federal and privately managed wetlands, and maximizing operational flexibility within existing law and regulations. These critical operational considerations are detailed further in the 2015 DCP." (Attachment 1, p. 2)

Comment: Early last year the Board determined that "essential health and safety needs" could be met by exports less than 1500 cfs. The TUCP levels would be well above these levels to provide more water for water contractors during the present drought. Continuing such higher exports will put the future availability of water for health and safety exports at risk. The proposed changes will not maintain protections for endangered species and other fish and wildlife resources. Higher exports and demands on reservoir storage will put all of the Central Valley fish and wildlife at greater risk.

“Upstream Reservoirs: Upstream reservoirs will be operated through the winter and spring to preserve and build storage. Upstream reservoir storage, while improved from end of September 2014 storage, remains extremely low in the early part of WY 2015. Reclamation and DWR will be trying to develop cold water resources in the winter and spring in those reservoirs where temperature management is needed later in the year. This may include working with the Sacramento River Settlement Contractors to shift early spring demand later into the year to conserve water in Shasta Reservoir, if warranted.” (Attachment 1, p. 5)

Comment: The TUCP changes will increase demands on reservoirs, reducing “cold water resources” in Shasta and Folsom reservoirs. Shifting demands of Settlement Contractors will make more water available for planned summer water transfers that increase risks to smelt as well as winter run salmon in summer.

Water Supply: Throughout dry conditions, CVP and SWP systems will be operated to lessen critical economic losses to agricultural, municipal, and industrial uses due to water shortages through project water deliveries and by facilitating voluntary water transfers and exchanges to the extent possible, while balancing the needs of upstream storage, fishery and wildlife resource protection, and operational flexibility. A key to minimizing water supply shortages for economic purposes will be to take advantage of opportunities to export natural or abandoned flow in the winter and spring while maintaining Delta water quality and minimizing adverse effects to listed fish. Release of stored water in summer and fall will be managed to concurrently benefit in-stream temperature objectives, wildlife objectives, meet Sacramento Valley in-basin needs, and preserve carry over storage to meet objectives in WY 2016. (Attachment 1, p. 5)

Comment: The existing standards have already “balanced” needs while providing far from needed resource protections over the past 20 years. The TUCP asks to remove what little protections exist. Taking advantage of “opportunities to export natural or abandoned flow” is an ominous statement of the true intent of the TUCP. There are no natural or abandoned flows into, through and out of the Delta, only those that have been painstakingly negotiated over the past several decades. These conditions are termed “in balance”. Removing these protections will permanently setback recovery of Delta and Central Valley river systems and their protected resources.

D-1641 Related Actions: Reclamation and DWR may seek adjustments under D-1641, including: (1) triggers for modified X2 criteria to balance upstream storage and fish protection, (2) triggers for moving Western Delta Ag compliance point (i.e., Emmaton to Three-Mile Slough), (3) San Joaquin flows at Vernalis, (4) Rio Vista flow requirements, and (5) Net Delta Outflow requirements. Additionally, Reclamation and DWR may exercise the flexibility provided in D-1641 to adjust the E/I ratio’s averaging period for sporadic storm events (similar to 2014). (Attachment 1, p. 6)

Comment: This is an ominous statement suggesting the further removal of limited protections from D-1641 in upcoming TUCPs. We will specifically address any such requests when they are formally proposed.

Preferential Pumping: The projects will consider a facility shift in exports in April and

May so that minimal pumping will occur at the SWP's Banks Pumping Plant and the majority will occur at the CVP's Jones Pumping Plant. This export shift will increase survival of salmonids through these facilities, since fewer fish will enter the SWP, where loss is higher due to substantial pre-screen mortality associated with Clifton Court Forebay. Combined exports would remain the same. The amount of shifted pumping from Banks to Jones would be made available to the SWP. (Attachment 1, p. 6)

Comment: In January the projects did the opposite: they shifted exports to Banks to reduce the salvage count of smelt as it approached its federal BO take limit. Banks "takes" less smelt because smelt do not make it through Clifton Court Forebay to be salvaged and counted as take. Exports from Banks are far worse because water is taken directly from the north and west Delta via the central Delta, thus having greater probability of involving salmon and smelt and the LSZ. Loss of salmon and smelt in Clifton Court Forebay prior to the fish salvage facilities is 70-90% or higher. Therefore, focusing exports at Banks not only limits the total take count, but also has a greater effect on smelt and their critical habitat. However, there is considerable evidence that "take" at the federal facility is underreported, and this should also be addressed.

Temporary Emergency Drought Barriers: If hydrologic forecasts show there will be insufficient water in upstream reservoirs to repel the saltwater and meet health and safety and other critical needs, then installation of Emergency Drought Barriers will be considered to lessen water quality impacts. Excessive salinity increases in the Delta could render the water undrinkable for 25 million Californians and unusable by farms reliant upon this source. Temporary rock (rip-rap) Emergency Drought Barriers may be installed at up to three locations in the Delta during drought conditions in 2015, or in a subsequent year if necessary, to manage salinity in the Delta when there is not enough water in upstream reservoirs to release to rivers to repel the saltwater. Consultation on installation and operation of the barriers will be conducted on the barriers prior to installation and may require additional adjustments to D-1641. (Attachment 1, p. 6)

Comment: Again, an ominous statement for the future, which bears some immediate response. Drought barriers on Sutter and Steamboat Slough would degrade over 30 miles of designated critical habitat for endangered species (salmon, smelt, sturgeon, and steelhead) in Sutter, Steamboat, Cache, and Miners sloughs by making the sloughs "dead-end" with little or no flow, more invasive aquatic plants, warmer water temperatures, and lower concentrations of dissolved oxygen. At present, the sloughs pass over 20 percent of the Sacramento River inflow to the Delta, more than 1000 cfs in each channel. Blocking these channels will force this flow down the main Sacramento channel into the interior Delta. With the DCC open (as proposed in the TUCP), more of the inflow will flow into the central Delta and be available for exports. Higher exports could then be achieved without higher inflows (reservoir releases). Simply put, the projects would export more water than presently available for the same reservoir releases. That water will come from reduced Delta outflow (also proposed in TUCP). In addition, less fresh water would enter the 30+ miles of sloughs and mixes into the critical habitats of the lower Yolo Bypass (Cache Slough, Liberty Island, and Ship Channel). The third barrier on False River would do the same: higher exports could be achieved with the same Delta inflow, because salinity from False River would no longer enter Old River and the south Delta on incoming tides.

Hatchery Operations: Livingston Stone National Fish Hatchery (LSNFH) managers will coordinate with Delta Operations for Salmonids and Sturgeon (DOSS) to time the hatchery release of winter-run Chinook salmon to coincide with favorable hydrologic conditions, and to track their movement down the Sacramento River into and through the Delta utilizing acoustically-tagged winter-run Chinook salmon released at approximately the same time and real-time acoustic receivers deployed in the Sacramento River and Delta at various locations. DOSS will review the real-time acoustic tag data to determine the likely migration timing and distribution of the hatchery winter-run in the Sacramento River and into the Delta, and advise NMFS and Water Operations Management Team (WOMT) of potential risks to hatchery winter-run salmon. (Attachment 1, p. 6)

Comment: With the DCC opening, higher exports, and lower Delta outflow, significant numbers of winter-run Chinook salmon are unlikely to survive transit to and through the Delta to the Bay and Ocean. There will be no "favorable hydrologic conditions" under the TUCP. Hatchery winter-run should be trucked and barged to the Bay. Reclamation should fund this provision. These winter- run hatchery smolts will have as little chance of survival as the 60,000 spring run Chinook hatchery smolts released in 2014 in the San Joaquin River (few if any survived).

Transfers and Exchanges: Reclamation and DWR will continue to facilitate water transfers and exchanges. If these transfers or exchanges are conveyed through the Delta outside the transfer window described in the 2008 and 2009 BiOps (July-September), Reclamation and DWR will consult with USFWS and NMFS prior to conveyance of the transfer water and DWR will request a consistency determination from CDFW. (Attachment 1, p. 7)

Comment: Transfers within and outside the "transfer window" will occur under the TUCPs to move water through the Delta from the north to the south. Transfers are exempt from rules and allow substantial added exports as well as reservoir releases in drought years. Transfers are devastating to the delta smelt in the summer of drought years. Any transfers involving storage releases are devastating to all listed fish species as well as future water supplies. Transfers outside the "summer window" could be devastating to other species such as winter-run and spring-run Chinook. To date, all transfer requests have been approved with little environmental review or affects assessment.

Throughout dry conditions, CVP and SWP systems will be operated to lessen critical economic losses to agricultural, municipal, and industrial uses due to water shortages through project water deliveries and by facilitating voluntary water transfers and exchanges to the extent possible, while balancing the needs of upstream storage, fishery and wildlife resource protection, and operational flexibility. (Attachment 1, p. 5)

Comment: To date, no formal "balancing" has occurred.

The proposed export limits are intended to provide additional water deliveries while not exceeding proportional regulatory standards regarding exports (e.g. E/I). The proposed DCC gate operations balance risks to both water quality and outmigrating anadromous fish during February and March, in the event of the extreme low Delta inflows. Hence, this proposal seeks to *balance the short-term and long-term habitat needs of some of the covered anadromous and pelagic species during the entirety of WY2015.* (Attachment 1, p. 10)

Comment: The proposed changes are not "proportional". The present constraints are minimal at best at protecting the listed species. Opening the DCC in winter will kill listed salmon and steelhead. Reductions in outflow will kill listed pelagic species. The "take" will not be observable except in future population counts and in sport and commercial fisheries. The TUCP provides no "balancing." It simply takes more of what little is left.

Unlike WY2014, winter-run Chinook salmon and Delta Smelt are currently at an elevated risk of entrainment impacts, due to their spatial distribution, abundance, and productivity. (Attachment 1, p. 11)

Comment: With its drought conditions, TUCP changes, and summer water transfers, WY2014 was a great debacle leading to devastation of winter run and delta smelt: Delta smelt had record low indices (see Order, p. 9). Because of the 2014 orders, the species are already at elevated risk and exposure, which will hinder future potential recovery of their populations. Adding to these conditions, as proposed in the TUCP, would have huge environmental and economic consequences far beyond what is considered in the TUCP or the Temporary Barriers EIS/EIR.

Spring-run Chinook and steelhead are predicted to have an increased risk of entrainment in the South Delta as their migration increases through February and March. Green sturgeon are typically exposed to a broad spectrum of flows and exports over the course of the year, and thus not likely to have increased risk of entrainment due to changes in flows. Increased monitoring and coordination, extending from the interagency drought response efforts in WY2014, is intended to support management of key entrainment risk indicators in the Interior and South Delta as part of the proposed operations. The evidence for the risk of entrainment for each species of concern will be considered as part of the biological review being conducted to support the Endangered Species Act consultation process." (Attachment 1, p11)

Comment: Fisheries already have an increased risk during the February-March migration period. The TUCP proposes to increase that risk by adding higher exports, lower outflows and DCC openings. These are "the key entrainment risk indicators." Adult delta smelt were being collected in January and February at all the key indicator stations, and little was done to protect them. The Smelt Working Group appeared confused and was not unanimous in its review, warnings, or recommendations. Apparently, there was little concern that the LSZ was moving into the Delta with its population of larval longfin smelt. The absence of January fishery protections was devastating to fish populations and their critical habitats. The TUCP seeks to remove the slightly stronger but limited February-March D-1641 protections. The primary purpose is to preserve reservoir storage for higher exports and contractor deliveries and not to provide storage that benefits the Bay-Delta ecosystem and its listed fish species.

Specific comments on the USFWS Concurrence Letter[18]

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[18] http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/fws2usbr_pitts013015.pdf

"*Reclamation has determined that the proposed drought actions will result in no additional adverse effects on Delta Smelt or its critical habitat for the months of February and March 2015 beyond those previous analyzed in the 2008 BiOp. The Service accepts Reclamation's determination.*" (Letter.)

Comment: It is incredible that the Service would state that 1) 4000 cfs outflow with 1500 cfs exports, and 2) 5500 cfs outflow and 3500 cfs exports would not cause adverse effects on Delta Smelt or its critical habitats. It is particularly vexing given their subsequent statements on the positive relationship between population abundance and winter-spring Delta outflow.

*"The smelt supporting information document includes an analysis of the effects of the actions on larval Delta Smelt production using the recently published new information in the Interagency Ecological Program (IEP) Management, Analysis, and Synthesis Team's (MAST) An Updated Conceptual Model of Delta Smelt Biology technical report. The MAST report may provide valid new information that spring outflow has a positive impact on the relative abundance of Delta Smelt surviving to the early juvenile phase of their life cycle." (*Letter*)*

Comment: It is further incredible that the Service acknowledges that science points to a positive relationship between outflow and smelt abundance, but treats it as "new science" worthy of consideration in future assessments of the effects of TUCPs. Yet they are fine with lower outflow and higher exports, and concur with the TUCP changes.

Comments On The NMFS Concurrence Letter[19]

"As mentioned above, winter-run eggs and juveniles in broodyear 2014 experienced approximately 95% temperature related mortality of the egg and fry life history stages last year. NMFS included this high mortality rate in its JPE, and estimated that approximately 124,521 wild juvenile winter-run from brood year 2014 are expected to enter the Delta. Based on discussions at the Delta Operations for Salmonids and Sturgeon Technical Work Group, >95% of young-of-year winter-run are currently rearing in the Delta, and <5% have exited the Delta (past Chipps Island)." (Letter, p. 5)

Comment: NMFS shows concern for summer river temperature conditions (need to maintain storage and cold-water pool), but recognizes that most of the 2014 wild smolt production is already in the Delta and subject to the harmful consequences of the TUCP's proposed changes.

"*In addition, Livingston Stone National Fish Hatchery increased its winter-run broodstock collection in 2014 by three-fold, and is currently rearing approximately three times (current estimate is 610,000) the typical hatchery production of juvenile winter-run, awaiting release into the upper Sacramento River in February. The hatchery winter-run are an important component of broodyear 2014, and therefore, are important to track as they migrate down the Sacramento River, and enter and exit the Delta.*" (Letter, p. 5)

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[19] http://www.waterboards.ca.gov/waterrights/water_issues/programs/drought/docs/tucp/2015/nmfs_stelle012915.pdf

<u>Comment</u>: NMFS shows concern for these hatchery smolts that have yet to pass through the Delta but appears to be less concerned that these smolts will be adversely impacted by the TUCP's proposed increased exports, reductions in outflow and opening of DCC.

"Inherent in the interim contingency plan is the objective to meet multiple needs with limited water resources. Most of the adverse effects to species identified in the Biological Review (e.g. , the potential for reduced survival of outmigrating salmonids from the Sacramento Basin due to modifications to outflow criteria in D-1641) are the consequences of actions intended to result in conditions (e.g., greater Shasta Reservoir storage and a greater cold water pool) that will preempt more severe adverse effects to species (e.g., potentially running out of cold water in Shasta Reservoir to meet the needs of winter-run and spring-run egg incubation throughout the temperature management season). Some adverse effects to species identified in the Biological Review (e.g., the potential for increased entrainment of salmonids in the South Delta region due to modifications to export limits that allow above-minimum exports when outflow is at least 5,500 cfs, but less than the requirement in footnote 10 of Table 3 of D-1641) are the consequences of actions intended to result in conditions (e.g., greater south-of-delta storage) that will pre-empt adverse effects to non-fish-and-wildlife beneficial uses of CVP and SWP project water (e.g., municipal and agricultural purposes)." (Letter, p. 6)

<u>Comment</u>: NMFS assumes that the TUCP actions will save upstream storage when in fact the minimal conserved storage will largely benefit of exports and water deliveries. Maintaining 7000 cfs outflow with 1500 cfs exports is clearly preferable to 5500 outflow and 3500 cfs exports under the same minimum allowed reservoir releases.

"In conclusion, NMFS concurs that Reclamation's Project Description is consistent with Action 1.2.3.C and meets the specified criteria for an interim contingency plan. We are making this finding based on both the Biological Review attached to Reclamation's letter, which describes the additional adverse effects of the drought and drought operations, and our conclusion that the potential effects of the types of operations proposed in the interim contingency plan were considered in the underlying analysis of the CVP/SWP Opinion, which considered that droughts would occur and concluded that implementation of the RPA, including Action I.2.3.C, is <u>not likely to jeopardize the continued existence</u> of Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, California Central Valley steelhead, the Southern Distinct Population Segment of North American green sturgeon, and the Southern Resident killer whales, and <u>will not result in the destruction or adverse modification of their designated critical habitats</u>. Furthermore, the best available scientific and commercial data indicate that implementation of the interim contingency plan will not exceed levels of take anticipated for implementation of the RPA specified in the CVP/SWP Opinion." (Letter, p. 7)

<u>Comment</u>: We disagree that lower outflows and higher exports in February and March are not likely to further jeopardize the listed salmonids or negatively affect their designated critical habitats. Lower outflow in February and March from the present 7000 cfs to 4000 cfs would have adverse effects to winter-run and spring-run salmon survival to and through the Delta. Exports of 3500 cfs at relaxed outflow (5500 cfs outflow) would have adverse effects on salmon and their designated critical habitats in the Delta. Opening the DCC when exports are below 1500 cfs will result in increased take. Because these changes would have little or no benefit to preserving the storage or cold-water pools in upstream reservoirs, there are no beneficial tradeoffs.

Under what conditions may this Objection and Petition for Reconsideration be disregarded and dismissed?

The TUCP should be denied and the Order rescinded.

In its place, the Board should order the following short-term measures to protect fish and wildlife:

1. Allow only minimum exports when EC Collinsville >2.64 mmhos or when outflow is less than 7100 cfs as determined by daily average Delta outflow from the USGS gages at Rio Vista, Three Mile Slough, Jersey Point, and Dutch Slough. Minimum exports are 1500 cfs or lower if less is needed for Health and Safety. We recommend this action be taken to preserve the listed species and their critical habitat in the Delta. The action is consistent with the original intent of D-1641 to protect public trust resources in the Bay and Low Salinity Zone, because the location of X2 (2.64 EC) was found to and continues to be related to the success of many Bay-Delta fishes and the quality of many Bay-Delta estuary habitat features.
2. If inflow increases from storms and unbalanced Delta conditions occur, then exports should only be allowed up to the D-1641 35% of Delta inflow, provided the conditions in #1 above are met. All existing OMR restrictions per the OCAP BOs must apply. During the ascending and descending limbs of storm derived high outflows, exports should be ramped up and down, respectively to (1) preserve habitat integrity (e.g., habitat gradients of salinity and temperature) within the interior Delta most influenced by exports, and (2) to reduce risks to any localized concentrations of special status fish species.
3. Hatchery programs should be enhanced to ensure maximum production and survival to the ocean during the drought. Hatchery operators should truck or, preferably, barge hatchery produced salmon and steelhead to the Bay to ensure maximum survival. If possible, such transport should occur before April 1. Winter-run and spring-run hatchery Chinook smolts should be trucked to the lower Sacramento River near Knights Landing and then barged to the Bay. This would greatly enhance survival and minimize straying. This approach is already being developed by East Bay MUD with fall-run on the Mokelumne. A similar approach should be adopted at the Feather and American hatcheries for the respective runs of salmon raised at these facilities, as well as any planned releases of San Joaquin River spring-run salmon. The Bureau and DWR should be required to fund any added costs associated with these enhanced hatchery practices.
4. The Board should require management of delta hydrology through EC and gauged outflow, not NDOI. EC recorders and USGS gauges located throughout the river, Delta, and Bay provide a better management tool than the estimated NDOI.
5. The Bureau and DWR should install the Head of Old River Barrier to increase migration success of San Joaquin salmon young.
6. The projects should release 200 cfs into the Yolo Bypass through the Fremont Weir, Colusa Basin Drain, and Sacramento Ship Channel to minimize poor habitat conditions in the Cache Slough lower bypass region of the north Delta. This would alleviate the

negative net flows occurring in the area from local diversion demands that threaten rearing salmon and smelt.

7. DWR should use the Montezuma Slough salinity control weir to sustain Low Salinity Zone habitat in Montezuma that would be present under proposed conditions (#1 above).
8. The Board should require the RTDOMT to operate the Delta Cross Channel gates in real time to minimize export losses of smelt and San Joaquin salmonids during periods of high Delta inflows to minimize negative OMR and improve positive QWEST flows.
9. The Board should require the DWR and the Bureau to adjust exports to the natural monthly tidal cycle to minimize negative effects on Delta hydrology and fish habitat and entrainment risk conditions.
10. The Board should require DWR and the Bureau to shift exports to Tracy facility to minimize effects of exports. Per unit of export, Banks impacts appear to be greater than Tracy impacts.
11. The Board should require pulse flow releases timed to coincide with storms to stimulate outmigration of fish directly below rim dams and to improve and sustain benefits of natural high flow events.
12. The Board should require the projects to reduce exports during higher flows (if any) from San Joaquin. The Board should not allow exports greater than 1500 cfs exports during San Joaquin pulses. The Board should not allow export of San Joaquin pulses as is currently allowed under D-1641 Critically Dry year standards and as was allowed regardless of Delta outflow last year.
13. At no time in the December-March period should OMR flows exceed the -5,000 cfs limit. At no time should they exceed -2,000 cfs when EC at Jersey Point exceeds a daily average of 500.
14. The Board must hold an evidentiary hearing on the requested TUCP and on necessary measures to protect gravely threatened fish species during current drought and depleted storage conditions.

A true copy of this protest has been served upon the petitioners by e-mail (see below).

Date: February 13, 2015

Chris Shutes, Water Rights Advocate
California Sportfishing Protection Alliance

____

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Bill Jennings
____

Barbara Vlamis, Executive Director
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B. Vlamis

Carolee Krieger, Executive Director
California Water Impact Network

Carolee Krieger

Michael Jackson
Counsel to California Sportfishing Protection Alliance,
AquAlliance, and
California Water Impact Network

/s/ Michael Jackson

Attachments:
Att. 1, Summer 2013
Att. 2, Summer 2014
Att. 3, 2014 FMWT
Att. 4, Demise of Winter-run 2014
Att. 5, Delta Smelt on the Scaffold
Att. 6, CSPA Presentation 2014

Pursuant to the January 27, 2015 Notice of Temporary Urgency Change Petition, we have filed this protest, objection, petition for reconsideration and petition for hearing, on 13 February, via e-mail to: Rich.Satkowski@waterboards.ca.gov

Also pursuant to the January 27, 2015 Notice of Temporary Urgency Change Petition, we have served this protest, objection, petition for reconsideration, and petitions for hearing, on 13 February, via e-mail to the following:

Department of Water Resources, c/o James Mizell: P.O. Box 942836; Sacramento, CA 94236-0001; James.Mizell@water.ca.gov

Regional Solicitor's Office, c/o Amy Aufdemberge: Room E-1712; Cottage Way; Sacramento, CA 95825; Amy.Aufdemberge@sol.doi.gov

Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=107

Re: 2009 Drought Water Bank Transfers

State Clearinghouse #1996032083

Prepared by the State of California
The Resources Agency
Department of Water Resources

March 04, 2009

March 04, 2009

Addendum to the
Environmental Water Account
Environmental Impact Statement/Environmental Impact Report

http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=107

State Clearinghouse #1996032083

Prepared by the State of California
The Resources Agency
Department of Water Resources

Introduction

This Addendum has been prepared as part of the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) (2004) and Supplement (2008) for the Environmental Water Account (EWA). The Addendum notes and discusses three minor changes to the EWA project as analyzed. The EWA EIS/EIR includes the Department of Water Resources (DWR) as the lead State agency for the California Environmental Quality Act (CEQA) and the Bureau of Reclamation (Reclamation) the lead Federal agency for the National Environmental Policy Act (NEPA). *CEQA Guidelines Section 15164* provides guidelines for preparation of an Addendum to an EIR.

The EWA is an existing and ongoing CalFED program that seeks to increase protection to the fish resources of the Bay-Delta estuary. These protections go beyond those afforded by the regulatory baseline identified in the 2000 Record of Decision for the CalFED program through operational curtailments of the State Water Project (SWP) and Central Valley Project (CVP; collectively Project) operations at no net cost to Project deliveries and supply. The regulatory baseline was determined by the standards in the

1994 Bay-Delta Accord, as incorporated into Project operations and in the Project descriptions included in No Jeopardy Biological Opinions promulgated in 1995 under the federal Endangered Species Act (ESA) for Project operations. EWA operational curtailments include reductions in pumping, increases in flow through the Delta, and changes in the flow regime within Delta channels. The primary means for compensating for delivery reductions in Project water to the Project contractors on account of the curtailments is through transfers of up to 600,000 acre-feet per year of non-Project water.

Thus, two key features of the EWA are:

(1) Reductions in water deliveries resulting from Project operation curtailments beyond the water costs of the regulatory baseline; and
(2) Replacement of water supplies lost to the Project on account of these curtailments from non-Project sources through the acquisition and transfer of non-Project supplies.

The EWA originally provided that curtailments for additional fish protection beyond the regulatory baseline would be determined by the three Management Agencies (US Fish and Wildlife Service, National Marine Fisheries Service, and Department of Fish and Game). However, such curtailments have recently been pre-empted and imposed on the Project by the Federal District Court as an injunctive remedy under the federal ESA, with no provision, however, for the replacement of lost water supplies. Along with this asymmetrical, uncompensated application of curtailments beyond the regulatory baseline, two years of statewide drought and the prospect of a third year, were addressed in the summer of 2008 in an Executive Order issued by the Governor and in a subsequent Governor’s Proclamation of Drought Emergency for the Central Valley. In these documents, the Governor called for increased water transfers and in particular the establishment of a Drought Water Bank for 2009 to alleviate the reduction in deliveries and water shortages.

The 2009 Drought Water Bank (DWB) thus will be the mechanism for acquiring and transferring water to replace Project supplies lost and that will be lost due to the judicially mandated operational curtailments, aggravated by the conditions of drought. These transfers will not come close to making up the mandated losses below the regulatory baseline. Nor will they be at no cost to Project contractors. This source of water must be paid for by its recipients, and no offset or credit is planned to be given for losses due to the imposed curtailments.

In addition, the DWB acquisitions will be available to users others than SWP and CVP contractors. In this sense, the purpose of the EWA transfers is being generalized on account of the dry conditions to all water users suffering curtailments, not just Project contractors; but the essential purpose of the transfers program remains the same: the need to replace reductions in accustomed water deliveries and supplies by water transfers. Although the DWB is not restricted to SWP and CVP contractors, the fact that Project facilities will be used in securing or delivering the water under the DWB means that the great majority will go the SWP and the CVP service areas; as does the fact that Project contractors represent the vast majority of the state’s population.

The EWA originally looked to selected areas in the Central Valley for transfer water supplies, but only because at the time they represented the location of willing sellers. There is nothing in the EWA that intended to preclude looking to sellers in other similar areas of the Central Valley, and one purpose of this Addendum is to assess those other areas that appear to be available for transfers in 2009 that were previously unavailable. As the EWA’s exclusive mechanism in 2009 for securing replacement water for curtailed operations through transfers, the DWB is limited to the maximum 600,000 acre-feet analyzed in the EIS/EIR for the program.

There are three changes and additions proposed by the DWR in the DWB that differ from the Flexible Purchase Alternative project described in the EWA EIS/EIR. DWR, acting as Lead Agency, has determined that none of these changes involves new significant environmental effects, a substantial increase in the severity of previously identified significant effects, or substantial changes in the circumstances under which the project will be implemented. For these reasons, DWR has elected to prepare this Addendum to the EWA EIS/EIR.

The three changes that are discussed in this Addendum are as follows:

1. Change in giant garter snake mitigation in response to the Draft US Fish and Wildlife Service (USFWS) Biological Opinion
2. Change in the areas from which water may be purchased
3. Change in the areas to which water may be delivered

Following are explanations of each of these changes and the rationale for the determination that they constitute only minor technical changes and additions that involve no new significant environmental effects or substantial increases in severity of previously identified significant effects.

1. Change in Giant Garter Snake Mitigation

As part of the DWB, DWR will implement a series of conservation measures to offset the potential effects of rice crop idling and crop substitution water transfers on Sacramento Valley populations of giant garter snakes. These measures can be found in conditions in a Draft Biological Opinion issued by USFWS on November 18, 2008. This Draft Biological Opinion includes the following protections for the giant garter snake: 1) exclusion areas from rice crop idling that are known giant garter snake core habitats and habitat corridors, 2) description of rice land best management practices for the giant garter snake, 3) and idled rice crop land limitations of no more than 320 continuous acres, using a checkerboard pattern as the preferred layout.

DWR has prepared a Giant Garter Snake Baseline Monitoring and Research Strategy.

The implementation of this Strategy will provide significant contributions towards the development of a Giant Garter Snake Conservation Strategy for the Sacramento Valley. The Strategy has been reviewed and endorsed by State and Federal agencies and two giant garter snake experts, Eric Hansen and Glenn Wylie. Monitoring and research will be the primary tools to gather information on giant garter snake distribution, life history, and ecology. Monitoring will be designed to assess population structure, distribution, and movement within the Sacramento Valley and determine the existing (baseline) population of study sites. The duration of the monitoring and research study designs will incorporate the goal of including wet, dry, and normal hydrologic years.

Broad monitoring and research goals include:

a. Developing and implementing a monitoring plan for giant garter snake populations in the Sacramento Valley,
b. Monitoring giant garter snake populations for a minimum of ten years (subject to appropriations) using multiple survey methods (e.g., trapping, hand captures, and mark-recapture),
c. Using radio-telemetry and mark-recapture to study habitat use and selection, mortality rates, response to crop idling, and use of rice lands for a minimum of five years, and
d. Gathering enough data to make recommendations to minimize the effects of crop idling practices on the giant garter snake and make general conservation recommendations to the California Rice Industry Association to update their 1995 publication *Managing Ricelands for Giant Garter Snakes*. Conservation recommendations may include actions that rice farmers could implement to reduce potential impacts to the giant garter snake from rice farming, or actions a rice farmer could implement to increase the habitat value for the giant garter snake.

Specific research goals include:

a. Developing and implementing a radio-telemetry study for a minimum of five years (subject to appropriations),
b. Quantifying and evaluating the response (*e.g.*, movement patterns and survival) of giant garter snakes to changes in habitat conditions and landscape cropping patterns,
c. Quantifying and evaluating the response of giant garter snakes to crop idling including a specific experimental design to evaluate different block sizes and landscape patterns,
d. Examining the relationship of giant garter snake habitat use in relation to habitat availability and surrounding land use using GIS technologies,
e. Quantifying giant garter snake survival and population fecundity (*e.g.*, number of immature to adults) in relation to changing environmental and habitat conditions and identify variables that may be important correlates of survival and fecundity,
f. Quantifying minimum size of buffer zone between idled rice fields and suitable habitat, and
g. Providing recommendations for adaptive management of giant garter snakes with respect to water transfers.

In light of new scientific information, there are two modifications to the conservation measures contained in the 2003 EWA EIS/EIR. Both are based on the recognition of new data and changed circumstances since 2003. 1) A change in the idled block size from 160 to 320 acres, and 2) the locations from which water transfers can occur.

The expansion of the block size from 160 acres (1/2 mile on each side of a square) to 320 acres (approximately 3/4 mile on each side of a square) would change the distance a giant garter snake would travel through an idled block by approximately 1/4 mile or 1,320 feet. The original 160 acre block size was largely based on estimates of median home range size. Although the median is a useful number, the home range size of an animal is affected by many variables and may be a misleading indicator of the distance an animal can successfully travel between habitats. Estimates of maximum home range sizes and distances traveled suggest that a 320 acre block is a navigable size for a giant garter snake.

It is important to consider that when a giant garter snake emerges from aestivation in March or April, not all rice fields are flooded, and during that time, rice fields may not provide a habitat component that is significantly different from idled fields. Hansen (1986) found that giant garter snakes in the Sacramento Valley avoided large bodies of shallow open water (rice fields are generally over 100 acres in size and flooded to a depth of 3-5 inches). In general, rice fields do not provide high quality habitat for the giant garter snake until the rice plants emerge in the flooded rice field and reduce the amount of open water, typically in June. Before this time, permanent wetlands, flooded ditches, and flooded canals are important habitats. The seller will be required to maintain baseline water in major irrigation and drainage canals to serve as movement corridors and habitat for giant garter snakes during this period.

The expansion of the block size has the potential to expose giant garter snakes to more adverse habitat conditions and potentially increase their exposure to predators if a snake chooses to cross an idled block. However, telemetry studies suggest that a giant garter snake is unlikely to leave suitable habitat to cross large areas of upland (Wylie et. al 2003, Wylie and Amarello 2008). The probability that a snake enters a large block of upland is not likely to be significantly different based on whether an upland block size is 160 or 320 acres. External factors such as habitat disturbance and the surrounding landscape are likely more significant factors affecting long movements (Wylie et. al 1997, Wylie 1998, Wylie et. al 2002). Constraining idled parcels to a checkerboard pattern in which idled parcels may not completely share a common boundary, maintaining water in main ditches and canals, and excluding core habitats and corridors is expected to help reduce any potential impacts of increasing the crop idled block size on the giant garter snake population.

A part of the Giant Garter Snake Baseline Monitoring and Research Strategy will include implementation of a radio-telemetry study to evaluate and quantify the response of the giant garter snake to riceland idling, thereby providing additional data on giant garter snake behavior and ecology. Furthermore, ongoing studies funded through the Ecosystem Restoration Program will also provide data on giant garter snake response to cropland idling and habitat restoration.

The EWA Biological Opinion excluded Yolo County east of Highway 113 from crop idling and substitution actions. Yolo County is known to support the giant garter snake, yet very little data is available on the population size, or distribution within this area. Surveys in 2005-2007, documented snakes at the Yolo Wildlife Area, Conaway Ranch, and Davis Wetlands (Hansen 2008). A giant garter snake Conservation Bank has been established south of Interstate 80 inside the Yolo Bypass and habitat has been created for the giant garter snake within the Yolo Wildlife Area. The area of Yolo County east of Highway 113 will be included in the DWB.

Existing protected habitats within the area and the conservation measures outlined in the DWB, should reduce any potential impacts to the giant garter snake population by including this area in the DWB.

At the request of the USFWS, the Natomas Basin is excluded from the DWB. This area is currently implementing a Habitat Conservation Plan that includes impacts to the giant garter snake.

In summary, DWR is initiating a number of conservation measures to reduce the effect of crop idling and crop substitution actions on the giant garter snake. These actions include requiring rice farmers to follow Best Management Practices as described in the Draft Giant Garter Snake Recovery Plan (USFWS 1999), requiring baseline water in main canals and ditches, minimizing the size of idled parcels, idling parcels using a checkerboard pattern as the preferred layout, and excluding lands adjacent to habitat corridors and lands with known populations. Together, these actions are expected to reduce any impacts to the giant garter snake population to less than significant.

2. Change in the areas from which water may be purchased

The Supplemental EWA EIS/EIR study area includes areas of California that might receive benefits from EWA actions or areas potentially affected by EWA because they serve as a site for EWA water asset acquisition, conveyance, or storage. The EWA study area comprises the land and tributaries upstream from the Delta, the Delta, and the CVP and SWP Export Service Area. This is roughly the same study area that will be a part of the DWB. The CVP and SWP Export Service Area is defined as those lands that receive SWP and CVP water via the south Delta pumping plants, as well as reservoirs that are used for EWA asset management.

The overall EWA study area includes areas that may be directly or indirectly affected by potential EWA acquisitions. These areas include the same areas found as part of the DWB. Those areas that may participate in the DWB, but are not specifically described in the EWA documentation are located adjacent to those areas that are described and include the same ecosystem features, and the same species composition. Thus the analysis and conclusions done as part of the EWA document would be the same as any analysis and conclusions that would be done for those areas that are not specifically described as part of the EWA but may be a part of the DWB.

As done in the EWA document, the effects analysis done on fisheries and water quality in the Delta does not depend on the location of the water seller, but on the total amount of water to be transferred via a particular tributary and receiving water body. Thus, fisheries and water quality effects were evaluated based on the largest amount of water that EWA agencies could manage in the Delta for fish actions (approximately 600,000 acre-feet, per the analyses in the EWA EIS/EIR), regardless of whether the specific water sellers could be identified. Therefore, the effects analysis represents a “worst-case scenario" based on the maximum amount of water that may be purchased by the EWA agencies. The circumstances mentioned above will be exactly the same for the DWB.

The EWA document evaluated impacts by regions and does not analyze impacts as a complete list of specific areas. Some of the regions described in the EWA EIS/EIR include the following:

a. Agricultural lands in the Sacramento Valley (Butte, Colusa, Glenn, Placer, Sutter, and Yolo counties) and the San Joaquin Valley (Kings, Fresno, Kern, and Tulare counties) in which farmers participate in crop idling and/or crop substitution; and

b. Groundwater basins that participate in acquisition of EWA water via groundwater substitution, stored groundwater purchase, or groundwater storage.

c. Areas upstream of the Delta include the Sacramento Valley, the Sacramento River, and its tributary rivers: Feather, Yuba, and American rivers. Because the San Joaquin River also flows into the Delta upstream from the Delta pumps, the portions of the San Joaquin Valley that are drained by the San Joaquin River are also considered to be "upstream" from the Delta. The Merced River, a San Joaquin River tributary, is also part of the Upstream from the Delta region.

The areas described above are the same or similar in nature to the areas that are a part of the DWB. Table 1 lists agencies (those that are covered in the EWA documentation and those that are not) that may be willing to sell water to the DWB along with a maximum amount of potentially available water volumes. DWR would only make purchases from willing sellers. The numbers presented in Table 1 are estimates and do not necessarily reflect the amount of water that would be available in 2009. Generally, these estimates reflect the potential upper limit of available water in order to include the maximum extent of potential transfers in the environmental analysis. Actual purchases would depend on the year type, DWB funding (interested buyers), and the amounts that sellers would ultimately be willing to transfer in 2009. The potential transfers identified in Table 1 may not all occur. All of the potential transfers are in regions identified and analyzed in the EWA documentation.

Table 1. Potential Sellers (Upper Limits, in Acre Feet)

Water Agency (County)	*Stored Reservoir Water*	*Groundwater Substitution*	*Crop Idling Substitution*	*Method TBD*
Upstream from the Delta Region				
Sacramento River Area of Analysis				
*Amaral Ranch (Sutter)	-	2,000	2,000	
*Carter MWC (Colusa)	-	650	0	
*+Conaway Preservation Group (Yolo)	-	0	25,000	
+Glenn-Colusa ID (Glenn and Colusa)	-	0	50,000	
*Lewis Ranch (Colusa)	-	2,000	0	
*Maxwell ID (Colusa)	-	1,200	2,500	
*+Meridian Farms (Sutter)	-	1,000	2,000	
+Natomas Central MWC (Sutter and Sacramento)	-	10,000	0	
*Orland Unit Water User’s Association (Glenn)	10,000	-	-	
*Parrott Investment Company (Butte)	-	0	1,500	
*+Pelger MWC (Sutter)	-	1,500	2,000	
*Pinnacle Land Ventures, LLC (Broomieside Farms) (Sutter)	-	10,000	0	
*+Pleasant Grove-Verona MWC (Sutter)	-	6,000	4,000	
*+Princeton-Codora-Glenn ID (Glenn and Colusa)	-			3,000
*+Provident ID (Glenn and Colusa)	-			3,000
*+River Garden Farms (Yolo)	-	3,500	0	
+Reclamation District 108 (Colusa and Yolo)	-	4,000	20,000	
*+Reclamation District 1004 (Colusa)	-	50,000	10,000	
*Sacramento River Ranch (Yolo)	-	1,000	1,275	
*+Sutter MWC (Sutter)	-	0	10,000	
*Sycamore MWC (Colusa)	-	2,400	6,360	
*Upper Swanston Ranch (Yolo)	-	8,500	0	
Subtotal	-	103,750	136,635	6,000
Feather River Area of Analysis				
*Browns Valley ID	5,000	0	0	
Butte WD (Butte and Sutter)	-	10,000	10,000	
Garden Highway MWC (Sutter)		2,000	0	
*Goose Club Farms (Sutter)	-	0	3,500	
Richvale ID (Butte)		0	10,000	
South Sutter WD(Sutter and Placer)		-	-	10,000
Sutter Extension WD (Sutter)		11,000	14,000	
*Plumas MWC		2,800	1,750	
Western Canal Water District (Butte and Glenn)	-	0	20,000	
Yuba County Water Agency		110,000		
Subtotal	5,000	135,800	59,250	10,000

Table 1 cont. Potential Sellers (Upper Limits, in Acre Feet)

American River Area of Analysis				
+Placer County WA (Placer)	20,000			
Sacramento Suburban WD		17,000		
+City of Sacramento (Sacramento)		5,000		
Subtotal	20,000	23,000		
Merced/San Joaquin River Area of Analysis				
Merced ID(Merced)				25,000*
	-	-	-	-
Total	35,000	261,550	195,885	41,000
Grand Total	**533,435**			
GW: Groundwater		WA: Water Agency		
ID: Irrigation District		WD: Water District		
MWC: Mutual Water Company		TBD: To be Determined		

Note: Those agencies/project components with an * are not specifically identified in the EWA EIS/EIR

Note: Those agencies with a + will require Bureau of Reclamation approval

3. Change in the areas to which water may be delivered

The State Legislature has established legal principles that must be satisfied if the DWB and its participating buyers are to be involved in the purchase or conveyance of water. These legal principles require the buyers to be concerned about the impacts of its water purchases on the water source areas. This concern about possible local area impacts of water transfer makes the buyers an “enlightened consumer” as it enters the water market.

As defined by the EWA documents, the export service area is defined as the area that receives, stores, and uses CVP and SWP water pumped from the Delta. It includes the San Joaquin Valley and CVP/SWP customers in the Bay Area, south central California Coast, and southern California. These areas are similar in nature to those that are a part of the DWB. Any analysis and conclusions done as part of the EWA EIS/EIR will be the same if done for the DWB.

Table 2 identifies potential buyers (those that are covered in the EWA documentation and those that are not) who have indicated interest in participating in the DWB. Not all of these potential buyers may end up actually purchasing water from the DWB in 2009.

Table 2

Potential Buyers (Upper Limits in Acre Feet)

Water Agency		***Amount Requested***
Downstream from the Delta		
Alameda County Water District		20,000
Antelope Valley East Kern Water Agency		28,212
Central Cost Water Authority		15,000
Castaic Lake Water Agency		10,000
*Contra Costa Water District		20,000
Desert Water Agency		10,000
Dudley Ridge Water District		7,500
Kern County Water Agency		123,333
Metropolitan Water District of Southern California		300,000
Mojave Water Agency		1,000
Oak Flat Water District		1,000
Palmdale Water District		8,000
San Bernardino Valley Municipal Water District		20,000
San Diego County Water Authority		10,000
San Luis & Delta Mendota Water Authority, which includes:		150,000
Byron Bethany Irrigation District	Oro Loma Water District	
Del Puerto Water District	Pacheco Water District	
Eagle Field Water District	Panoche Water District	
James Irrigation District	Patterson Irrigation District	
Laguna Water District	Reclamation District 1606	
Mercy Springs Water District	San Benito County Water District	
Tranquility Irrigation District	Banta Carbona Irrigation District	
West Side Irrigation District	City of Coalinga	

Table 2

Potential Buyers (Continued)

Water Agency		***Amount Requested***
San Luis & Delta Mendota Water Authority (continued):		
West Stanislaus Irrigation District	City of Huron	
Westlands Water District	City of Avenal	
Broadview Water District	Avenal State Prison	
Santa Clara Valley Water District		30,000
Tulare Lake Basin Water Storage District		20,000
Upstream from the Delta		
*Bella Vista Water District		2,000
*Dunnigan Water District		2,000
City of Yuba City		2,000
Napa County Flood Control and Water Conservation District		13,860
*Tehama Colusa Canal Authority		25,000

Note: Those agencies with an * are not specifically Identified in EWA EIS/EIR

Currently, there are four potential buyers of DWB water that are outside of those identified in the EWA EIS/EIR; 1) Bella Vista Water District, 2) Dunnigan Water District, 3) Contra Costa Water District, and 4) the Tehama Colusa Canal Authority. All four buyers will not be using the purchased water for any new users or contribute to any level of use above their baseline usage.

The Bella Vista Water District is located in Shasta County and provides water to approximately 5,700 municipal users in the northeast portion the City of Redding and 300 agricultural users (primarily, irrigated pasture). They have a contract with the Bureau of Reclamation for 24,578 acre-feet of water. Over the last five years, annual water consumption averaged 20,645 acre-feet.

The Contra Costa Water District (CCWD) provides water to primarily industrial and municipal users in Contra Costa County. Over the last five years, annual water consumption has averaged 120,000 acre-feet. CCWD provides less than 100 acre-feet a year to agricultural users.

The Dunnigan Water District is located in northern Yolo County and uses contracted water from the CVP delivered from the Tehama Colusa Canal. Over the last five years, annual water consumption has average 16,000 acre-feet. The majority of water, approximately 98 percent, goes to agricultural users and the remaining 2 percent to landscaping. The variety of crops within the district includes permanent orchards and vineyards.

The Tehama-Colusa Canal Authority (TCCA) is a Joint Powers Authority comprised of 17 CVP water contractors. The service area spans four counties (Tehama, Glenn, Colusa, and Yolo) along the west side of the Sacramento Valley, providing irrigation water to farmers growing a variety of permanent and annual crops. TCCA operates and maintains the 140 mile Tehama-Colusa and Corning canals irrigation water supply system. The service area is approximately 150,000 acres.

Conclusion

The use of an addendum to the Supplemental EWA EIS/EIR for the DWB is consistent with CEQA guidelines. The DWB comprises no substantial changes to the analysis done in the Supplemental EWA EIS/EIR. The actions for the DWB are the same as described in the EWA document.

The sellers and buyers as part of the DWB will have asset acquisition amounts that are the same or less than that described in the EWA document. Therefore, any analysis will be the same and any resource impacts will be the same or less. All DWB water transfer actions have been described and analyzed in the EWA documents.

For further clarification on the environmental factors potentially affected by the DWB, a copy of the checklist found in Appendix G of the CEQA Guidelines can be found after the bibliography. Any environmental issues found below in the checklist are explained as part of the addendum.

Bibliography

Hansen, E.C., 2008. Letter to Dave Kelly dated February 2008.

Hansen, G. C., 1986. Status of the Giant Garter Snake *Thamnophis couchii gigas* in the Southern Sacramento Valley during 1986. Final Report to the CDFG.

Reclamation, DWR, CDFG, and National Marine Fisheries Service 2003. Draft Environmental Water Account Environmental Impact Statement/Environmental Impact Report (State Clearinghouse #1996032083). August 2003. http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=107

Reclamation, DWR, CDFG, and National Marine Fisheries Service 2007. Environmental Water Account Supplemental Environmental Impact Statement/Environmental Impact Report –to the EWA Final EIS/EIR. October 2007. http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=107

U.S. Fish and Wildlife Service, 1999. Draft Recovery Plan for the Giant Garter Snake (*Thamnophis gigas*) U.S. Fish and Wildlife Service, Portland, Oregon. ix+192 pp.

Wylie, G.D., Casazza, M. L, and J.K. Daugherty, 1997. 1996 Progress Report for the Giant Garter Snake Study. USGS Dixon Field Station, Dixon, CA.

Wylie, G.D. 1998. Giant Garter Snake Project: 1998 Progress Report USGS Dixon Field Station, Dixon.

Wylie, G.D., Casazza, M. L. and N.M. Carpenter, 2002. 2001 progress report for the giant garter snake study. USGS Dixon Field Station, Dixon, CA.

Wylie, G.D., Casazza, M. L., Martin, Lisa L., and N.M. Carpenter, 2003. Monitoring Giant Garter Snakes at Colusa National Wildlife Refuge: 2002 Progress Report USGS Dixon Field Station, Dixon, CA.

Wylie, G.D., and M. Amarello. 2008. Results of 2006 Monitoring for Giant Garter Snakes (Thamnophis gigas) For the bank protection project on the left bank of the Colusa Basin Drainage Canal in Reclamation District 108, Sacramento River Bank Protection Pr [Technical Report]

March 04, 2009

Environmental Checklist Form

ENVIRONMENTAL FACTORS POTENTIALLY AFFECTED:

The environmental factors checked below would be potentially affected by this project, involving at least one impact that is a "Potentially Significant Impact" as indicated by the checklist on the following pages.

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**
1. **AESTHETICS** – Would the project:				
a. Have a substantial adverse effect on a scenic vista?	☐	☐	☑	☐
b. Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☐	☐	☐	☑
c. Substantially degrade the existing visual character or quality of the site and its surroundings?	☐	☐	☐	☑
d. Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact

2. AGRICULTURE RESOURCES: In determining whether impacts to agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (1997) prepared by the California Department of Conservation as an optional model to use in assessing impacts on agriculture and farmland. Would the project:

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
a. Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to non-agricultural use?	☐	☐	☐	☑
b. Conflict with existing zoning for agricultural use or a Williamson Act contract?	☐	☐	☐	☑
c. Involve other changes in the existing environment which, due to their location or nature, could result in conversion of farmland to non-agricultural use?	☐	☐	☑	☐

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**
3. AIR QUALITY--Where available, the significant criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:				
a. Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☐	☑
b. Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☑	☐
c. Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or State ambient air quality standard (including releasing emissions that exceed quantitative thresholds for ozone precursors)?	☐	☑	☐	☐
d. Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☑
e. Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☑

The following text (in italics) is excerpted from the EWA DEIS/DEIR, July 2003, pp. 8-16 and if:

The potential effects on air quality due to groundwater substitution, stored groundwater purchase, and crop idling would not differ by county. Therefore, the effects of the EWA actions are evaluated for the Upstream from the Delta Region as a whole.

Groundwater substitution would require use of groundwater pumps to retrieve groundwater. Groundwater substitution would take place in Glenn, Colusa, Yolo, Butte, Sutter, Sacramento, Shasta, and Yuba Counties. Agricultural users would use groundwater instead of surface water for their water supply. The use of groundwater would require pumps to lift the groundwater to the surface. Groundwater pumps can be driven by many different means. Table 8-4 shows the estimated NOx and PM10 *emissions for a 115 hp pump with electric, propane, and diesel motors, operating under the assumptions described in Section 8.2.1.1. NOx and PM10 emissions are presented because several counties are in nonattainment for ozone and PM10 and NOx is considered an ozone precursor. This information is for comparison purposes, but actual pollutants emitted depend on how the pump is powered, the size of the pump, the efficiency of the well, the length of time the pump is running, and the depth to groundwater.*

Table 8-4

Groundwater Pump Emissions by Motor Type

Motor Type	*NOx (lbs/year)*	*PM10 (lbs/year)*
“Dirty” Diesel	*2,544*	*236*
“Clean” Diesel	*2,007*	*236*
Electric	*84*	*5.6*
Propane	*562*	*66*

Source: California Farm Bureau Federation 1999.

These calculations assume that the pump would operate 2,000 hours in an average year. Electric pumps do not emit pollutants at the pump; the source of pollutants can be traced to emissions from the powerplant. Powerplants are given permits based on their maximum operating potential. Although the electricity required to power the groundwater pumps would not be needed under the Baseline Condition, the additional electricity would not cause any powerplant to exceed operating capacity. A majority of power is derived from fossil fuel combusted at powerplants to generate electricity required to run the groundwater pumps. CO2 is the primary pollutant emitted as a result of the oxidation of the carbon in the fuel. NOx and PM10 are also emitted. As mentioned previously, these pollutants are noteworthy because many of the counties in the Upstream from the Delta Region are nonattainment areas for ozone and PM10.

Diesel pump engines emit air pollutants through the exhaust. The primary pollutants from the pumps are NOx, TOC, CO, and particulates (including visible and nonvisible *emissions). Pumps that run on propane burn much cleaner than diesel, but still contribute NOx, CO2, VOCs, and trace amounts of SO2 and particulate matter.*[6]

The pumps that would be used for groundwater substitution are existing pumps; no new pumps would be installed as a result of this alternative. The pumps have most likely been used in the past and will be used in the future; thus, the pumps are not a new source of emissions. However, groundwater substitution activities would result in use of the pumps at times when they would otherwise not be used.

According to CARB surveys, approximately 74.7 percent of groundwater pump emissions occur between April and September. The project-related emissions, both NOx and PM10, in Sacramento, Yolo, Sutter, Glenn, and Colusa Counties have been accounted for within CARB's inventory as is demonstrated by the fact that the annual average EWA project emissions produced from groundwater pumping would fall below the diesel-fueled groundwater pump emission inventory. (see Table 8-5, pg. 8-18, EWA DEIS/DEIS, 2003) *However, because the project-related emissions would be produced in a nonattainment area, the project would contribute to an existing air quality violation, which is a significant impact. Butte, Shasta, and Yuba Counties exceed CARB's inventory, also producing a significant impact. The mitigation measures listed in Section 8.2.7 would lower emissions to a negligible amount; therefore, these significant impacts would be reduced to a less-than-significant level.*

[6] *NOx = Nitrogen oxides, TOC = Total organic carbon, CO = Carbon monoxide, CO2 = Carbon dioxide, VOCs = Volatile organic compounds, SO2 = Sulfur dioxide.*

The mitigation measures specified in the EWA DEIS/DEIR for groundwater substitution water transfers are as follows:

8.2.7.1 Groundwater Substitution

If the EWA agencies obtain water from groundwater substitution, increased groundwater pumping would increase NOx emissions. The EWA agencies and willing sellers would work together to implement one, or a combination, of the following mitigation measures that is appropriate to reduce impacts to a less-than-significant level. The mitigation measures will be implemented within the willing seller's air district.

EWA agencies will require willing sellers to use only electric pumps.

EWA agencies will require willing sellers to use electric or propane-fueled pumps. For each propane-fueled pump, a diesel engine within the district that is not a part of the EWA must be replaced with a propane or electric pump to 'offset' the emissions from the project-related pump.

EWA agencies will require the willing sellers to purchase offsets to compensate for producing project-related emissions.

The 2009 DWB intends to implement the last mitigation measure listed above in the following manner. Actual NOx emissions from diesel groundwater pumps will be calculated using actual anticipated operating conditions (i.e., fuel type) and scheduled hours of operation. Emissions of NOx that would have been emitted by farm equipment that would have been used on lands fallowed for water transfers for the 2009 DWB will also be calculated, and these foregone emissions will be used to offset NOx emissions from groundwater pumping. As long as emissions generated by groundwater substitution pumping do not exceed NOx emissions foregone due to land fallowing as part of the 2009 DWB, this impact will be reduced to a less than significant level.

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
4. BIOLOGICAL RESOURCES -- Would the project:				
a. Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?	☐	☑	☐	☐
b. Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, or regulations or by the California Department of Fish and Game or the U.S. Fish and Wildlife Service?	☐	☐	☑	☐
c. Have a substantial adverse effect on federally protected wetlands (including, but not limited to, marsh, vernal pool, coastal, etc.) or other wetlands through direct removal, filling, hydrological interruption, or other means?	☐	☐	☑	☐
d. Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☐	☑	☐	☐
e. Conflict with any local applicable policies or ordinances protecting biological resources?	☐	☐	☐	☑
f. Conflict with the provisions of an adopted Habitat Conservation Plan, Natural Community Conservation Plan, or other applicable habitat conservation plan?	☐	☐	☐	☑

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**
5. CULTURAL RESOURCES -- Would the project:				
a. Cause a substantial adverse change in the significance of a historical resource as defined in Section 15064.5 of the California Code of Regulations (CCR)?	☐	☐	☐	☑
b. Cause a substantial adverse change in the significance of an archaeological resource pursuant to CCR §15064.5?	☐	☐	☐	☑
c. Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☐	☐	☐	☑
d. Disturb any human remains, including those interred outside of formal cemeteries?	☐	☐	☐	☑
e. Exceed an applicable Land Resource Development Plan (LRDP) or Program EIR standard of significance?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
6. GEOLOGY AND SOILS – Would the project:				
a. Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i. Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the State Geologist for the area or based on other substantial evidence of a known fault? Refer to Division of Mines and Geology Special Publication 42.	☐	☐	☐	☑
Ii. Strong seismic ground shaking?	☐	☐	☐	☑
Iii. Seismic-related ground failure, including liquefaction?	☐	☐	☐	☑
iv. Landslides?	☐	☐	☐	☑
b. Result in substantial soil erosion or the loss of topsoil?	☐	☐	☐	☑
c. Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction, or collapse?	☐	☐	☐	☑
d. Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	☐	☐	☐	☑
e. Have soils incapable of adequately supporting the use of septic tanks or alternative wastewater disposal systems where sewers are not available for the disposal of wastewater?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact

7. HAZARDS AND HAZARDOUS MATERIALS – Would the project:

a. Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☑
b. Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☑
c. Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	☐	☐	☐	☑
d. Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5, and, as a result, would it create a significant hazard to the public or the environment?	☐	☐	☐	☑
e. Result in a safety hazard for people residing or working in the project area for a project located within an airport land use plan or where such a plan has not been adopted within two miles of a public airport or public use airport?	☐	☐	☐	☑
f. Result in a safety hazard for people residing or working in the project area for a project within the vicinity of a private airstrip?	☐	☐	☐	☑
g. Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
h. Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	☐	☐	☐	☑

8. HYDROLOGY AND WATER QUALITY – Would the project:

a. Violate any water quality standards or WDRs?	☐	☐	☐	☑
b. Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☐	☐	☑	☐
c. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river in a manner which would result in substantial erosion or siltation on- or off-site?	☐	☐	☐	☑
d. Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner, which would result in flooding on- or off-site?	☐	☐	☐	☑
e. Create or contribute runoff water which would exceed the capacity of existing or planned storm water drainage systems or provide substantial additional sources of polluted runoff?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
f. Otherwise substantially degrade water quality?	☐	☐	☐	☑
g. Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	☐	☐	☐	☑
h. Place structures within 100-year flood hazard area, which would impede or redirect flood flows?	☐	☐	☐	☑
i. Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☐	☐	☐	☑
j. Inundation by seiche, tsunami, or mudflow?	☐	☐	☐	☑
9. LAND USE AND PLANNING - Would the project:				
a. Physically divide an established community?	☐	☐	☐	☑
b. Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the LRDP, general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☐	☐	☐	☑
c. Conflict with any applicable habitat conservation plan or natural community conservation plan?	☐	☐	☐	☑
10. MINERAL RESOURCES -- Would the project:				
a. Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the State?	☐	☐	☐	☑

b. Result in the loss of availability of a locally important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	☐	☐	☐	☑

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**
11. NOISE – Would the project result in:				
a. Exposure of persons to or generation of noise levels in excess of standards established in the local plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☑
b. Exposure of persons to or generation of excessive ground-borne vibration or ground-borne noise levels?	☐	☐	☐	☑
c. A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☑
d. A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	☐	☐	☐	☑
e. Exposure of people residing or working in the project area to excessive noise levels for a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport?	☐	☐	☐	☑
f. Exposure of people residing or working in the project area to excessive noise levels for a project within the vicinity of a private airstrip?	☐	☐	☐	☑

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**

12. POPULATION AND HOUSING – Would the project:

a. Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	☐	☐	☐	☑
b. Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑
c. Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	☐	☐	☐	☑

13. PUBLIC SERVICES

Would the project result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities and the need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times, or other performance objectives for any of the public services:

Fire protection?	☐	☐	☐	☑
Police protection?	☐	☐	☐	☑
Schools?	☐	☐	☐	☑
Parks?	☐	☐	☐	☑
Other public facilities?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
14. RECREATION				
a. Would the project increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☐	☐	☐	☑
b. Does the project include recreational facilities or require the construction or expansion of recreational facilities, which might have an adverse physical effect on the environment?	☐	☐	☐	☑
15. TRANSPORTATION/TRAFFIC – Would the project:				
a. Cause an increase in traffic, which is substantial in relation to the existing traffic load and capacity of the street system (i.e., result in a substantial increase in either the number of vehicle trips, the volume to capacity ratio on roads, or congestion at intersections)?	☐	☐	☐	☑
b. Exceed, either individually or cumulatively, a level of service standard established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☑
c. Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location that results in substantial safety risks?	☐	☐	☐	☑
d. Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☑
e. Result in inadequate emergency access?	☐	☐	☐	☑

Symbols ☑ ☐	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant	No Impact
f. Result in inadequate parking capacity?	☐	☐	☐	☑
g. Conflict with adopted policies, plans, or programs supporting alternative transportation (e.g., bus turnouts, bicycle racks)?	☐	☐	☐	☑

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**

16. UTILITIES AND SERVICE SYSTEMS – Would the project:

a. Exceed wastewater treatment requirements of the applicable Regional Board?	☐	☐	☐	☑
b. Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☑
c. Require or result in the construction of new storm water drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☐	☐	☐	☑
d. Have sufficient water supplies available to serve the project from existing entitlements and resources or are there new or expanded entitlements needed?	☐	☐	☐	☑
e. Result in a determination by the wastewater treatment provider, which serves or may serve the project, that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☑
f. Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☑
g. Comply with applicable federal, State, and local statutes and regulations related to solid waste?	☐	☐	☐	☑

Symbols ☑ ☐	**Potentially Significant Impact**	**Less Than Significant with Mitigation Incorporated**	**Less Than Significant**	**No Impact**
17. MANDATORY FINDINGS OF SIGNIFICANCE --				
a. Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?	☐	☑	☐	☐
b. Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?	☐	☑	☐	☐
c. Does the project have environmental effects, which will cause substantial adverse effects on human beings, either directly or indirectly?	☐	☐	☐	☑

The Bay Institute

ENVIRONMENTAL AND PUBLIC INTEREST CONSIDERATIONS REGARDING THE BAY INSTITUTE'S PROTEST OF THE JANUARY 23, 2015, PETITION TO THE STATE WATER RESOURCES CONTROL BOARD FOR TEMPORARY URGENCY CHANGES TO LICENSE AND PERMIT TERMS AND CONDITIONS REQUIRING COMPLIANCE WITH DELTA WATER QUALITY OBJECTIVES IN RESPONSE TO DROUGHT CONDITIONS AND OBJECTIONS TO THE FEBRUARY 3, 2015, SWRCB EXECUTIVE DIRECTOR'S ORDER APPROVING IN PART AND DENYING IN PART THE PETITION

The Bay Institute's protest of the January 23, 2015 petition and objections to the February 3, 2015 order are based on the following environmental and public interest considerations:

1. Reducing Delta outflows required under D-1641 in February and March will exacerbate extremely adverse habitat conditions for pelagic fish species of the San Francisco Bay-Delta estuary that are at extremely high risk of extinction. In addition, reducing required Delta outflows in combination with the proposed relaxation of the Vernalis flow objective will also decrease river flows into the Delta (to the extent that those are controlled by reservoir releases) and degrade habitat conditions for migratory fish species. The benefits afforded to imperiled populations from D-1641 objectives for March – required by February runoff well in excess of the triggers for relaxing these objectives – would be completely eliminated, and one of the few chances to ameliorate the effects of the drought on the estuary lost.

2. Part of the stated basis for relaxing Delta outflow requirements is to preserve storage to provide adequate upstream habitat conditions for salmonids, but there is little assurance or likelihood that such storage can or will be used to provide for the needs of salmonids spawning in 2015 and migrating downstream in subsequent years. Failure to protect either 2014 outmigrating salmonids or the 2015 year class throughout the freshwater stages of their life history could very well result in the extinction of winter-run Chinook salmon and severe impacts to other runs. Maintaining required outflows, on the other hand, will reduce extinction risk for both imperiled pelagic species and migratory species by minimizing the degradation of habitat conditions in the Delta.

3. Increasing Delta exports, especially when flows into and out of the Delta are low and OMR restrictions have also been relaxed, risks major population losses to both pelagic species and migratory salmonids, and the February 3 order rightly denies this part of the petition.

These considerations are addressed in greater detail below.

Reducing Delta outflows required under D-1641 in February and March will exacerbate adverse habitat conditions for pelagic fish species of the San Francisco Bay-Delta estuary at extremely high risk of extinction. In addition, reducing required Delta outflows in combination with the proposed relaxation of the Vernalis flow objective will also decrease river flows into the Delta (to the extent that those are controlled by reservoir releases) will degrade habitat conditions for migratory fish species. The benefits afforded to imperiled populations from D-1641 objectives for March – required by February runoff well in excess of the triggers for relaxing these objectives – would be completely eliminated, and one of the few chances to ameliorate the effects of the drought on the estuary lost.

The population viability of many aquatic organisms in the Bay-Delta estuary is strongly and significantly correlated to Delta outflow (Figure 1), and for these organisms viability increases as outflow increases. The vast and overwhelming evidence for the critical importance of these flow-viability relationships is well documented, and described in detail in the SWRCB's 2010 "Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem" report and the record of the 2012 workshops pertaining to Phase 2 of the SWRCB's update of the Bay-Delta Water Quality Control Plan. The Interagency Ecological Program's January 2015 "Delta Smelt MAST Synthesis Report" updates available information regarding flow effects on this once common, now extremely rare species.

Flow-dependent estuarine species include American shad, Delta smelt, longfin smelt, Sacramento splittail, starry flounder, striped bass, and *Crangon* shrimp. Some of these species are at high risk of extinction and most are experiencing record or near-record low population levels (Figure 2; Figure 4). The 2014 Fall Mid-Water Trawl survey found that Delta smelt abundance is the lowest level ever recorded, and longfin abundance is at the second lowest level on record[1]. Populations of American shad, striped bass, and threadfin shad are also at near-record low levels, clearly indicating that estuarine habitat conditions are grossly inadequate to support fish and wildlife beneficial uses.

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[1] In presentations to the SWRCB in the last several years, the Metropolitan Water District of Southern California has suggested that the tremendous decline in the FMWT index of longfin smelt was due to changing environmental conditions and/or changing efficiency of the sampling gear. However, two other data sets, which sample the entire pelagic extent of the estuary with different gear (the Bay Study's midwater trawl and otter trawl) have also detected statistically significant and very large declines in longfin smelt. Preliminary analysis of longfin smelt catches in these other surveys in 2014 indicate that longfin smelt abundance was either the third lowest on record, as measured by the Bay Study Otter Trawl, or the fourth lowest on record, as measured by the Bay Study Midwater Trawl respectively (Figure 4). This should lay to rest the suggestion that the decline (of more than 99%) in longfin smelt abundance is attributable to the particulars of any one sampling program or region of the estuary.

Due to long-term water management (and occasional natural droughts), these species have experienced catastrophically low outflow conditions for half of the past 45 years (Figure 3). The long-term decline in populations caused by persistently inadequate flows has been exacerbated by the current drought. In addition, migratory species, including Chinook salmon, steelhead, green sturgeon, and Sacramento splittail, benefit from higher river inflows to the Delta. As a result of human water management practices and habitat degradation, two Sacramento River Chinook salmon runs (winter and spring), Central Valley steelhead, and green sturgeon are listed as threatened or endangered, and the fall run of Chinook salmon has suffered very large population impacts. Reducing river inflows this year (both as a result of reduced Delta outflow requirements and as a direct modification to the San Joaquin flow standard at Vernalis) will add severe impacts to these populations as their juveniles migrate to and through the Delta. Similar impacts were noted last year when fresh water flows into, through, and out of the Delta were reduced as part of a temporary urgency change (USFWS. 2014. Contingency Release Strategies for Coleman National Fish Hatchery Juvenile Fall Chinook Salmon due to Severe Drought Conditions in 2014).

For many of these species, there is no margin of error. Causing additional impacts on top of those created by the natural drought risks the loss of imperiled populations forever. In particular, species with short life spans that spawn only one time (semelparous species such as Delta smelt, longfin smelt, and Chinook salmon) are extremely vulnerable to the negative conditions contemplated by the proposed changes to fresh water flow and water quality; they simply cannot wait out bad years and spawn when wetter conditions return. The extremely depressed population levels that these species now are experiencing therefore make them highly vulnerable to acute reductions in outflow. Relaxing Delta outflow requirements (and associated levels of flow into and through the Delta) during the critical February through June period in 2015 could result in the extinction of these species; at best, reduced Delta outflows will continue to cause their populations to contract.

Denying the petition's request to relax Delta outflows will not result in recovery of these species to viable population levels. Only timely action by the SWRCB to adopt and implement water quality objectives and other requirements to fully protect estuarine habitat and other fish and wildlife beneficial uses will accomplish that goal. But ensuring that the minimal Delta outflows and San Joaquin River inflows required by D-1641 actually occur will significantly reduce the very real risk of extinction for several pelagic and migratory species.

Indeed, projected March outflows under D-1641 could contribute significantly to population increases for many of these species. The current estimated February 8-River index is 2.511 MAF, which would trigger 31 days of compliance with the Chipps Island outflow objective in March. Far from reducing outflows from 7,100 cfs to 4,000 cfs, the proposed relaxation would decrease outflows by over two thirds of the required 11,400 cfs outflow under D-1641. To reduce outflows so drastically from the existing requirements is neither justified by current hydrological conditions nor responsible in the face of the severe and perhaps irreversible consequences likely to ensue for populations at record or near-record lows.

Part of the stated basis for relaxing Delta outflow requirements is to preserve storage to provide adequate upstream habitat conditions for salmonids, but there is little assurance or likelihood that such storage can or will be used to provide for the needs of salmonids spawning in 2015 and migrating downstream in subsequent years. Failure to protect either 2014 outmigrating salmonids or the 2015 year class throughout the freshwater stages of their life history could very well result in the extinction of winter-run Chinook salmon and severe impacts to other runs. Maintaining required outflows (and river inflows), on the other hand, would reduce extinction risk for both imperiled pelagic species and migratory species by minimizing the degradation of habitat conditions in the Delta.

There are rational arguments to be made that relaxing Delta outflow requirements during extreme drought conditions may be prudent. Such actions might allow the Central Valley Project and the State Water Project to store cold water in their upstream facilities in order to release water to maintain downstream spawning habitat conditions for salmonids later in the year. The question for the SWRCB to consider in evaluating this particular petition is whether relaxing outflows is likely to result in increased protection of this year's salmonid year class during its incubation phase *and* when those fish hatch and begin their journey downstream to the ocean. The evidence is that approving the petition will not.

The SWRCB approved a previous petition by the CVP and SWP in 2014 based on a similar rationale. As a result, very poor estuarine habitat conditions in 2014 were further degraded, and estuarine fish population indices fell to record or near-record lows. In addition, salmonid juveniles that were migrating into and through the Delta during 2014 (fish that spawned during 2013) experienced elevated mortality resulting from reduced fresh water flow rates[2]. The proposed benefits for salmonids spawning in 2014 that justified the relaxation were not realized, however. CVP and SWP operations failed to protect either the outmigration of the 2013 salmonid year class nor the egg stage of the 2014 year class; only 5% of the 2014 year class of winter-run salmon is estimated to have survived to-date, and these fish must still transit the Delta.

Now, petitioners propose to reduce the flow into and through the Delta needed to aid the remnants of the 2014 year class as it struggles to reach the ocean as a tradeoff for "protecting" the 2015 spawning class. Maintaining the minimum Delta outflow requirements in 2015 is the only way to protect the remaining 5% of the 2014 winter-run Chinook salmon year class. If the drought continues, the ability of the projects to maintain sufficient storage to protect *both* the egg stage and the outmigration of the 2015 year class is extremely doubtful (protection of only a

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[2] For example, in 2014, USFWS wrote: "Decreased flows in the Sacramento River lead to significantly reduced survival of juvenile salmon because of reduced travel times exposing the fish to increased predation and increased risk of diversion into the interior Delta where survival is significantly reduced." [p. 2-3 in USFWS 2014, cited above]

fraction of the life cycle, at the expense of protections in the remainder of the life cycle simply does not make sense). If the proposal to reduce fresh water flows needed by the 2014 year class to complete their freshwater journey is implemented, the 2014 year class will be lost – and the 2013 year class was sacrificed to protect the 2014 year class. The best chance to avoid the potential destruction of the 2014 year class of all runs of Chinook salmon and steelhead and at the same time prevent extinction of estuarine pelagic species at risk and of the winter Chinook salmon run and to ameliorate the effects of the continuing drought on the public trust values of the Bay-Delta ecosystem is to maintain the minimal Delta outflow requirements in 2015.

Increasing Delta exports, especially when flows into and out of the Delta are low and OMR restrictions have also been relaxed, risks major population losses to both pelagic species and migratory salmonids, and the February 3 order rightly denies this part of the petition.

Both estuarine fish species and migrating salmonids are highly vulnerable to entrainment mortality and other effects of Delta export pumping. The impact of export pumping to these populations is greatest when flows through and out of the Delta are low. Allowing elevated exports when Delta outflows are lower than the level set in D-1641 represents a very grave risk that the projects will entrain and kill a disproportionately large fraction of one or more imperiled populations.

The best available scientific evidence indicates that up to 40% of the delta smelt population and 15% of outmigrating Chinook salmon are lost to entrainment when Delta exports occur at high levels relative to Delta outflows[3]. These figures do not factor in the indirect effects of entrainment on survival of these species.

Longfin smelt are particularly susceptible to entrainment impacts (as indexed by salvage at the CVP/SWP fish screening facilities) during years with low outflow (Figure 5). This is hypothesized to be because the location of longfin spawning and early rearing is focused upstream of the salinity field – as the salinity field moves to the east during January through April (the longfin spawning period), the fish move closer to the export facilities[4]. In addition, the rate of longfin entrainment accelerates rapidly as OMR flows become more negative[5]. Thus, allowing decreased freshwater flows out of the Delta puts the already severely imperiled longfin population in harm's way and increasing exports and reducing San Joaquin inflow to the Delta

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[3] See: Kimmerer, W.J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science, 6(2).

[4] See: Rosenfield, J.A. 2010. Conceptual life-history model for longfin smelt (Spirinchus thaleichthys) in the San Francisco Estuary. California Department of Fish and Game, Sacramento, CA.

[5] See: Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, B. Herbold, and P. Smith. 2009. Factors Affecting Fish Entrainment into Massive Water Diversions in a Tidal Freshwater Estuary: Can Fish Losses be Managed? North American Journal of Fisheries Management 29:1253-1270.

(both of which lead to increasingly negative OMR flows) is a recipe for entraining and killing a very large fraction of the longfin spawning and larval rearing populations.

In conclusion, the D-1641 objectives for Delta outflow and Vernalis inflows should not be relaxed, and the D-1641 export criteria maintained per the February 3 order, in order to:

- Avoid the very real prospect of causing the extinction of one or more pelagic estuarine or migratory salmonid populations.

- Avoid repeating the mistakes of 2014, when Delta outflows were relaxed for the ostensible purpose in part of protecting migratory salmonids, and as a result both pelagic estuarine and migratory salmonid populations were devastated.

- Avoid the likelihood of catastrophic effects on imperiled populations from the combined effects of relaxing outflow and export criteria in tandem.

- Ameliorate the effects of the drought on the Bay-Delta estuary ecosystem by providing the benefit of improved conditions as required under D-1641 – a long-awaited opportunity to ease the pressure on an ecosystem and species at risk.

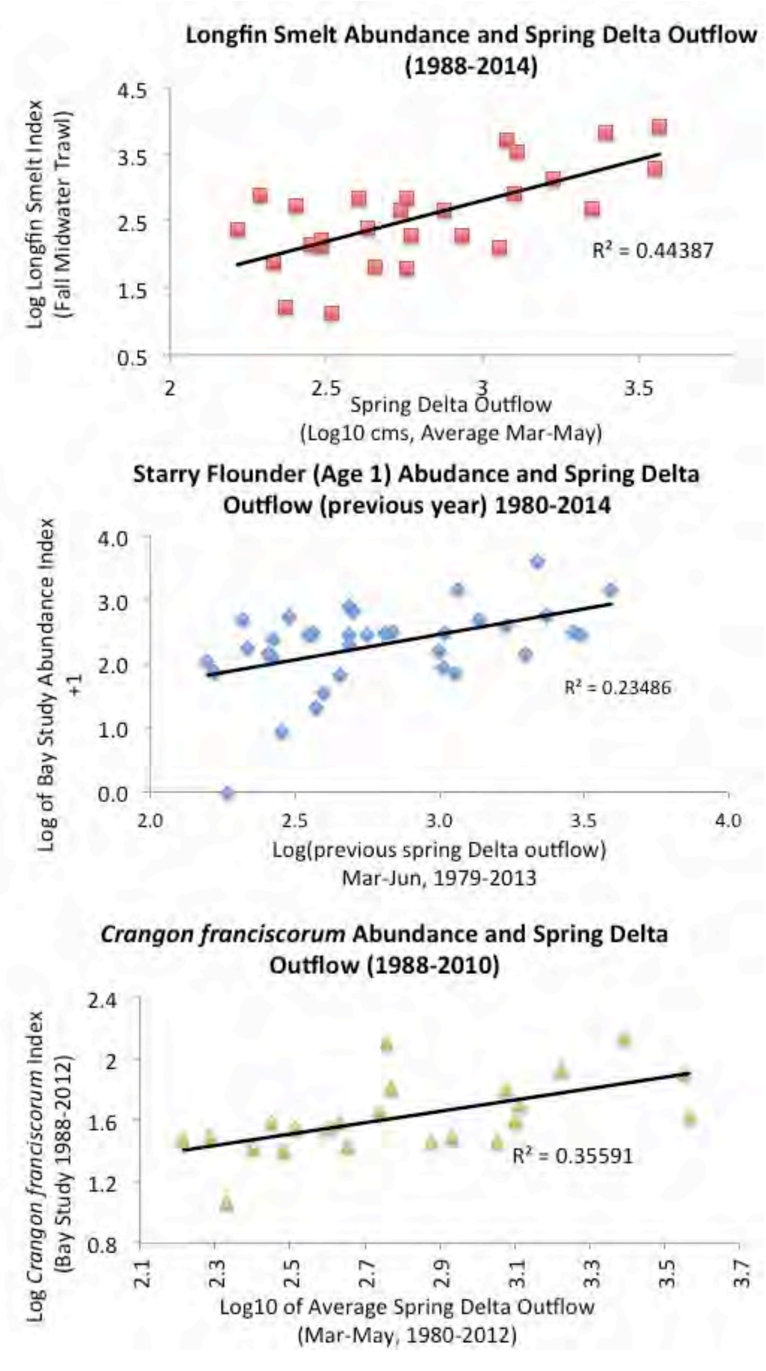


Figure 1: Long term relationship of Delta outflow and abundance indices for three estuarine species. These species display a range of trophic levels, behaviors, and ecological tolerances. They are also representative of a broader suite of species that show similar long-term positive relationships between abundance and winter-spring Delta outflow. Starry flounder and *Crangon* shrimp data courtesy of CDFW's San Francisco Bay Study and the Interagency Ecological Program for the San Francisco Estuary.

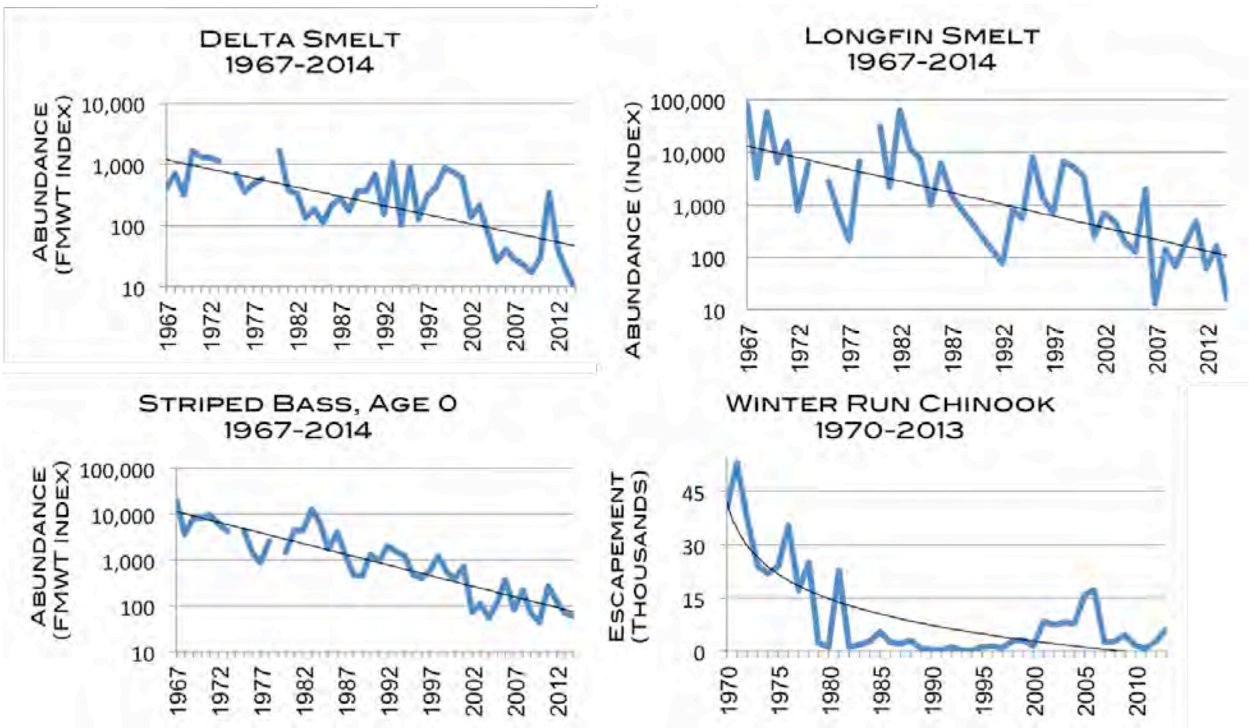


Figure 2: Long-term decline of four fish species of the San Francisco Bay-Delta estuary. The pelagic species have declined by at least 99% over the period of record. Note that the y-axis for Delta smelt, longfin smelt, and Age-0 striped bass is a log-scale; each scale value is 10x the scale value immediately below. The y-axis for the winter-run Chinook salmon is linear.

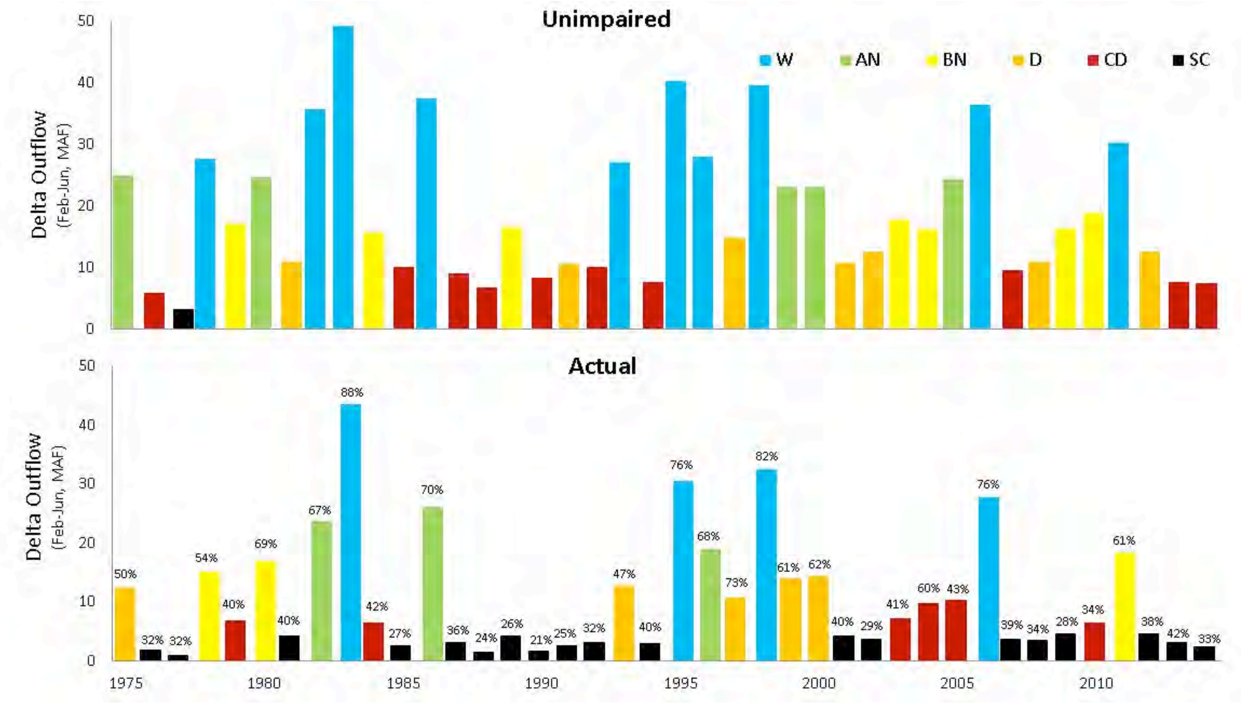


Figure 3: Persistent, man-made drought experienced by the San Francisco Bay-Delta estuary ecosystem. Bars represent the volume of Delta fresh water outflows that would be expected under current landscape conditions without storage or diversion (upper panel; unimpaired) and those that actually occurred (lower panel; actual). Colors represent water year types (W=wet, AN=Above Normal, BN = Below Normal, etc.). Black bars represent Super-critically Dry (SC) runoff conditions that occur naturally in <3% of years (e.g., 1977 in the upper panel). Actual outflows have been equal to or less than the Super-critical threshold in 19 of 40 years since 1975 (47.5% of years). Since 1995, Wet years and Above Normal years have occurred naturally 40% of the time, but the estuary has only experienced those conditions in 20% of years. Since 1995, Super-critically Dry conditions have occurred in the estuary in twice as many years as Wet + Above Normal conditions.

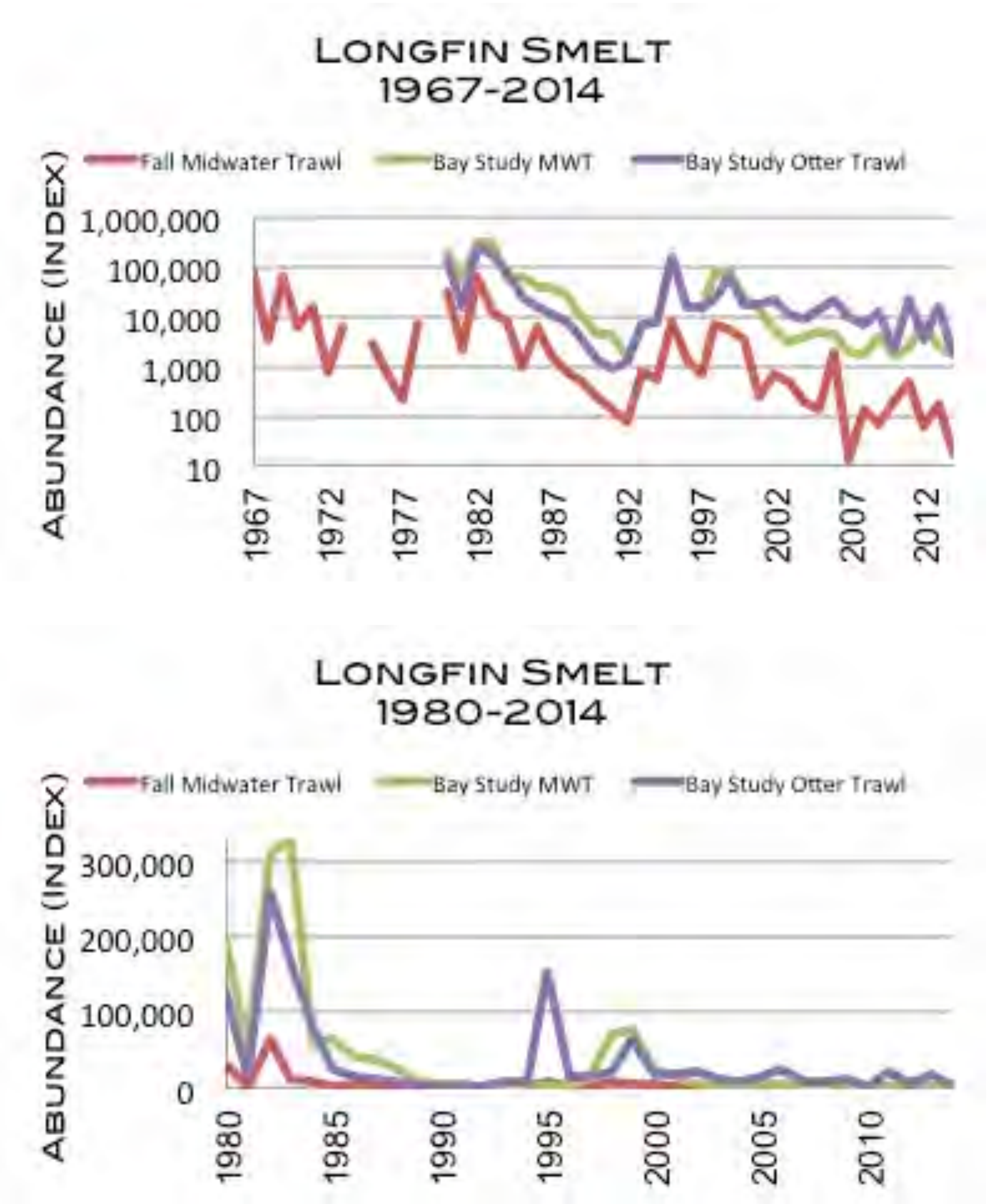


Figure 4: Decline in longfin smelt abundance indices from three different sampling programs in the San Francisco Bay Estuary. For each sampling program the decline from the largest index on record to the most recent (2014) index is greater than 99%. The y-axis in the top panel displays index values on a $\log_{10}$-scale; this allows for visualization of the orders of magnitude changes in all three indices over time. The y-axis in the bottom panel shows index value on a normal linear y-axis – the x-axis here begins in 1980 to show only the period when all three sampling programs were active.

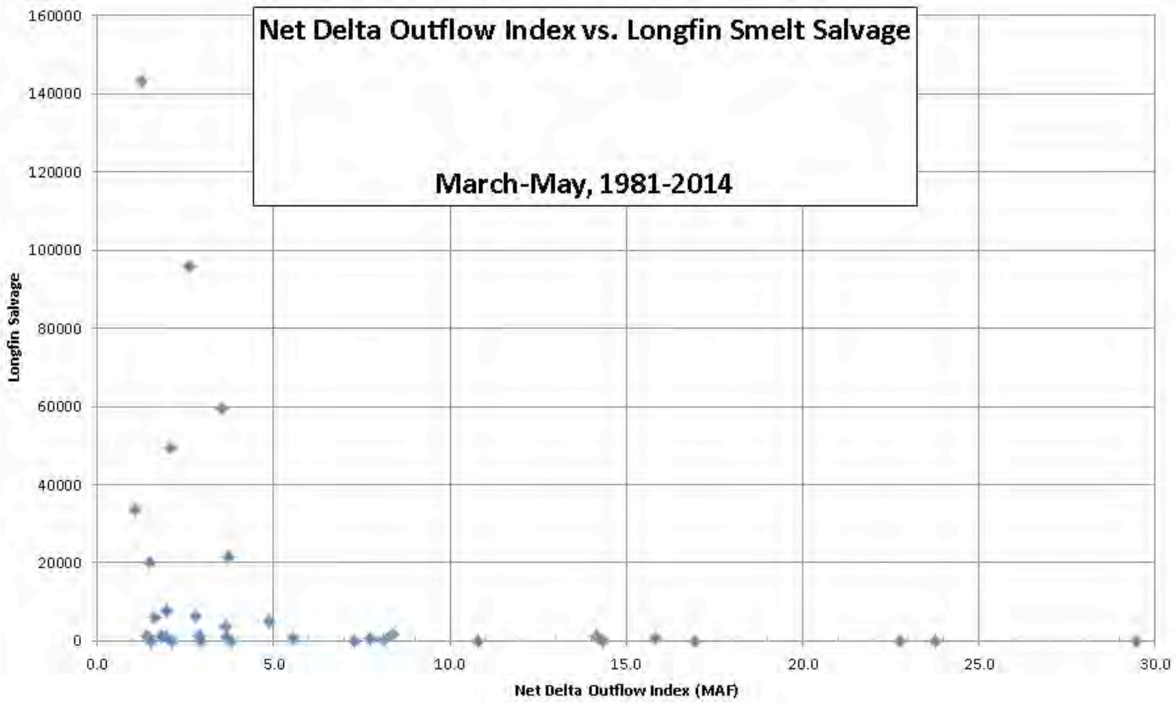
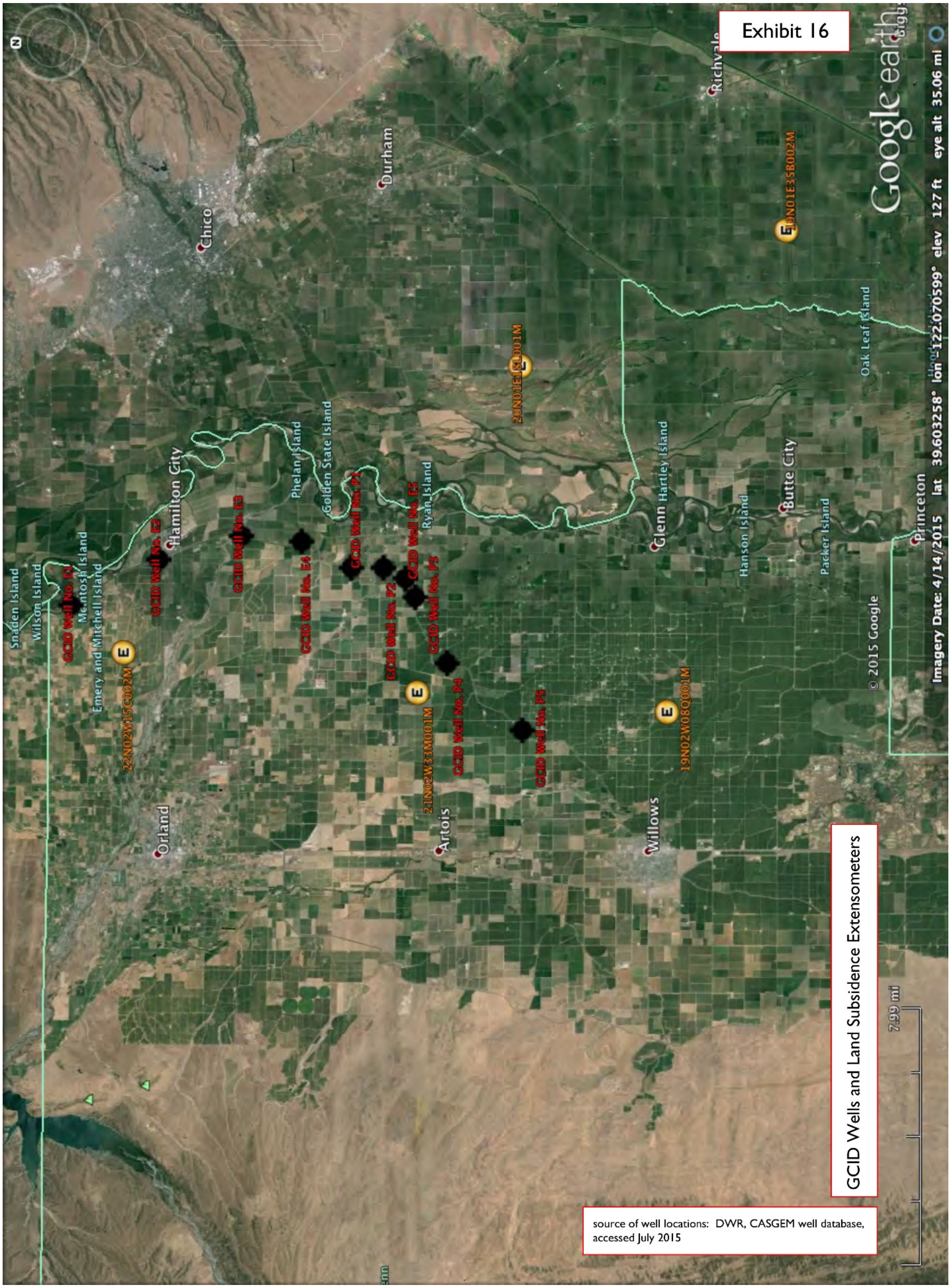


Figure 5: Historical salvage of longfin smelt at SWP and CVP salvage facilities, as a function of Delta outflow. Most salvage occurs when Delta outflows are low in the winter and spring, probably because longfin smelt focus spawning east of the salinity field and, as the salinity field moves further east, spawning adults, larval, and juvenile longfin aggregate closer to the export facilities. This effect, combined with the strong correlation between salvage and OMR flows or exports, suggests that longfin smelt entrainment risk is highest when outflows are low and exports are high.

Exhibit 16



GCID Wells and Land Subsidence Extensometers

source of well locations: DWR, CASGEM well database, accessed July 2015

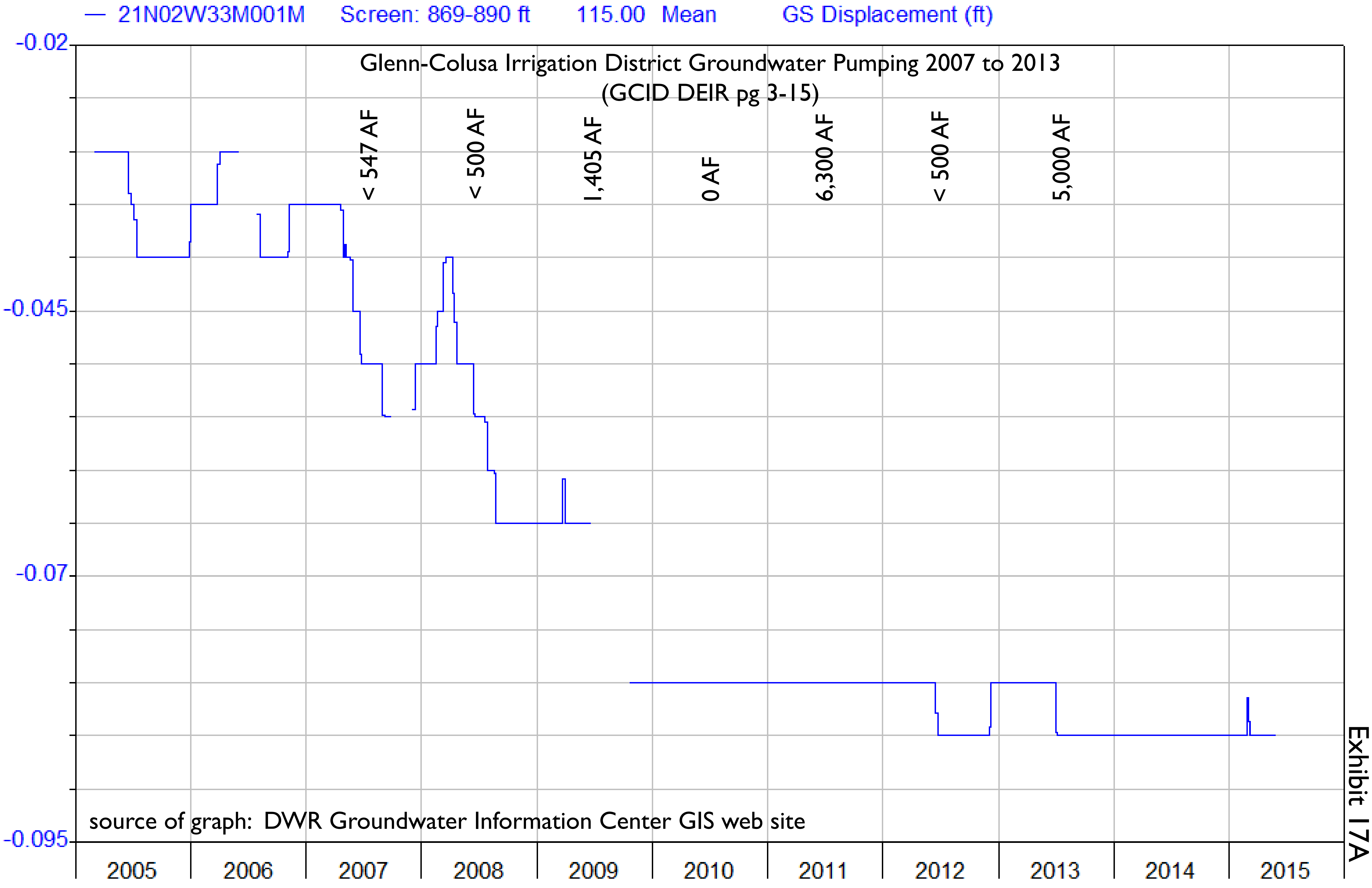
California Department of Water Resources

HYPLOT V133 Output 07/04/2015

Period 11 Year Plot Start 00:00_01/01/2005
Interval 6 Day Plot End 00:00_01/01/2016

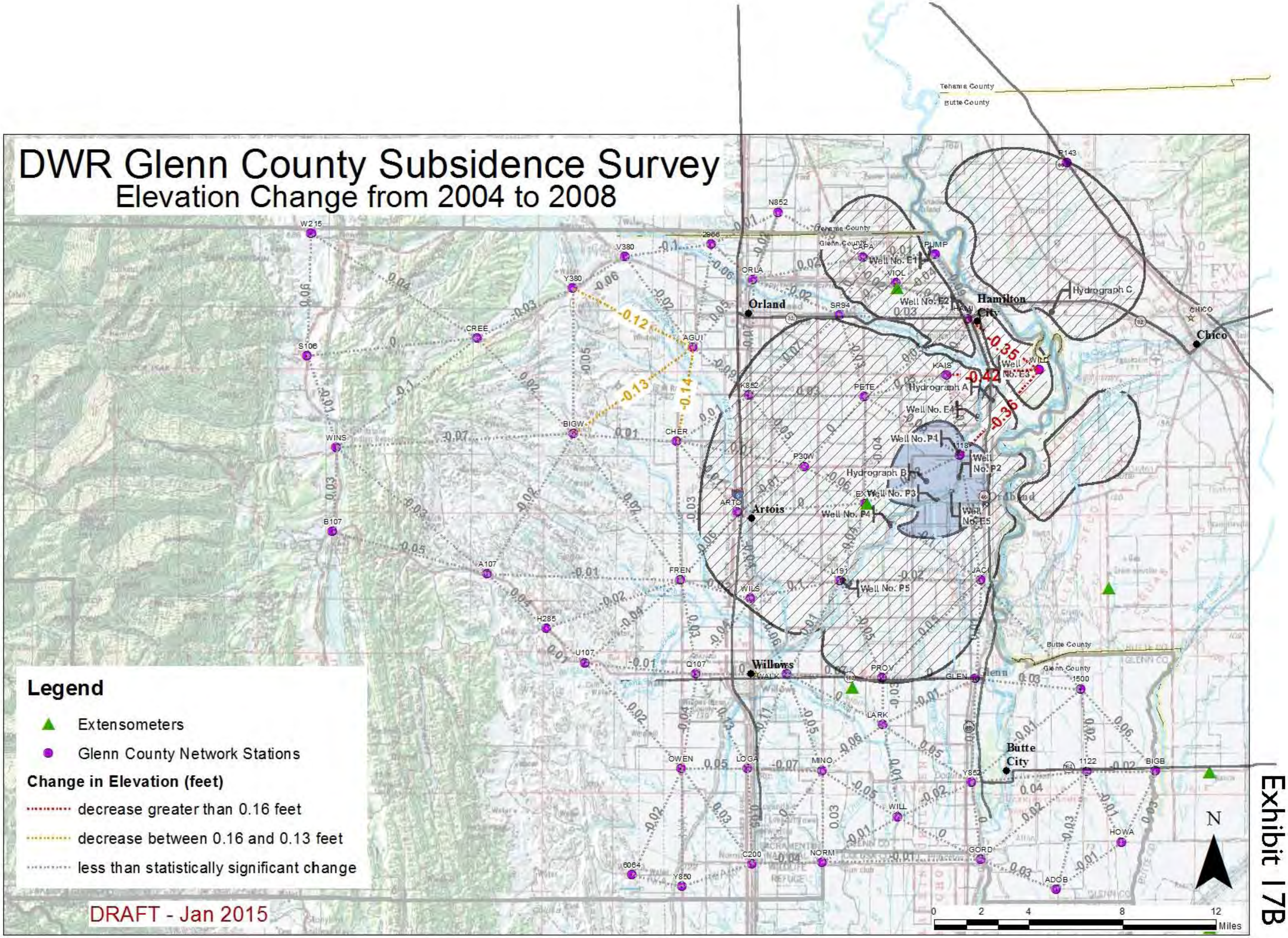
Extensometer 21N02W33M001M, Glenn County

2005-16



source of graph: DWR Groundwater Information Center GIS web site

Exhibit 17A



DWR Glenn County Subsidence Survey

Elevation Change from 2004 to 2008

Legend

▲ Extensometers

● Glenn County Network Stations

Change in Elevation (feet)

decrease greater than 0.16 feet

decrease between 0.16 and 0.13 feet

less than statistically significant change

DRAFT - Jan 2015

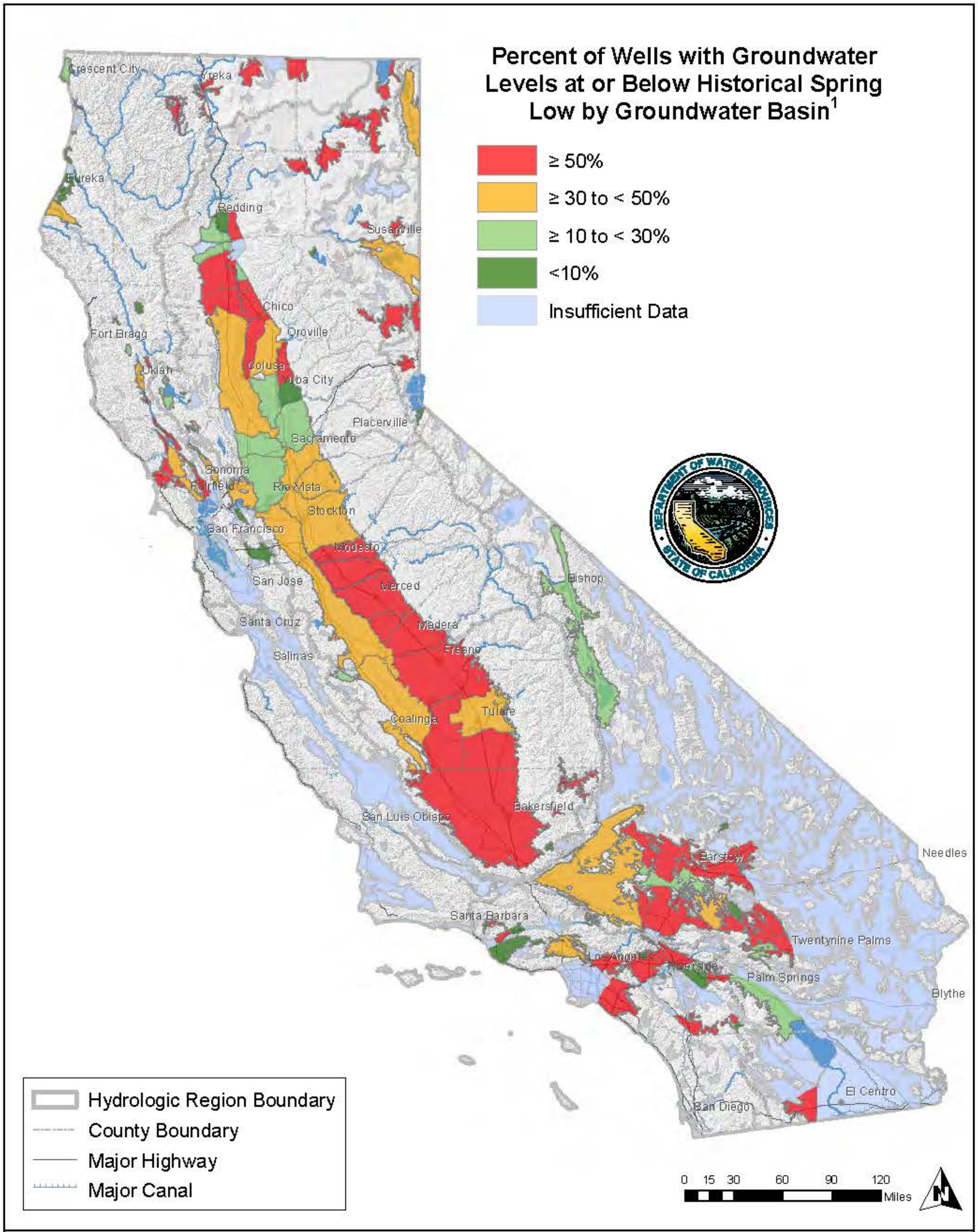
Exhibit 17B

base map source: DWR, Letter from Bill Ehorn to Glenn Co. Supervisors and Water Advisory Committee, Spring 2008 Subsidence GPS survey results, dated February 3, 2015

Exhibit 18

FIGURE 2

Percent of Wells with Groundwater Levels at or Below Historical Spring Low by Groundwater Basin



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[1] Wells with greater than or equal to 10 years of record were used for this analysis. Percentage based on wells at historical Spring low in current drought period 2008-2014 divided by total number of wells in each groundwater basin.
Map based on available data from the DWR Water Data Library (http://www.water.ca.gov/waterdatalibrary) as of 5/19/2014.

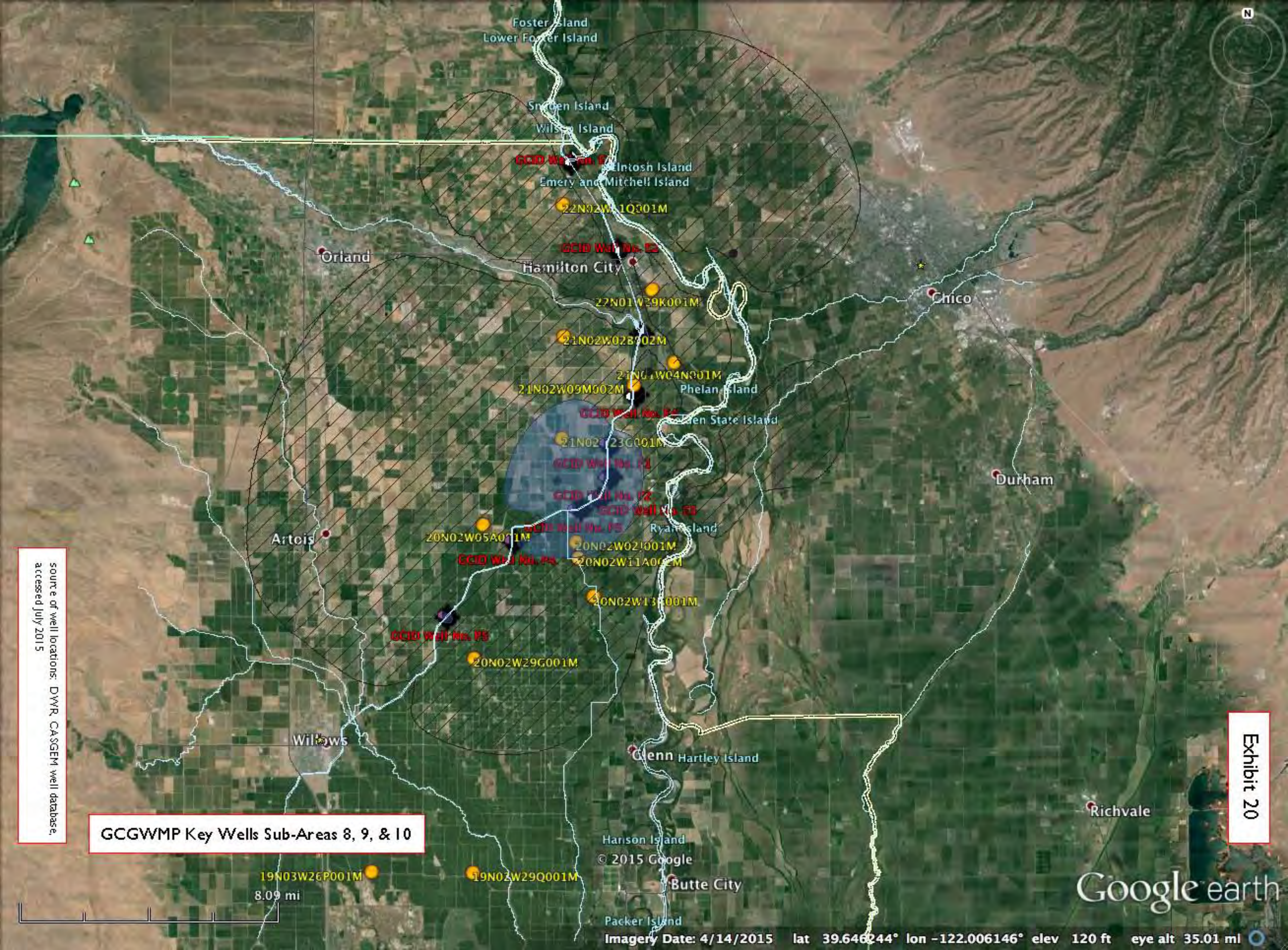
base map source: DWR, Summary of Recent, Historical, and Estimated Potential for Future Land Subsidence in California, 2014

Exhibit 19

Glenn Colusa Irrigation District Sub-Areas 8, 9 & 11 BMO Monitoring Wells

Map ID Number	Latitude	Longitude	Name	BMO	Description	Start Date	End Date
S8-1	39.6971	-121.9893	21N01W04N001M	4	Irrigation	8/24/59	6/2/15
S8-2	39.7687	-122.0547	22N02W11Q001M	4	Irrigation	8/8/73	6/2/15
S8-3	39.7301	-122.0022	22N01W29K001M	4	Irrigation	12/13/73	6/2/15
S9-1	39.7090	-122.0542	21N02W02B002M	1	Residential	3/9/60	6/3/15
S9-2	39.6869	-122.0130	21N02W09M002M	1	Irrigation	6/19/63	6/3/15
S9-3	39.6628	-122.0553	21N02W23G001M	1	Irrigation	1/20/65	6/3/15
S11-1	39.4661	-122.1076	19N02W29Q001M	3	Residential	9/13/41	7/15/15
S11-2	39.4665	-122.1670	19N03W26P001M	3	Residential	2/6/74	6/1/15
S11-3	39.6159	-122.0471	20N02W02J001M	3	Residential	12/22/41	7/15/15
S11-4	39.6237	-122.1016	20N02W05A001M	3	Irrigation	8/26/59	10/12/06
S11-5	39.6087	-122.0456	20N02W11A001M	3	Observation 70-90'	11/17/76	6/1/15
S11-6	39.6087	-122.0456	20N02W11A002M	3	Observation 140-180'	11/16/76	6/1/15
S11-7	39.6087	-122.0456	20N02W11A003M	3	Observation 490-510'	11/17/76	6/1/15
S11-8	39.5913	-122.0367	20N02W13G001M	3	Residential	8/26/59	7/15/15
S11-9	39.5632	-122.1069	20N02W29G001M	3	Residential	12/20/41	6/1/15

Exhibit 20



GCGWMP Key Wells Sub-Areas 8, 9, & 10

source of well locations: DWR, CASGEM well database, accessed July 2015

Summary

The Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report Public Draft (henceforth referred to as the "EIR/EIS") articulates an ambitious plan to transfer water within the state of California. But this ambition is not matched by a similar degree of technical merit, as the modeling components of the EIR/EIS are potentially inadequate, inaccurate, and insufficient to the task. Because of this shortcoming, the EIR/EIS fails to demonstrate that environmental impacts of these transfers will be acceptably small. In particular, the groundwater substitution components of the proposed water transfers are based on modeling assumptions that likely limit their practical accuracy, and on computational simulation techniques that cannot be trusted for their intended use without additional work.

The EIR/EIS as written fails to make a technically-persuasive case for these water transfers, and therefore the proposed transfers should be rejected until the various water transfer stakeholders can advocate more effectively for these transfers by using sound scientific principles instead of mere assertions of negligible impact on the environment.

Critique Overview

This critique concentrates on the groundwater modeling portions of the EIR/EIS, as those portions of the EIR/EIS provide the least technical information relative to the importance of this particular part of the transfer plans. Groundwater resources are seldom seen directly, but their influence is present throughout the hydrological cycle. When the water table sinks, streams dry up and fish die. And when that phreatic surface drops below the level available to domestic water-supply wells, families lose their water supply. Groundwater mining is an all-too-common source of environmental woes, including irreversible loss of aquifer capacity and subsidence observable at the surface of the ground. So accurate groundwater modeling is an essential component of any trustworthy assessment of potential negative environmental effects.

This critique focuses on four particular aspects of the groundwater modeling efforts outlined in the EIR/EIS, namely:

- the lack of a defensible technical basis for the use of the SacFEM2013 groundwater model in assessing man-made hazards due to groundwater substitution activities,
- the inherent assumptions and potential inaccuracies present in the SacFEM2013 model, including an exposition of how better groundwater modeling techniques could have been deployed to engender more trust in the computed results,
- the lack of any formal characterization of uncertainty in the model that might be used to assess the impact of those SacFEM2013 model inaccuracies, and
- some general comments on the EIR/EIS's all-too-often inadequate technical treatment of aquifer mechanics.

Sins of omission and commission are thus found in the EIR/EIS, and this critique will attempt to guide the reader through a discussion of each, towards the goal of more accurate and technically-defensible modeling that would be required to support the proposed water transfers.

Professional Background

My professional experience has long been concentrated in the development and deployment of large-scale computational models for engineered and natural systems. I have worked in this professional field for well over thirty years, and have published refereed journal publications on subsurface mechanics and computational simulation of geological processes, as well as texts and related educational works on computational modeling in solid and fluid mechanics. I have served as a regular faculty member on the Civil Engineering faculties of two major U.S. research universities (the University of California, Davis, and the University of Oklahoma), as well as in leading-edge technical and administrative capacities at federal national laboratories. With my academic colleagues and graduate students, I have published journal articles and technical reports on aquifer mechanics, computational geomechanics, fluid-solid interaction, high-performance computing, and on the inherent limits to accuracy of computational modeling for complex systems in the presence of inherent uncertainties. I have an earned M.S. and Ph.D. in Civil Engineering and a B.S. in Mathematics, all from the University of California, Davis. I have lived in Northern California for more than one-half of my adult life, and have long provided *pro bono* technical assistance on science and engineering topics of import to the quality of life for residents of California. My current work involves simulation of complex man-made and natural systems using some of the largest computers in the world, and so I am well-equipped to describe the state-of-the-art in predictive modeling for large-scale water transfers in California.

Overview of Technical Concerns

This review focuses primarily on the groundwater substitution aspects of the EIR/EIS, because those aspects are where my own expertise is deepest. The groundwater model utilized in the EIR/EIS has enough shortcomings to call into question the trustworthiness of the entire EIR/EIS, and until these shortcomings are remedied, such groundwater transfers should not be permitted. Some representative problems with the SACFEM2013 model are presented below.

Fundamental Technical Problems with the SacFEM2013 Model

In simplest terms, the EIR/EIS fails to make a compelling case for the use of the SacFEM2013 groundwater model in assessing man-made hazards due to groundwater substitution activities.

For example Appendix D of the EIR is provided to document the SacFEM2013 model, but this section of the EIR/EIS raises more questions than answers about the suitability of the model. Some of the assertions made in Appendix D are incorrect, while others are irrelevant to the purpose of the EIR/EIS. And the most fundamental problem with the information presented on the SacFEM2013 model is that Appendix D fails to provide enough technical context to justify the use of SacFEM2013. A technically-informed citizen interested in providing accurate public commentary on the EIR/EIS must search the literature and other open-source documents to find relevant information about the suitability of the SacFEM2013 model. Unfortunately, these searches prove fruitless, because there simply is not enough information provided in the EIR/EIS to perform a technically-defensible characterization of the suitability of SacFEM2013. Because of this, some of the my comments include qualifiers such as “appears to be” or “apparently”. These qualifiers do not imply any insufficiency in my own understanding: they are explicit reminders that the EIR/EIS fails to provide an adequate technical basis for use of SacFEM2013.

One example of incorrect modeling assertions in the EIR/EIS is the characterization[1] of SacFEM2013 and its parent code MicroFEM as "three-dimensional" and "high-resolution". In fact, the SacFEM2013 model provides only a linked set of two-dimensional analyses[2], and would more charitably be described as "two-and-a-half dimensional" instead of possessing a fully-3D modeling capability. This limitation is not an unimportant detail, as a general-purpose 3D groundwater model could be used to predict many important physical responses, e.g., the location of the phreatic surface within an unconfined aquifer. For the SacFEM2013 model, this prediction is part of the data instead of part of the computed solution, and hence SacFEM2013 apparently has no predictive capability for this all-important aquifer response. Here is the relevant EIR/EIS content on this topic[3]:

> The uppermost boundary of the SACFEM2013 model is defined at the water table. To develop a total saturated aquifer thickness distribution and, therefore, a total model thickness distribution, it was necessary to construct a groundwater elevation contour map and then subtract the depth to the base of freshwater from that groundwater elevation contour map. Average calendar year groundwater elevation measurements were obtained from the DWR Water Data Library. These measurements were primarily collected biannually, during the spring and fall periods; and these values were averaged at each well location to compute an average water level for each location. These values were then contoured, considering streambed elevations for the gaining reaches of the major streams included in the model, to develop a target groundwater elevation contour map for the year 2000.

Note that, in order to begin a SacFEM2013 analysis, the phreatic surface must be specified instead of predicted, and that this specification is based on past records of water table location instead of on verifiable accurate predictions of future groundwater resources. Since California is currently in an unprecedented drought, and because the assessment of similarly-unprecedented future large-scale groundwater transfers is the whole point of the EIR/EIS, it is technically inappropriate to use an averaged historical basis to locate the water table surface simply because the SacFEM2013 is unable to predict that important parameter from first principles!

A good example of an irrelevant assertion in the EIR/EIS is the list of reasons given[4] why MicroFEM was chosen as the modeling platform. The first reason is true of *any* finite-element code used to model groundwater response, and the second and third arise from the existence of a graphical user interface for the model input and output data. Any modern computational tool (e.g., the word-processing application I'm using to write this critique) possesses such a user interface, so all three reasons apply equally well to any well-designed finite element application, yet they are used to motivate the choice of only one such application. Why this specific choice of MicroFEM was made is never developed in the EIR/EIS, but it should be, as with the choice of computational model comes a set of model constraints that can limit the model's utility.

> ***Technical sidebar:*** *finite element models are particularly easy to develop and deploy graphical user interfaces for, because the interpolation scheme used to generate the finite element results provides uniquely-defined and easy-to-compute results for every point in the spatial domain. In addition to this readily-accessible supply of spatial data available for visual interpretation of results, these models also can produce results at regular time*

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[1] *EIR/EIS, Appendix D, Page 1*

[2] *S.A. Leake and P.A. Mock, "Dimensionality of Ground Water Flow Models", Ground Water, Volume 35, Number 6, Page 930, 1997*

[3] *EIR/EIS, Appendix D, Page 4*

[4] *EIR/EIS, Appendix D, Page 1*

> *intervals (e.g., monthly) that make it easy to generate animations of the spatial data. So the presence of a graphical user interface is a poor reason to choose a particular finite element application, as custom visualization tools are readily developed at low cost to support the use of the model, or public-domain visualization tools can be utilized instead.*

Unfortunately for the results presented in the EIR/EIS, MicroFEM is a poor choice for such large-scale modeling. It is an old code that apparently utilizes only the simplest (and least accurate) techniques for finite-element modeling of aquifer mechanics, and MicroFEM (and hence SacFEM2013) embed serious limitations into the model that compromise the accuracy of the computed results. These limitations include, but are not limited to, the following:

- The model places a remarkably-low upper limit on problem resolution, i.e., 250,000 surface nodes are available to the modeler, but no more. This limit would appear to the technically-oriented reader to indicate that the advanced age of the MicroFEM program has constrained its software architecture so that high-resolution and high-fidelity models are beyond its capabilities. In particular, its MS/DOS origins might indicate an inability to address sufficient computer memory to support a higher-resolution model, or that its solver routines do not scale to support the multiple-processor capabilities available on virtually all current computers. If this is the case, then this problem should be explicitly noted in the EIR/EIS as a model limitation. If it is not the case, then some justification for this upper limit should be provided to aid in the impartial evaluation of the SacFEM2013 model.
- As mentioned above, the SacFEM2013 model is only partially predictive, in that some aquifer responses are entered as input data instead of being computed as predictive quantities. The most serious of these is the lack of ability to predict the location of the phreatic surface in the aquifer. This location is a natural candidate as the single the most important predicted quantity available for understanding near-surface environmental effects of groundwater motion, yet it is apparently not computed by SacFEM2013, which instead relies on its location via the a priori data-entry process quoted above.
- As mentioned earlier, the model is not a three-dimensional model, but instead estimates groundwater response via approximations involving a suite of two-dimensional layers with uniform horizontal permeabilities coupled via estimated leakage parameters that represent the actual three-dimensional flow fields of groundwater resources. The limitations of this self-induced model constraint are outlined in more detail below, but the summary is simple enough: the real-world complexities of California’s groundwater aquifers are over-simplified by the SacFEM2013 model into no more than 25 available two-dimensional layers of uniform composition, and hence the model results are at best computational simplifications not necessarily representative of actual groundwater responses to pumping.

In addition to the model not being a true 3D model of the actual geometric nature of the state’s groundwater resources, some other problems with the model include the following:

- The model requires considerable data manipulation to be used, and these manipulations are necessarily subject to interpretation. This fact implies that the model results depend on the choices made by the analyst, and are hence not necessarily reproducible. In other words, adjusting of the results (by accident or by design) is an inherent characteristic of the model, and that characteristic alone erodes trust in the model. There are technically-defensible ways to provide accurate assessments of how such adjustments might affect output results used in decision-making (e.g., sensitivity analyses for these parameters), but these means for evaluating trust in the model are not mentioned in the EIR/EIS, and one can only conclude that they have never been performed.

- The model description in the EIR/EIS presents no validation results that can be used to provide basic quality-assurance for the analyses used in the EIR/EIS. The reader can seek information on the parent code MicroFEM, but precious little data is available on that code's capabilities, so the question of "can the results of this model be trusted?" is not answered by the EIR/EIS. An expert reviewing the EIR/EIS might seek to examine the MicroFEM code directly, but the underlying source code is not available, and the MicroFEM tool can only be purchased for a substantial fee ($1500), so it is infeasible to gain informed public comment on the suitability of MicroFEM or SacFEM2013 without paying a substantial price.
- The model is not predictive in some aquifer responses (as mentioned above), so its results are a reflection of past data (e.g., streamflows, phreatic surface location, etc.) instead of providing a predictive capability for future events. Since accurate prediction of future environmental effects is the whole point of the EIR/EIS, the SacFEM2013 model is arguably not even suitable for use in the EIR/EIS, much less in real-world hydrological practice.

The problem of data manipulation mentioned in the first bullet above represents a serious limitation of the SacFEM2013 model. Model quality can be measured by standard quality-assurance processes utilized for software development, such as the CMM model[5] widely used in software practice. The five stages of increasing quality in the CMM model are termed ad hoc (or chaotic), repeatable, defined, managed, and optimized, and the repeatable stage is generally accepted as the minimal level of quality appropriate for any critical analysis methodology. Since analyst intervention in data preparation creates an obvious risk of analyst dependencies in the output data used to set policy, the current SacFEM2013 workflow is likely only at the "ad hoc/chaotic" state of quality assurance for a model. This is simply not appropriate for critical analyses that are used in decision-making on such important resources as water in California.

A typical example of analyst intervention in data preparation can be found in Appendix D of the EIR/EIS[6]:

> After a transmissivity estimate was computed for each location, the transmissivity value was then divided by the screen length of the production well to yield an estimate of the aquifer horizontal hydraulic conductivity (Kh). The final step in the process was to smooth the Kh field to provide regional- scale information. Individual well tests produce aquifer productivity estimates that are local in nature, and might reflect small-scale aquifer heterogeneity that is not necessarily representative of the basin as a whole. To average these smaller scale variations present in the data set, a FORTRAN program was developed that evaluated each independent Kh estimate in terms of the available surrounding estimates. When this program is executed, each Kh value is considered in conjunction with all others present within a user-specified critical radius, and the geometric mean of the available Kh values is calculated. This geometric mean value is then assigned as the representative regional hydraulic conductivity value for that location. The critical radius used in this analysis was 10,000 meters, or about six miles. The point values obtained by this process were then gridded using the kriging algorithm to develop a Kh distribution across the model domain. The aquifer transmissivity at each model node within each model layer was then computed using the geometric mean Kh values at that node times the thickness of the model layer. Insufficient data were available to attempt to

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[5] *M.C. Paulk, C.V. Weber, B. Curtis, M.B. Chrissis, "Capability Maturity Model for Software (Version 1.1)". Technical Report, Software Engineering Institute, Carnegie Mellon University, 1993*

[6] *EIR/EIS, Appendix D, Page 13*

> subdivide the data set into depth-varying Kh distributions, and it was, therefore, assumed that the computed mean Kh values were representative of the major aquifer units in all model layers. The distribution of K used throughout most of the SACFEM2013 model layers is shown in Figure D-4. During model calibration, minor adjustments were made to the Kh of model layer one east of Dunnigan Hills and in model layers six and seven in the northern Sacramento Valley based on qualitative assessment of Lower Tuscan aquifer test data in this area.

Note the presence of terms such as “adjustments”, “assumed”, “insufficient data”, and “representative”. What is being described in this paragraph is a potentially non-repeatable process that converts the three-dimensional permeability tensor into a homogenized number Kh that is then used to estimate conductivity in a plane parallel to the ground surface. Permeability is a local tensorial property of the aquifer (i.e., it varies from point to point in the 3D subsurface domain), but the resulting Kh is smeared across the domain to convert this tensor with six independent spatially-dependent components into a single number that is applied over a huge geographical area instead. And this conversion is subject to the judgment of each analyst, so the results depend on the skill (or lack thereof) of the particular analyst doing the modeling.

> ***Technical sidebar:*** *it is remarkably straightforward to perform accurate and technically-defensible computational analyses to assess the ultimate effect of these data adjustments. One of the most easily-deployed of these techniques is the use of a sensitivity analysis that measures how computed output results depend on adjustments to input parameters. Sensitivity analyses are readily grafted onto nearly any computational model, and while these computations require more effort than not using them, most of the additional effort can readily be offloaded to the computer, so that undue levels of human efforts are not required for their application. Formal sensitivity analyses can also be used to aid in the assessment of model uncertainty (see discussion below), so their omission in the EIR/EIS is a mystery to the technically-informed impartial reviewer of the EIR/EIS.*

And that’s only the tip of the larger iceberg of problems with these ad hoc techniques. It is actually quite easy to avoid all these adjustments and oversimplifications entirely, and treat the aquifer as it is, namely as a true three-dimensional physical body of large extent, with a time-varying location of the water table, and with accurate treatment of the complex hydraulic conductivity inherent to the subsurface conditions of California. It’s also remarkably simple to include poromechanical effects (see discussion below) in such a 3D model so that accurate local and regional estimates of environmental impacts such as subsidence and loss of aquifer capacity can be predicted and validated. All of this technology has been available for decades, but it is not utilized in the SacFEM2013 model. *The citizens of California clearly deserve a better model for decision-making involving one of their most precious resources!*

Regarding The Need to Characterize Uncertainty in Engineered and Natural Systems

Some discussion is warranted at this point on the difference between a natural and an engineered system, towards the goal of appreciating why characterizing uncertainty in any proposed water-transfer strategy is an essential goal of a well-considered EIR/EIS. An engineered system is designed entirely by humans, so each component of that system is reasonably well-understood *a priori*, and the uncertainties that are inherent in any system (natural or man-made) are limited to defined uncertainties such as materials chosen, geometric specifications, and conditions of construction and use. So an engineered system such as an automobile (or a groundwater-pumping facility) is uncertain in many aspects, but that uncertainty can in theory be constrained by quality-control efforts or similar means of repeatability. Constraining these uncertainties comes at a price, of course: that is a large part of what we mean when we refer to *quality* in an engineered system such as in cars or consumer electronics.

A natural system has a much higher threshold for uncertainty, as we often do not even know of all the components of the system, much less their precise characterization (e.g., in a water-bearing aquifer, the materials that entrain the water are by definition unavailable for characterization, and the mere act of digging some of them up for laboratory inspection often changes their physical behaviors so that the tests we perform in the laboratory may not be entirely relevant to the response of the actual subsurface system). So when studying a natural system, a scientist or engineer must exercise due diligence in the examination and characterization of the system's response to stresses of operational use, and must consistently provide means to determine the presence and effect of these inherent uncertainties. To do otherwise is to risk visitation by Murphy's Law, i.e, "anything that can happen, will happen."

Thus one of the most obvious metrics for evaluating the quality of any environmental plan is to examine the plan's use of terms such as "uncertainty", as well its technical relatives that include "validation" (testing of models via physical processes such as laboratory experiments), "verification" (testing of models via comparison with other generally-accepted models), and "calibration" (tuning a model using a given set of physical data that will be used as initial conditions for subsequent verification, validation, and uncertainty characterization). These basic operations are fundamental characteristics of any computational model, and are used in everyday life for everything from weather prediction (where uncertainty dominates and limits the best efforts at forecasting) to the simple requirement that important components of infrastructure such as highway bridges be modeled using multiple independent analyses to provide verification of design quality before construction can begin.

Unfortunately, the EIR/EIS does not contain a formal characterization of model uncertainty, either for the SacFEM2013 application itself, or for the underlying data gathered to support the SacFEM2013 analyses. As described in previous sections, both the model and the input data contain simplifications that potentially compromise the model's ability to provide accurate estimates of real-world responses of water resources, and these idealizations create *more* need for uncertainty characterization, not less. And the all-important technical terms "validation" and "verification" do not appear the EIR/EIS. The term "calibration" occurs twice[7] with regard to groundwater models, but only in the context of ad-hoc "adjustments" of the model data.

Lack of Trust in the SacFEM2013 Model

In addition to generally-poor modeling assumptions inherent in the SacFEM2013 model, the all-important task of characterizing uncertainty in the model's implementation and data is neglected in the EIR/EIS. On page 19 of Appendix B, the reader is promised that model uncertainty will be described in Appendix D, but that promise is never delivered: the only mention of this essential modeling component occurs merely as an adjunct to discussion of deep percolation uncertainty.

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[7] *EIR/EIS, Appendix D, Pages 10 and 13*

This lack of any formal measure of uncertainty is not an unimportant detail, as it is impossible to provide accurate estimates of margin of error without some formal treatment of uncertainty. Many such formal approaches exist, but apparently none were deployed for the EIR/EIS modeling efforts. In simple terms, this lack of uncertainty characterization removes the basis for trust in the model results, and hence the entire groundwater substitution analysis presented in the EIR/EIS is not technically defensible. Until this omission is remedied, the EIR/EIS simply proposes that water interests in California trust a model that is arguably not worthy of their trust.

And it's even worse than this, as while the model is asserted to be "high-resolution", in fact the SacFEM2013 model is quite the opposite. The actual spatial resolution of the model is given in Appendix D as ranging from 125 meters for regions of interest, up to 1000 meters for areas remote from the transfer effects. Nodal spacing along flood bypasses and streams is given as 500 meters. No mention is made in the EIR/EIS of exactly what this means in terms of trust in the model, but in accepted computational modeling practice, this is not a particularly high resolution.

In fact, there are formal methods for characterizing the ability of a discretized model such as SacFEM2013 to resolve physical responses of interest. These methods are based on elementary aspects of information theory (e.g., the Nyquist-Shannon sampling theorem), and their practical result is that a discrete analog (i.e., a computer model) of a continuous system (i.e., the actual subsurface geological deposits that entrain the groundwater) cannot resolve any feature that is less than a multiple of the size of the discretization spacing. For regular periodic features (e.g., the waveforms that make radio transmission possible), that multiple can be a small as two, but for transient phenomena (e.g., the response of an aquifer), established practice in computational simulation has demonstrated that a factor of five or ten is the practical limit on resolution.

Thus the practical limit of the SacFEM2013 model to "see" (i.e., to resolve) any physical response is measured in kilometers! The model can compute results smaller than this scale, but those results cannot be implicitly trusted: they are potentially the computational equivalent of an optical illusion. For this reason alone, the SacFEM2013 model cannot be trusted without substantial follow-on work that the EIR/EIS gives no indication of ever having been performed. And thus any physical response asserted by the model's results has a margin of error of 100% if that response involves spatial scales smaller than a kilometer or more, i.e., there is little or no predictive power in the model for those length scales.

The additional verification effort required to gain some measure of trust in the model (i.e., refining the nodal spacing by a factor of two and four to create more refined models, and then comparing these higher-resolution results to gain assurance that no computational artifacts exist in the original model, i.e., no optical illusions are being used to set water transfer policy) is quite straightforward and is also standard practice in verifying the utility of a computational model. It is something of a mystery why this standard modeling quality-assurance technique is not presented in the EIR/EIS, but this omission provides yet-another sound technical reason to reject the results of the EIR/EIS until better modeling efforts are provided.

> ***Technical sidebar:*** *one important side benefit of performing verification studies by refining the finite element mesh in the spatial and temporal domains is that this extra effort provides important information as to whether the resolution of the model is sufficient. In practice, improving the resolution of a computer model is only a means to*

> *the desired end of gaining higher fidelity, i.e., a closer approximation to reality. So what we really desire from a computer model is not resolution, but fidelity, and while it is notoriously difficult to assess measures of fidelity, verification techniques based on refining the finite element mesh do provide some measure of trust in model results. One particularly simple verification measure involves plotting the computed results for a quantity of interest (e.g., groundwater flux at some point in the aquifer) as a function of model resolution (e.g., a metric indicating the number of the elements in the model, or a representative spatial scale used) for successive refinements of the finite-element mesh. Such plots help the analyst estimate whether the results at any given resolution yield an asymptotically-accurate estimate of the best results the model can provide given its inherent modeling assumptions. When combined with validation data (e.g., model predictions compared to real-world measured data), these verification-and-validation techniques provide a more sound basis for trust in the model than the minimal motivations found in the EIR/EIS.*

It is likely that the SacFEM2013 model may be incapable of performing these more refined higher-resolution analyses because of its underlying assumptions (e.g., idealizing the three-dimensional subsurface domain as a set of coupled two-dimensional layers), and if that is the case, then the underlying groundwater model is simply not up to the requirements of accurate regional water transfer modeling. The underlying MicroFEM model is an old simulation tool, originally written for the MS/DOS platform, and it appears to be near the practical limit of its resolution at the stated size[8] of 153,812 nodes (compared to the maximum nodal resolution in MicroFEM of 250,000 nodes cited above). But the current generation of desktop computers can easily handle many millions of nodes for such simulations, and enterprise computers well within the budgets of government agencies are routinely utilized to model systems with hundreds of millions of nodes, so if the SacFEM2013 model is already at its limit of resolution, then it’s clear that a newer, better computational model should be used to replace it.

Inadequacy of Basic Aquifer Mechanics Principles in the EIR/EIS

In addition to all the fundamental problems inherent in the SacFEM2013 model, the EIR/EIS presents a biased view of basic principles of aquifer mechanics, and this bias serves to understate the risks of serious environmental problems that have long been a bane of water policy in California. In particular, the EIR/EIS simply understates the risk of these environmental effects, beginning with its executive summary and continuing throughout the rest of the document. Here’s a representative sample of the problem at its first occurrence[9]:

> Groundwater substitution would temporarily decrease levels in groundwater basins near the participating wells. Water produced from wells initially comes from groundwater storage. Groundwater storage would refill (or “recharge”) over time, which affects surface water sources. Groundwater pumping captures some groundwater that would otherwise discharge to streams as baseflow and can also induce recharge from streams. Once pumping ceases, this stream depletion continues, replacing the pumped groundwater slowly over time until the depleted storage fully recharges.

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[8] *EIR/EIS, Appendix D, Page 3*

[9] *EIR/EIS, Executive Summary, Page 10*

The use of the adverb "fully" implies that the original storage is entirely recovered, but this is not necessarily the case. The science of poromechanics demonstrates that irreversible loss of aquifer capacity can occur with groundwater extraction, and while this physical phenomenon is explained elsewhere in the EIS/EIR, it is apparently ignored by the SacFEM2013 model, and hence it is not predicted with any degree of accuracy for use in estimating this important environmental effect. California has seen many examples of the accumulation of this environmental risk, as the readily-observable phenomenon known as subsidence is the surface expression of this loss of aquifer capacity. The small strains induced in the aquifer skeleton by groundwater extraction accumulate over the depth of the aquifer, and are expressed by the slow downward movement of the ground surface. The EIR/EIS makes little connection between groundwater extraction process modeled by SacFEM2013 and the all-too-real potential for surface subsidence, and the attendant irreversible loss of aquifer capacity. It is remarkably simple to model these coupled fluid- and solid-mechanical effects using modern computers, and it is thus a fatal shortcoming of the EIR/EIS that such a rational science-based approach to estimating these environmental risks has not been undertaken.

The problem is especially important during drought years, when groundwater substitution is most likely to occur. In a drought, the aquifer already entrains less groundwater than normal, so that additional stresses due to pumping are visited upon the aquifer skeleton. This is exactly the conditions required to cause loss of capacity and the risk of subsidence. Yet the EIR/EIS makes scant mention of these all-too-real problems, and no serious modeling effort is presented in the EIR/EIS to assess the risk of such environmental degradation.

Taken together with the other problems catalogued above, it is clear that the EIR/EIS does not accurately estimate potential environmental risks due to groundwater extraction. And since this component of the water transfer process is only one aspect of how water might be moved within the state, the interested reader of the EIR/EIS can only wonder what other important environmental effects have not been accurately assessed in the EIR/EIS.

Conclusions

The current draft version of the EIR/EIS fails to accurately estimate environmental effects likely to occur during water transfers. The model used to predict groundwater resources is flawed by being based on old technology that is apparently not up to the task of accurate large-scale modeling as combined with requisite validation measures and uncertainty characterization efforts needed to justify the use of the model. The reasons given for the use of this model do not stand up even to the most rudimentary examination, and the model neglects important environmental effects that have long been observed in California. The proposed transfers should be rejected until a more sound scientific basis can be established for prediction of all substantial environmental effects, and established practices in the use of computational models are developed and deployed in all aspects of computational prediction of those effects.

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

May 21, 2013

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Subject: Comments on the Draft Environmental Assessment and Findings of No Significant Impact for the *2013 Water Transfer Program* and the *2010-2011 Water Transfer Program*

Dear Messrs. Hubbard and Messer:

AquAlliance submits the following comments and questions for the Draft Environmental Assessment ("EA") and Findings of No Significant Impact ("FONSI"), for the *2013 Water Transfer Program* ("Project"). We also provide comments about the purpose and need for the 2013 state and federal water transfer programs that are mirror images of the *2009 Drought Water Bank* and the *2010/2011 Water Transfer Program*.

The Bureau of Reclamation's draft environmental review of the Project does not comply with the requirements of National Environmental Policy Act ("NEPA"), 42 U.S.C. §4321 *et seq.* First, we believe that the Bureau needs to prepare an environmental impact statement ("EIS") on this proposal, as we believed for the *2009 Drought Water Bank* ("DWB") that allowed up to 600,000 acre-feet (AF) of surface water transfers, up to 340,000 AF of groundwater substitution, and significant crop idling. It also mirrors the *2010-2011 Water Transfer Program* that sought approval for 200,000 AF of CVP related water and assumed NEPA coverage for additional non-CVP transfer water up to 195,910 AF.

Bureau reliance on the EA itself violates NEPA requirements because, among other things, the EA fails to provide a reasoned analysis and explanation to support the Bureau's proposed finding of no significant impact. The EA contains a fundamentally flawed alternatives analysis, and treatment of the chain of cause and effect extending from project implementation leading to inadequate analyses of nearly every resource, growth inducing impacts, and cumulative impacts. An EIS would afford the Bureau, DWR, the State Water Resources Control Board, and the California public far clearer insight into how, where, and why the Project might or might not be needed. Litigation by AquAlliance and partners challenged the *2010-2011 Water Transfer Program* and appeared to prod the Bureau toward the necessary environmental review for their multi-year, serial, so-called "temporary" water transfers with the scoping meetings that were held in January 2011 for the *Long-Term North to South Water Transfer Program* ("10-Year Plan") (http://www.usbr.gov/mp/cvp/ltwt/). The 10-Year Plan's proposal to transfer up to 600,000 AF of river water has stalled despite Bureau optimism that an EIS would be available in the fall of 2011 and again in the fall of 2012. Absent serious and comprehensive NEPA and California Environmental Quality Act ("CEQA") review, the Bureau offers another EA/FONSI here, which again fails to provide adequate disclosure of impacts.

Second, CEQA analysis of the 2013 Water Transfer Program is completely absent at the programmatic level. The Project's actual environmental effects —which are similar to the 2009 DWB, the Sacramento Valley Water Management Agreement, and the proposed 1994 Drought Water Bank (for which a final Program Environmental Impact Report was completed in November 1993) – are not presented in any document. The Bureau and DWR have known for over a decade that programmatic environmental review was and is necessary. The following examples highlight the Bureau and DWR's ("Agencies") deficiencies in complying with NEPA and CEQA.

- The Sacramento Valley Water Management Agreement was signed in 2002 and the need for a programmatic EIS/EIR was clear at that time it was initiated, but never completed.
- In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken.
- Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate.
- Last, but not least, is the attempt of the Bureau and San Luis Delta Mendota Water Authority to analyze the 10-Year Plan, which also has failed to materialize.

The Bureau's failure to conduct scientifically supported environmental review in an EIS and DWR's negligence to provide *any* form of CEQA review reflects an end-run around established law through the use of so-called "temporary" water transfers, in multiple years and is therefore vulnerable to legal challenge under NEPA and CEQA.

Finally, we also question the merits of and need for the Project itself. The existence of very dry conditions in California should not surprise the Agencies or require an urgent and "temporary" response once again. The existence of this water transfer program reflects the Agencies' abandonment of a sensible water policy framework. Our organizations believe the Bureau's EA/FONSI and the absence of programmatic CEQA review go too far to help a few junior water right holders at the expense of agriculture, communities, and the environment in and north of the Delta. The *2013 Water Transfer* Program will directly benefit the areas of California whose water supplies are the least reliable by operation of state water law and climate. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful and irrational uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The proposed Project will have significant effects on the environment—both standing alone, as serial, so-called "temporary" water transfers, and when reviewed in conjunction with the multitude of other plans and programs (including the non-CVP water that is mentioned in the EA cumulative impacts section) that incorporate and are dependent on Sacramento Valley water. Ironically, the Bureau appears to recognize in its cumulative impacts discussion that there is potential for significant adverse impacts associated with the Project, but instead of conducting an EIS as required, attempts to assure the public that the *2013 Water Transfer Program* will be deferred to the "willing sellers" through individual "monitoring and mitigation programs" as well as through constraining actions taken by both DWR and Bureau professional staff whose criteria ought instead be incorporated into the Proposed Action Alternative (EA at p. 6, FONSI at pp. 1-4). It is impossible to evaluate whether or not the mitigation and monitoring plans will be adequate to relieve the Bureau and DWR of responsibility for impacts from the Project (including the non-CVP water transfers). The language used in the EA (pp.12-14, 25-27) and the *Draft Technical Information for Water Transfers in 2013* (February 2013) (pp. 39-45) fails to pass the blush test (details below).Of course, this is not a permissible approach under NEPA; significant adverse impacts should be mitigated—or avoided altogether as CEQA normally requires.[1] Moreover, in light of the wholly inadequate monitoring and mitigation planned for the 2013 Water Transfer Program's extensive water sales, the suggestion that the public should be required to depend on the insufficient monitoring to provide the necessary advance notice of "significant adverse impacts" is an unacceptable position.

We incorporate by reference the following documents:

- AquAlliance, California Sportfishing Protection Alliance, and California Water Impact Network *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay--Delta Estuary*. 2012.
- AquAlliance comments on the *Draft Environmental Assessment/Initial Study and Finding of No Significant Impact/Mitigated Negative Declaration for the Anderson-Cottonwood Irrigation District Integrated Regional Water Management Program – Groundwater Production Element Project*. 2011.
- AquAlliance scoping comments for the 10-Year Plan. 2011.
- AquAlliance et. al comments on the *2010/2011 Water Transfer Program*. 2010.
- Jim Brobeck's comment letter for Butte Environmental Council on the Supplemental Environmental Water Account EIR/EIR, 2007.

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[1] Perhaps even more telling, the Bureau actually began its own Programmatic EIS to facilitate water transfers from the Sacramento Valley, and the interconnected actions that are integrally related to it, but never completed that EIS and now has impermissibly broken out this current segment of the overall Program for piecemeal review in the present draft EA. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "includ[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" *Id.* At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").

- Lippe Gaffney Wagner LLP letter for Butte Environmental Council to DWR regarding the Drought Water Bank Addendum, 2009.
- Barbara Vlamis' letter for Butte Environmental Council to DWR regarding the 2009 Drought Water Bank Addendum.
- Multi-Signatories letter regarding the Drought Water Bank, 2008.
- Professor Kyran Mish's White Paper, 2008.
- Professor Karin Hoover's Declaration, 2008.

I. The Bureau and DWR Must Prepare an Environmental Impact Statement/ Environmental Impact Report on the Proposed *2013 Water Transfer Program*

We strongly urge the Bureau to withdraw this inadequate environmental document and instead prepare a joint EIS/R on the *2013 Water Transfer Program*, before approaching the State Water Resources Control Board (SWRCB) for a change in place of use, in order to comply with both NEPA and CEQA requirements for full disclosure of human and natural environmental effects. NEPA requires federal agencies to prepare a detailed environmental impact statement on all "major Federal actions significantly affecting the quality of the human environment . . . ." 42 U.S.C. §4332(2)(C). This requirement is to ensure that detailed information concerning potential environmental impacts is made available to agency decision makers and the public before the agency makes a decision. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989). CEQA has similar requirements and criteria.

Under NEPA's procedures, an agency may prepare an EA in order to decide whether the environmental impacts of a proposed agency action are significant enough to warrant preparation of an EIS. 40 C.F.R. §1508.9. An EA must "provide sufficient evidence and analysis for determining whether to prepare an [EIS]" (*id.*), and must demonstrate that it has taken a "'hard look' at the potential environmental impact of a project." *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208, 1212 (9th Cir. 1998) (internal quotation marks omitted). However, the U.S. Court of Appeals for the Ninth Circuit has cautioned that "[i]f an agency decides not to prepare an EIS, it must supply a convincing statement of reasons to explain why a project's impacts are insignificant." *Id.* (internal quotation marks omitted). The Bureau has not provided a convincing statement of reasons that would explain why the Projects's impacts are not significant. So long as there are "substantial questions whether a project *may* have a significant effect on the environment," an EIS must be prepared. *Id.* (emphasis added and internal quotation marks omitted). Thus, "the threshold for requiring an EIS is quite low." *NRDC v. Duvall*, 777 F. Supp. 1533, 1538 (E.D. Cal. 1991). Put another way, as will be shown through our comments, the bar for sustaining an EA/FONSI under NEPA procedures is set quite high, and the Bureau fails to surmount it in the *2013 Water Transfer Program*.

NEPA regulations promulgated by the Council on Environmental Quality identify factors that the Bureau must consider in assessing whether a project may have significant environmental effects, including:

(1) "The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks." 40 C.F.R. §1508.27(b)(5).
(2) "The degree to which the effects on the quality of the human environment are likely to be highly controversial." *Id.* §1508.27(b)(4).
(3) "Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate on a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).
(4) "The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration." *Id.* §1508.27(b)(6).
(5) "The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973." *Id.* §1508.27(b)(9).

Here, the Bureau has failed to take a hard look at the environmental impacts of the Project. As detailed below, there are substantial questions about whether the *2013 Water Transfer Program's* proposed water transfers will have significant effects on the region's environmental and hydrological conditions, especially groundwater; the interactions between groundwater and surface streams of interest in the Sacramento Valley region; and the species dependent on aquatic and terrestrial habitat. There are also substantial questions about whether the *2013 Water Transfer Program* will have significant adverse environmental impacts when considered in conjunction with the other related water projects that have occurred in the last dozen years and that are underway and proposed in the region. The Bureau simply cannot rely on the EA/FONSI for the foreseeable environmental impacts of the proposed *2013 Water Transfer Program* and still comply with NEPA's requirements.

A. The Proposed Action Alternative is poorly specified, making it difficult to identify chains of cause and effect necessary to analyze adequately the alternative's environmental effects.

The Proposed Action Alternative is poorly specified and needs additional clarity before decision makers and the public can understand the human and environmental consequences of the *2013 Water Transfer Program*. The EA describes the Proposed Action Alternative as one reflecting the Bureau's intention to approve transfers of Central Valley Project water from willing sellers who contract with the Bureau ordinarily to use surface water on their croplands. Up to 37,505 AF of CVP water are offered from these sellers, according to Table 2-1 (EA p. 9). In contrast to the EA/FONSI for the 2009 Drought Water Bank (p. 3-88), the Project EA contains no "priority criteria" to determine water deliveries and simply acknowledges that CVP river water will be transferred to San Luis & Delta Mendota Water Authority agricultural districts. The EA fails to indicate how much water has been requested by the buyers of CVP or non-CVP water, which is also in contrast to the EA/FONSI and DWR's addendum for the 2009 Drought Water Bank.

Potential buyers of non-CVP water are also not disclosed. These significant omissions eliminate the public's ability to consider, assess, and comment on possible impacts in the receiving areas. This denial of information further obfuscates the need for the Project.

The EA/FONSI's Background section (p. 3) states specifically that, "To facilitate the transfer of water within the State of California, Reclamation is considering whether to approve individual water transfers between willing sellers and buyers when Base Supply, Project Water or Project facilities are involved in the transfer." This paragraph omits mentioning DWR's role as an approving agency for SWP water sales while acknowledging its role in potentially wheeling both CVP and SWP river water. This failure to elucidate DWR's authority adds further confusion to a poorly defined project.

Another serious omission is that the EA/FONSI lacks a section that names and explains the purpose of the Project. AquAlliance agrees with the Bureau's *Reclamation's NEPA Handbook* (2012) that states, "The need for an accurate (and adequate) purpose and need statement early in the NEPA process cannot be overstated. This statement gives direction to the entire process and ensures alternatives are designed to address project goals." (p.11-1) While "need" is disclosed in section 1.2 (p. 4), there is no coherent discussion of the need. Merely stating that, "The hydrologic condition for 2013 is dry, and because the CVP and SWP are providing 20% and 35% of contract amounts, respectively, to contractors south of the Delta, there is a need for water to supplement local and imported supplies to meet demands," lacks context, specificity, and rigor. The purpose and need should also state that this transfer program would be subject to specific criteria for prioritizing transfers. The absence of a statement of purpose and the inadequate need statement renders the EA/FONSI wholly deficient.

The EA's description of the proposed action alternative needs to make clear what would occur if sale criteria are in fact applied and if exceptions will be allowed, and, if so, by what criteria would exceptions be made.. Do both Project Agencies, the Bureau and DWR, lack criteria to prioritize water transfers? What is the legal or policy basis to act without providing priority criteria? Without foundational criteria, the public is not provided with even a basic understanding of the need for the Project.

There is considerable ambiguity over just how many potential sellers there are and how much water they would make available. The EA states that, "Entities that are not listed in this table [2-1] may decide that they are interested in selling water, but those transfers would require supplemental NEPA analysis," (p. 9). Allowing a roving Project location is not permissible and avoids accurate analysis of all impacts including growth inducing and cumulative impacts.

Absent the names of buyers, buyers' request numbers, and the potential for the participation of unknown additional sellers, the EA signals that neither the Bureau nor DWR have a clear idea what the *2013 Water Transfer Program* is intended to be. This problem contributes greatly to and helps explain the poorly rendered treatment of causes and effects that permeate the Bureau's EA. The Project Agencies present decision-makers and the public with an ill-defined Project, purpose, and need: they are moving targets. Such chaos and blunders reflect hasty consideration and poor planning by project proponents. Nor can the Agencies reasonably attribute their inadequate or absent environmental reviews on lack of warning. The Agencies know better than anyone that California has a Mediterranean climate with major fluctuations in precipitation and has long periods of drought (Anderson, 2009).

From data available in the EA/FONSI, it is not possible to determine with confidence just how much water is requested by potential urban and agricultural buyers. There is no attempt to describe how firmly tendered are offers of water to sell or requests to purchase. Left to guess at the possible requests for water, we look at the 2009 DWB where there were between 400,000 and 500,000 AF of presumably urban buyer requests alone (which had priority over agricultural purchases, according to the 2009 DWB priorities) and a cumulative total of less than 400,000 AF from willing sellers. It is highly possible, based on the example during the 2009 DWB, that many buyers are not likely to have their needs addressed by the *2013 Water Transfer Program*. If so, the Bureau and DWR should state the likelihood that many requests will not be fulfilled in order to achieve a full and correct environmental compliance treatment of the proposed action. Such an estimate is necessary for accurate explication of the chains of cause and effect associated with the *2013 Water Transfer Program*—and which must propagate throughout a NEPA document for it to be adequate as an analysis of potential natural and human environmental effects of the proposed project. We have additional specific questions:

- Are the San Luis and Delta Mendota Water Authority (SLDMWA) requests for agricultural or urban use of Project water?
- What are the specific urban requests for water nested within the SLDMWA request?
- Who are the buyers and what are their requests for the non-CVP river water?
- Will sale criteria be premised on full compliance with all applicable environmental and water rights laws? If so, how will cumulative impacts be analyzed under CEQA?

If priority criteria were actually revealed in the EA/FONSI, how would intervening economic factors beyond the control of the Project be analyzed? Given the added uncertainty, an EIS should be prepared to provide the Agencies with advance information and insight into what the sensitivity of the program's sellers and buyers are to the influences of prices—prices for water as well as crops such as rice, orchard and vineyard commodities, and other field crops. It is plausible that crop idling occurs more in field crops, while groundwater substitution would be more likely for orchard and vineyard crops. However, high prices for rice—the Sacramento Valley's largest field crop— undermines this logic and have lead to substantial groundwater substitution. These potential issues and impacts should be recognized as part of the *2013 Water Transfer Program* description and should directly apply to the Agriculture and Land Use, and Socioeconomic sections of the EA, because crop prices are key factors in choices potential water sellers would weigh in deciding whether to idle crops, substitute groundwater, or decline to participate in the Project altogether. The EA is inadequate because it fails to identify and analyze the market context for crops as well as water that would ultimately influence the size and scope of the *2013 Water Transfer Program*.

Rice prices are high because of conditions for the grain in the world market. Drought elsewhere is a factor in reduced yields, but growing populations in south and east Asia demand more rice; the rice industry has gladly tried to meet that demand.[2]

This is very important. The Bureau tacitly admits that the Bureau—and by logical extension, DWR—has no idea how many sales of what type (public health, urban, agricultural) can be expected to occur. Put another way, there is a range of potential outcomes for the *2013 Water Transfer Program*, and yet the Bureau has failed utterly to use the EA to examine a reasonable and representative range of alternatives as it concerns how the priority criteria would be established and affect Project transfers. And DWR has not bothered to conduct an appropriate level of review under CEQA.

Nor does the *2013 Water Transfer Program* prevent rice growers (or other farmers) from "double-dipping," but actually encourages it. Districts and their growers have opted to turn back their surface supplies from the CVP and the State Water Project and substitute groundwater to cultivate their rice crop—thereby receiving premiums on both their CVP contract surface water as well as their rice crop this fall when it goes to market. There appear to be no caps on water sale prices to prevent windfall profits to sellers of Sacramento Valley water — especially for crops with high market prices, such as in rice.

As stated, neither the Bureau nor DWR disclose what quantity of water from the transfers would go to public health, urban, or agricultural buyers. The EA must also (but fails to) address the ability and willingness of potential buyers to pay for Project water given the supplies that may be available. Complaints from agricultural water districts were registered in the comments on the Draft EWA EIS/R and reported in the Final EIS/R in January 2004 indicating that they could not compete on price with urban areas buying water from the EWA. Given the absence of priority criteria, will agricultural water buyers identified in Table 2-2 of the EA be able to buy water when competing with urban districts? Since buyers are not disclosed in the EA for non-CVP river water (as they also were not, for example, in the Negative Declaration for Butte Water District's 2013 non-CVP river water sales), not only is there a significant lack of disclosure, but the failure to access ramifications on economic policy and competition between and agricultural sectors is a serious omission? What factors other than price should be considered in allocating water among our state's regions? This fails dramatically to encourage regions to develop their own water supplies more efficiently and cost-effectively without damage to resources of other regions.

Full disclosure of each offer of and request for *2013 Water Transfer Program* water should be provided as part of the EA including non-CVP river water. This is necessary so the public can understand and have confidence in the efficacy of the Project's need, although the Project

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[2] "Panic over rice prices hits California," *AZCentral.com*, April 24, 2008; UN News Service, "Bumper rice harvests could bring down prices but poor may not benefit, warns UN," 25 February 2009; "Era of cheap rice at an end in Taiwan: COA," *The China Post*, March 5, 2009; Jim Downing, "Sacramento Valley growers se rice prices soar," *Sacramento Bee*, 18 January 2009.

purpose, as discussed above, is completely absent. The public benefits from full disclosure of who requests what quantity of water, and for what uses, so that the public may easily verify chains of cause and effect. Agricultural and urban application of transferred surface water is not examined in the EA/FONSI, as though the ways potential buyers would use their purchased water had no environmental effects. Agriculture hardens demand by expansion and crop type and urban users harden demand by expansion. Both sectors may fail to pursue aggressive conservation and grapple with long-term hydrologic constraints with the delivery of more northern California river water that has been made available by groundwater mining. Since California has high variability in precipitation year-to-year (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST), how will purchased water be used and conserved? What growth inducing impacts will such transferred water facilitate and how will hardening of demand be evaluated?

Nor is a hierarchy of priority uses among agricultural or urban users for purchasing CVP and non-CVP water presented. Could purchased water be used for any kind of crop or landscaping, rather than clearly domestic purposes or strictly for drought-tolerant landscaping? We cannot tell from the EA/FONSI narrative. How can the citizens of California be assured that water purchased through the *2013 Water Transfer Program* will not be used wastefully, in violation of the California Constitution, Article X, Section 2?

If urban buyers are participating in the CVP and/or non-CVP river water sales, and the public has not been presented with any information in this regard except that, "[u]rban water users would face shortages in the absence of water transfers" in the No Action discussion, (pp. 6 and 27), will they need their Project purchased water only in July through September, or is that the delivery period preferred in the Project because of ecological and fishery impact constraints on conveyance of purchased water?

Should agricultural water users be able to buy Project water, how will DWR and the Bureau assure that transferred water for irrigation is used efficiently? Many questions are embedded within these concerns that DWR and the Bureau should address, especially when they approach the State Water Resources Control Board to justify consolidating their places of use in their respective water rights permits:

- How much can be expected to be purchased by agricultural water users, given the absence of any criteria, let alone priority criteria, in the *2013 Water Transfer Program*?
- How much can be expected to be consumptively used by agricultural water buyers?
- How much can be expected to result in tailwater and ag drainage?
- How much can be expected to add to the already high water table in the western San Joaquin Valley?
- What selenium and boron loads in Mud Slough and other tributaries to the San Joaquin River may be expected from application of this water to WSJ lands?
- What mitigation measures are needed to limit such impacts consistent with the public trust doctrine, Article X, Section 2 of the California Constitution, the Porter-Cologne Water Quality Control Act, and California Fish and Game Code Section 5937?

In other words, the most important chains of cause and effect— from the potential for groundwater resource impacts in the Sacramento Valley to the potential for contaminated drainage water from farm lands in the western San Joaquin Valley where many of the agricultural buyers are located—are ignored in the Bureau's EA/FONSI and completely missing due to DWR's failure to comply with CEQA.

Will more of river water transfers go to urban users than to ag users or not? The EA's silence on this is disturbing, and it highlights the absence of priority criteria. What assurances will the Bureau and DWR provide that criteria exist or will be developed and how will these criteria be presented to the public and closely followed?

- The more transfers to urban water agencies, the less environmental impacts there would be on drainage-impaired lands of the San Joaquin Valley, a neutral to beneficial impact of the Project's operation on high groundwater and drainage to the SJR.
- However, the more Project water goes to agricultural users than to urban users, the higher would be groundwater levels, the more contaminated the groundwater would be in the western San Joaquin Valley and the more the San Joaquin River would be negatively affected from contaminated seepage and tailwater by operation of the Project.

We are pleased that the EA provides a map indicating where the CVP sellers and buyers are located, but the cumulative buyers and sellers in 2013, which includes non-CVP river water and groundwater substitution, are omitted. This is a major error.

Two issues concerning water rights are raised by this EA/FONSI:

- **Consolidated Place of Use.** The EA should fully disclosure the consolidated places of use for DWR and the Bureau. Why is the flexibility claimed for the consolidated place of use necessary for this year's water transfer program? Could the transfers be facilitated through transfer provisions of the Central Valley Project Improvement Act? Will the consolidation be a permanent or temporary request, and will the consolidation be limited to the duration of just the *2013 Water Transfer Program*? Is there an actual sunset date to this Project, since it continues serially in multiple years and plans a 10-Year Program? How do the consolidated places of use permit amendments to the SWP and CVP permits relate to their joint point of diversion? Why doesn't simply having the joint point of diversion in place under D-1641 suffice for the purpose of the Project?
- **Description of the water right claims of sellers, buyers, the Bureau, and DWR.** Informing the public about water rights claims would necessarily show that buyers and the Agencies clearly possess junior water rights as compared with those of many willing sellers. Full disclosure of these disparate water right claims and their priority is needed to help explain the actions and motivations of buyers and sellers in the *2013 Water Transfer Program*. Otherwise the public and decision makers have insufficient information on which to support and make informed choices. We notice that a modicum of discussion is found in the *Draft Technical Information for Water Transfers in 2013*, but the EA/FONSI fails to take the opportunity to point the reader to it.

To establish a proper legal context for these water rights, the Project's Action Alternative section of the EA/FONSI should also describe more extensively the applicable California Water Code sections about the treatment of water rights involved in water transfers.

Thus, in many ways, the *2013 Water Transfer Program* is a poorly specified program for NEPA and CEQA purposes, leaving assessment of its environmental effects at best murky, and at worst, risky to all involved, especially users of Sacramento Valley groundwater resources. "Clearly, it is pointless to 'consider' environmental costs without also seriously considering action to avoid them." *Calvert Cliffs' Coordinating Comm., Inc. v. U.S. Atomic Energy Commn.*, 449 F.2d 1109, 1128 (D.C. Cir. 1971). It is thus the Bureau's duty to consider "alternatives to the proposed action" and to "study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning alternative uses of available resources." 42 U.S.C. §§ 4332(2)(C)(iii), 4332(2)(E); 40 C.F.R. § 1502.14(a).

B. Correcting the EA's poorly specified chains of cause and effect forces consideration of an expanded range of alternatives.

Bureau and DWR water transfers are not just one- or two-year transfers, but rather many serial actions in multiple years by the Agencies, sellers, and buyers without the benefit of comprehensive planning or environmental analysis under NEPA and CEQA. The Agencies have been implementing so called "temporary" or "short term" water transfers over a dozen years and has had those same years to adequately consider the ramifications of these serial actions in multiple years in an EIS/EIR, yet the Agencies have chosen not to complete the task. See table below[3].

Past Water Transfers from the Sacramento Valley Through the Delta TAF Annually

Program	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Potential 2012**
DWR Drought Water Bank/Dry yr. Programs	138	22	11	0.5	0	0	0	0	74	0	0	0
Environ. Water Acct	80	145	70	120	5	0	147	60	60	60	0	60
Others (CVP, SWP, Yuba, inter alia)	160	5	125	0	0	0	0	173	140	243	0	190
Totals	378	172	206	120.5	5	0	147	233	274	303	0	250

*Table reflects gross AF purchased prior to 2percent Delta carriage loss (i.e., actual amounts pumped at Delta are 20 percent less)

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[3] This table is derived from the Western Canal Water District's Negative Declaration for a 2012 water transfer.

Adequate treatment of alternatives should have been examined in the EA with several reasonable scenarios beyond simply the Proposed Action and a "no action" alternative. Three reasonable permutations would have considered relative proportions of crop idling versus groundwater substitution (e.g., high/low, low/high, and equal proportions of crop-idled water and groundwater substitution). Other reasonable dry-year response alternatives that can meet operational and physical concerns merit consideration and analysis by the Bureau includes:

- Planned permanent retirement of upslope lands in the western San Joaquin Valley where CVP-delivered irrigation water is applied to lands contaminated with high concentrations of selenium, boron and mercury, and which contribute to high water table and drainage problems for lowland farmers, wetlands and tributaries of the San Joaquin River. Retirement of these lands would permanently free up an estimated 3.9 MAF[4] of state and federal water during non-critical water years. Ending irrigation of these lands would also result in substantial human environmental benefits for the San Joaquin River, the Bay-Delta Estuary, and the Suisun Marsh from removal of selenium, boron, and salt contamination. Having such reasonable and pragmatic practices in place would go a long way to eliminate the need for drought water banks in the foreseeable future.
- More aggressive investment in agricultural and urban water conservation and demand management among CVP and SWP contractors even on good agricultural lands, including metering of all water supply hook-ups by all municipal contractors, statewide investment in low-flush toilets and other household and other buildings' plumbing fixtures, and increased capture and reuse of recycled water. Jobs created from such savings and investments would represent an economic stimulus that would have lasting employment and community stability benefits as well as lasting benefits for water supply reliability and environmental stabilization.

C. The *2013 Water Transfer Program* EA fails to specify adequate environmental baselines, or existing conditions, against which impacts would be assessed and mitigation measures designed to reduce or avoid impacts.

The Project's EA/FONSI incorporates by reference the *2010/2011 Water Transfer Program* (pp. 11-13). The Project EA narrative discloses that no water was transferred under the *2010/2011 Water Transfer Program* (p. 13), but fails to mention that litigation was filed in 2010 by AquAlliance, CSPA, and C-WIN challenging the adequacy of the NEPA review.

The Bureau's *2010/2011 Water Transfer Program* environmental review incorporated by reference, for specific facets of the review, the 2003/2004 and 2007/2008 Environmental Water Account EIS/R documents. In both cases, these environmental reviews were conducted on a program whose essential purpose is to "provide protection to at-risk native fish species of the Bay-Delta estuary through environmental beneficial changes in State Water Project/Central Valley Project operations at no uncompensated water cost to the Projects' water users. This

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[4] Pacific Institute, http://www.pacinst.org/reports/more_with_less_delta/index.htm.

approach to fish protection involves changing Project operations to benefit fish and the acquisition of alternative sources of project water supply, called the 'EWA assets,' which the EWA agencies use to replace the regular Project water supply lost by pumping reductions."

The two basic sets of actions of the EWA were to:

- Implement fish actions that protect species of concern (e.g., reduction of export pumping at the CVP and SWP pumps in the Delta); and
- Increase water supply reliability by acquiring and managing assets to compensate for the effects of the fish actions (such as by purchasing water from willing sellers for instream flows that compensates the sellers for forgone consumptive use of water).

Without going into further detail on the EWA program, there was no attempt by the EWA agencies to characterize its environmental review as reflective of water transfer programs generally; the EWA was a specific set of strategies whose purpose was protection of fish species of concern in the Delta, not dry-year aid for junior water right-holding areas of California. Is the Bureau still relying on the EWA analysis from 2003/2004 and 2007/2008 since it continues to point backward in each successive attempt to analyze water transfers? If so, one consequence of this attempt to rely on the EWA EIS/R is that it makes the public understanding of the environmental baseline of the *2013 Water Transfer Program* impossible, because environmental baselines, differing purpose and need for the project, and many relevant mitigation measures are not readily available to the public. Merely referring to the EWA documents in the *2010/2011 Water Transfer Program* (e.g.) p. 3-47) and then referring to the *2010/2011 Water Transfer Program* in the Project EA mocks the missions of NEPA and CEQA to inform the public adequately about the environmental setting and potential impacts of the proposed project's actions. Moreover, a Water Transfer Program for urban and agricultural sectors is plainly not the same thing as an Environmental Water Account.

Another consequence is that the chains of cause and effect of an EWA versus the *2010/2011 Water Transfer Program* or the *2013 Water Transfer Program* are entirely different because of their different purposes. While the presence of water purchases, willing sellers, and requesting buyers is similar, the timing of EWA water flows are geared to enhancing and protecting fish populations; the water was to flow in Delta channels to San Francisco Bay and the Pacific Ocean. In stark contrast, the *2010/2011 Water Transfer Program* and the *2013 Water Transfer Program* water flows focus water releases from the SWP and CVP reservoirs to exports for deliveries in the July through September period, whereas EWA assets would be "spent" year-round depending on the specific need to protect fish. EWA was about purchasing water to provide instream flows in the Delta, while the *2010/2011 Water Transfer Program* and the *2013 Water Transfer Program* facilitate water sales to serve consumptive uses outside of the Delta.

Furthermore, DWR and the Bureau do not even attempt to tease out the various ways in which the EWA review—itself a two-binder document consisting of well over 1,000 pages—could be used to provide appropriate environmental compliance for river water transfers with myriad potential for impacts in the areas of origin, despite at least having staff resources that could have undertaken such task. It is therefore well beyond the reach of non-expert decision-makers and the public, and the use of the EWA EIS/R as part of the environmental review for the *2010/2011 Water Transfer Program* or the *2013 Water Transfer Program* therefore violates both NEPA and CEQA.

Nor is any attempt made in the EWA EIS/Rs to characterize the EWA as a "program level" environmental review, off of which a Water Transfer Program-like project could perhaps legitimately tier. In our view, this reliance on the EWA EIS/R obscures the environmental baselines of the Project from public view, inappropriately conflates the purposes of two (or maybe three) distinct environmental reviews, and flagrantly violates NEPA and CEQA. This could only be redressed by preparation of an EIS/R on the *2013 Water Transfer Program*.

Finally, the most significant baseline condition omitted in the Bureau's inadequate and DWR's negligent reporting relates to Sacramento Valley groundwater resources, discussed in the next section.

D. Scientific uncertainties and controversy about Sacramento Valley groundwater resources merit consideration that only an EIS can provide.

There is substantial evidence that the *2013 Water Transfer Program* may have significant impacts on the aquifer system underlying the project and the adjacent region that overlies the Tuscan Formation. This alone warrants the preparation of an EIS.

Additionally, an EIS is necessary where "[a] project['s] … effects are 'highly uncertain or involve unique or unknown risks.'" *Blue Mountains Biodiversity Project*, 161 F.3d at 1213 (quoting 40 C.F.R. §1508.27(b)(5)). Here, the draft EA/FONSI fails to adequately address gaps in existing scientific research on the hydrology of the aquifer system and the extent to which these gaps affect the Bureau's ability—and by logical extension, DWR's ability—to assess accurately the Project's environmental impacts.

1. Existing research on groundwater conditions indicates that the *2013 Water Transfer Program* may have significant impacts on the aquifer system.

The EA fails to describe significant characteristics of the aquifers that the *2013 Water Transfer Program* proposes to exploit. These characteristics are relevant to an understanding of the potential environmental effects associated with the *2013 Water Transfer Program*'s potential direct extraction of up to 37,505 AF of groundwater (pp. 8, 9, 11, 28,29, 35) and the indirect extraction of 92,806 AF of groundwater (p. 31). First, the draft EA/FONSI fails to describe a significant saline portion of the aquifer stratigraphy of the *2013 Water Transfer Program* area, which includes the non-CVP regions. According to Toccoy Dudley, former Groundwater Geologist with the Department of Water Resources and former director of the Butte County Water and Resources Department, saline groundwater aquifer systems of marine origin underlie the various freshwater strata in the northern counties of Butte, Colusa, Glenn, and Tehama ("northern counties"). The approximate contact between fresh and saline groundwater occurs at a depth ranging from 1500 to 3000 feet. (Dudley 2005)

Second, the EA fails to discuss the pressurized condition of the down-gradient portion of the Tuscan formation, which underlies the northern counties. Dudley finds that the lower Tuscan aquifer located in the Butte Basin is under pressure. "It is interesting to note that groundwater elevations up gradient of the Butte Basin, in the lower Tuscan aquifer system, are higher than the ground surface elevations in the south-central portion of Butte Basin. This creates an artesian flow condition when wells in the central Butte Basin are drilled into the lower Tuscan aquifer." (Dudley 2005). The artesian pressure indicates recharge is occurring in the up-gradient portions of the aquifer located along the eastern margin of the Sacramento Valley.

Third, the EA fails to describe the direction of movement of water through the subbasins in the Sacramento Valley. To consider the Lower Tuscan Formation as an example, according to Dudley: "From Tehama County south to the city of Chico, the groundwater flow direction in the lower Tuscan is westerly toward the Sacramento River. South of Chico, the groundwater flow changes to a southwesterly direction along the eastern margin of the valley and to a southerly direction in the central portion of the Butte Basin." (2005) Adequate NEPA review would describe in detail all the subbasins where groundwater substitution transfers (or "mining" to be more direct) is planned to facilitate the Project.

Fourth, the draft EA fails to disclose that the majority of wells used in the Sacramento Valley are individual wells that pump from varying strata in the aquifers. The thousands of domestic wells in the target export areas of the Sacramento Valley are vulnerable to groundwater manipulation and lack historic monitoring. The Bureau's 2009 DWB EA elaborated on this point regarding Natomas Central MWC (p. 39) stating that, "Shallow domestic wells would be most susceptible to adverse effects. Fifty percent of the domestic wells are 150 feet deep or less. Increased groundwater pumping could cause localized declines of groundwater levels, or cones of depression, near pumping wells, possibly causing effects to wells within the cone of depression. As previously described, the well review data, mitigation and monitoring plans that will be required from sellers during the transfer approval process will reduce the potential for this effect."

As the latter statement made clear (even though the information from the 2009 DWB was excluded from the Project EA), the Bureau hoped that individual mitigation and monitoring plans created by the sellers would reduce the potential for impacts, but there wasn't in 2009 (and there certainly isn't in 2013) any assurance in the EA that it will reduce it to a level of insignificance for the thousands of well owners in the Sacramento Valley. AquAlliance questions the adequacy of individual mitigation and monitoring plans and suggests that an independent third party, such as USGS, oversee the mitigation and monitoring program, not the Bureau and DWR. After the fiasco in Butte County during the 1994 Drought Water Bank and with the flimsy, imprecise proposal for mitigation and monitoring in the *2013 Water Transfer Program* (see details below), the agencies lack credibility as oversight agencies.

In addition, even the Sacramento Valley Integrated Water Management Plan (2006) proposed a Framework for Sacramento Valley regional water resource monitoring that would also benefit shallow domestic-well owners. The Framework acknowledged that, "The lowering of groundwater levels due to the interception of groundwater underflow to surface water systems due to the increased groundwater extraction associated with conjunctive water management programs, have the potential to impact the native habitat areas," and that, "In order to identify potential habitat impacts associated with implementation of conjunctive water management alternatives, a program-specific network of shallow monitor monitoring wells should be developed to detect changes in water levels over the shallowest portion of the aquifer. The groundwater monitoring network should contain shallow monitoring wells that will record changes to the water table elevation in the vicinity of these sensitive habitat areas." Unfortunately, the Framework was shelved, and the shallow monitoring network never got off the ground.

Fifth, the draft EA fails to provide recharge data for the aquifers. Professor Karin Hoover, Assistant Professor of hydrology, hydrogeology, and surficial processes from CSU Chico, found in 2008 that, "Although regional measured groundwater levels are purported to 'recover' during the winter months (Technical Memorandum 3), data from Spangler (2002) indicate that recovery levels are somewhat less than levels of drawdown, suggesting that, in general, water levels are declining." According to Dudley, "Test results indicate that the 'age' of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the Lower Tuscan Formation along the eastern margin of the valley have the 'youngest' water and the deeper wells in the western and southern portions of the valley have the 'oldest' water," adding that "the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas." (2005). "This implies that there is currently no active recharge to the Lower Tuscan aquifer system (M.D. Sullivan, personal communication, 2004)," explains Dr. Hoover. "If this is the case, then water in the Lower Tuscan system may constitute fossil water with no known modern recharge mechanism, and, once it is extracted, it is gone as a resource," (Hoover 2008). In another sub-basin, Yuba County Water Agency has encountered troubling trends that, according to the Draft EWA EIS/EIR, are mitigated by deepening domestic wells (2003 p. 6-81). While digging deeper wells is at least a response to an impact, it hardly serves as a proactive measure to avoid impacts.

All aquifer characteristics are important to a full understanding of the environmental impacts of the *2013 Water Transfer Program*. In the Tuscan Aquifer, for instance, there are numerous indications that other aquifer strata are being operated near the limit of overdraft and could be affected by the *2013 Water Transfer Program* (Butte County 2007). The Bureau has not considered this important historic information in the draft EA/FONSI. According to Dudley, the Chico area has a "*long term average decline in the static groundwater level of about 0.35 feet-per-year*." (Letter to Lester Snow as presented to the Butte County Board of Supervisors as part of agenda item 4.05, 2007) (emphasis added.) Declining aquifer levels are not limited to the Chico Municipal area. This trend of declining aquifer levels in Chico, Durham and the Cherokee Strip is illustrated in a map submitted with these comments (CH2M Hill 2006).

Declining groundwater elevations in Butte County are relevant to the Tuscan Aquifer, but also are emblematic of a valley-wide trend affecting other aquifers that illustrates serious overuse of groundwater. It is disturbing that neither the specifics of overuse conditions nor summaries of the groundwater basins and sub-basins are disclosed in the Project EA/FONSI. Below are some examples:

1. The Butte Basin Groundwater Status Report describes the "historical trend" in the Esquon Ranch area as showing "seasonal fluctuation (spring to fall) in groundwater levels of about 10 to 15 feet during years of normal precipitation and less than 5 feet during years of drought." The report further notes: "Long-term comparison of spring-to-spring groundwater levels shows a decline of approximately 15 feet associated with the 1976-77 and 1986-94 droughts (Butte Basin Water Users Association, 2007). The 2008 report indicates that, "The spring 2008 groundwater level measurement was approximately three feet higher than the 2007 measurement, however it was still four feet lower than the average of the previous ten spring measurements. Fall groundwater levels are approximately nine feet lower than the averages of those measured during either of the previous drought periods on the hydrograph. At this time it appears that there may be a downward trend in groundwater levels in this well," (Butte Basin Water Users Association, 2008).Thus, "*it appears that there may be a downward trend in groundwater levels in this well*." *Id.* (emphasis added). The 2012 Esquon Subinventory Unit report confirms this downward trend:

    > Water elevations have been monitored since 1953 at this location [20N02E09L001M] and the historical averages, including 2011 data, are; Spring=128 feet and Fall=121 feet. The spring 201i groundwater level measurement was approximately six feet lower than the average during the previous drought periods. Recent fall groundwater levels are approximately eleven feet lower than the averages of those measured during either of the previous drought periods on the hydrograph. At this time it appears that there may be a downward trend in groundwater levels in this well.

    This Esquon well is also one that was hammered during the 1994 DWB when water sales with groundwater substitution by Western Canal Water District and others in southern Butte County cause significant impacts. *Id* (p. 6)

2. Groundwater elevations in the Pentz sub-area in Butte County also reveal significant historical declines. The historical trend for this sub-area "…shows that the average seasonal fluctuation (spring to fall) in groundwater levels averages about 3 to 10 feet during years of normal precipitation and approximately 3 to 5 feet during years of drought. Long-term comparison of spring-to-spring groundwater levels shows a decline in groundwater levels during the period of 1971-1981, perhaps associated with the 1976-77 drought. Since a groundwater elevation high of approximately 145 feet in 1985 the

measured groundwater levels in this well have continued to decline. Recent groundwater level measurements indicate that the groundwater elevation in this well is approximately 15-25 feet lower than the historical high in 1985. *(Butte Basin Water Users Association, 2007* and 2012 Pentz Subinventory Unit report, p. 5*).* Water elevations at the Pentz sub-area well have been monitored since 1967. "Since 1985 spring groundwater levels in this well have been declining and the spring 2008 measurement remained ten feet below historical high levels and continues the downward trend on the hydrograph." *Id.* p. 6 The Pentz and Esquon Ranch areas are located on the east and west sides of U.S. 99 respectively, in the eastern portion of the Tuscan aquifer.

3. Further evidence of changing groundwater levels appear in the Vina sub-region of Butte County, where water elevations have been monitored since 1947 at well 23N01W09E001M. The historical averages, including 2012 data, are; Spring=156 feet and Fall=150 feet (Butte County, Vina BMO report, p. 19). Unfortunately, the groundwater level measurement at this well in 2008 was the lowest recorded since 1994 *Id* Rock Creek, which is also in the Vina sub-unit once held water all year, and salmon fishing was robust prior to the 1930s (Hennigan 2010). Declining groundwater levels have caused the valley portion of Rock Creek to run completely dry each year and have also been noticed with Hennigan Farms' wells since the 1960s. For example, a 1968 well had to be lowered 40 feet in 1974, another well constructed in 1978 had to be lowered 20 feet in 2009, and an old 1940s flood pump was lowered in the early 1960s, lowered again in 1976 when it was converted to a pressure pump, and lowered again in 1997 (Hennigan 2010).

The Natural Heritage Institute and Glenn Colusa Irrigation District acknowledge the declines in the Northstate aquifers, "Based on the most recent (Fall 2011) data collected by DWR, there appear to be some areas in the northern Sacramento Valley with persistent groundwater level declines, primarily in Glenn and Tehama Counties." (*Feasibility Investigation of Re-Operation of Shasta and Oroville Reservoirs in Conjunction with Sacramento Valley Groundwater Systems to Augment Water Supply and Environmental Flows in the Sacramento and Feather Rivers* p. v) Although the Bureau and DWR provided funds for the NHI/GCID report, the general knowledge of groundwater declines in Glenn and Tehama counties is neither presented nor referenced in the Project's EA.

In light of this downward trend in regional groundwater levels, the Bureau's EA should closely analyze replenishment of the aquifers affected by the proposed *2013 Water Transfer Program*. The draft EA fails to provide any in-depth assessment of these issues. For example, the EA fails to discuss the best available estimates of where groundwater replenishment occurs. Lawrence Livermore National Laboratory analyzed the age of the groundwater in the northern counties to shed light on this process: "Utilizing the Tritium (H3) Helium-3 (He3) ratio, the age of each sample was estimated. Test results indicate that the "age" of the groundwater samples ranges from less than 100 years to tens of thousands of years,: (Dudley et al. 2005). As mentioned above, Dudley opines that the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas. (2005).

Are isotopic groundwater data available for other regions in the Sacramento Valley? If so, they would be crucial for all concerned to understand the potential impacts from the proposed *2013 Water Transfer Program*. Where does the EA identify areas most vulnerable to groundwater impacts? Does the Bureau identify how the Project conflicts with attempts at local management, particularly in areas where there are existing groundwater problems? Just consider that the City of Sacramento proposes to transfer surface water into the state water market and substitute 3,800 AF of groundwater (EA p.31), but the Sacramento County Water Agency *Water Management Plan* indicates that intensive use of this groundwater basin has resulted in a general lowering of groundwater elevations that will require extensive conservation measures to remediate. The Sacramento County Water Agency has devised a plan to help lead the city to a sustainable groundwater use to avoid problems associated with unrestrained overuse (2011). The most reliable strategy is to reduce demand, particularly from outside a groundwater basin. Integrating the City's water supply into the state water supply would obviously increase demand and make the SCWA goals impossible to achieve.

The Bureau should prepare an EIS that discloses the fallacies inherent in its policies and actions. The need for almost 400,000 AF per year of water south of the Delta (*2010/2011 Water Transfer Plan*), 190,000 AF with the 2013 Project, and 600,000 AF per year in the 10-Year Plan springs from failed business planning. The Bureau and DWR must acknowledge this and further disclose that their agencies are willing to socialize the risks taken by corporate agribusiness and developers while facilitating private profit. Instead of asking northern California water districts and municipal water purveyors to place at risk their own water (as well as the water of their neighboring communities and thousands of residential well owners), water quality, fisheries, recreation, stream flow, terrestrial habitat, and geologic stability, the Bureau and DWR must disclose all the uncertainty in the *2013 Water Transfer Program* and then evaluate the risks with scientific methodology. This has clearly not been done.

2. The *2013 Water Transfer Program* proposes to rely on inadequate monitoring and mitigation to avoid the acknowledged possibility of significant adverse environmental impacts.

The draft EA and the *Draft Technical Information for Water Transfer Proposals in 2013* (http://www.water.ca.gov/watertransfers/) referenced in the EA require "willing sellers" to prepare individual monitoring and mitigation plans and to conduct the monitoring with oversight provided by the Bureau and DWR (p. 12 - 14, 32). This fails to provide the most basic framework for governmental authority to enforce the state's role as trustee of the public's water in California, let alone a comprehensive and coordinated structure, for a very significant program that could transfer up to 190,906 AF of water from the Sacramento Valley. The draft EA further defers responsibility to "willing sellers" for compliance with local groundwater management plans and ordinances to determine when the effects of the proposed extraction become "adverse," (EA at p. 12). "Each district will be required to confirm that the proposed groundwater pumping will be compatible with state and local regulations and groundwater management plans," (EA at

p. 25). It is not acceptable that the draft EA/FONSI and the *Draft Technical Information for Water Transfers in 2013*merely provide monitoring direction to "willing sellers" without identifying rigorous standards for the risks at hand, specific actions, acceptable monitoring and reporting entities, funding that will be necessary for this oversight, or resources with which to handle possible impacts.

AquAlliance proposes instead that the Bureau and DWR require, at a minimum, that local governments select independent third-party monitors, who are funded by surcharges on Project transfers paid by the buyers, to oversee the monitoring that is proposed in lieu of Bureau and DWR staff, and that peer-reviewed methods for monitoring be required. If this is not done, the Project's proposed monitoring and mitigation outline is insufficient and cannot justify the significant risk of adverse environmental impacts.

To be clear, the EA/FONSI and the *Draft Technical Information for Preparing Water Transfer Proposals* in 2013 fail to identify standards that would be used to monitor the *2013 Water Transfer Program*'s impacts. The documents fail to identify any specific monitoring protocols, locations (particularly in up-gradient recharge portions of the groundwater basins), and why chosen locations should be deemed effective for monitoring the effects of the proposed groundwater extraction. The EA/FONSI and the *Draft Technical Information for Preparing Water Transfer Proposals* in 2013 points to the "seller" as the responsible party to meet the objectives in the *Draft Technical Information for Preparing Water Transfer Proposals* in 2013, but the Bureau and DWR are the responsible agencies that approve and move the water (EA at p.24-26). The EA asserts that, "If monitoring indicated that adverse effects related to the degradation of groundwater quality from the transfer occurred, willing sellers in the region will be responsible for monitoring this degradation and mitigating any adverse effects in accordance with all applicable regulations." (p. 24). There is no explanation as to how the Bureau will hold the "willing sellers" responsible to meet the Bureau's obligations under NEPA.

Moreover, the EA/FONSI fails to provide a mitigation strategy for review and comment by the public. Instead it defers this vital mitigation planning effort to future documents created by the "willing sellers," (EA at p.25-27) despite the fact that the EA acknowledges the potential for significant impacts, however weakly. For example:

> Groundwater substitution transfers could affect groundwater hydrology. The potential effects would be decline in groundwater levels, interaction with surface water, land subsidence, and water quality impacts. The well reviews and plans were required from sellers for review by Reclamation. Reclamation would not approve transfers without adequate mitigation and monitoring plans. The well review and required monitoring and mitigation plans described would minimize or avoid potential adverse effects to groundwater resources, to water quality and to wildlife habitat. (EA at p. 12)

If the Bureau and DWR's approvals are so rigorous and protective of the communities, economy, and environment in the Sacramento Valley, where are the standards for review and approval? With the expectation that groundwater levels will decrease (EA at p. 12) where is the explanation that reveals the amount by which the groundwater is expected to decrease and what level of decrease is considered to be acceptable? Where is an explanation as to why the amount of water to be extracted is not considered significant? Without thresholds and standards, there is no logical link that leads to the Bureau's conclusion that, "The well review and required monitoring and mitigation plans described would minimize or avoid potential adverse effects to groundwater resources, to water quality and to wildlife habitat." (EA at p.12)

The EA discloses that, "Emissions from the operation of diesel engines could exceed emissions thresholds for each air district and de minimis thresholds for General Conformity," and that , Emissions as a result of the Proposed Action were within thresholds for Glenn, Colusa, Sacramento, and Sutter counties." (EA at p. 12) Where are the support data to reach these conclusory statements? In addition, it is confusing is that the same paragraph assumes that, "Idling rice fields would reduce the use of farm equipment and associated pollutant emissions, resulting in a beneficial impact on air quality." This flies in the face of the Proposed Action that assumes groundwater substitution to replace river water that will be sold, so crop cultivation may continue, which could easily be rice. (EA at pp.6, 9) This incongruity must be explained or changed.

Coupled with the possible impacts that the Bureau is willing to disclose in the EA/FONSI are bold assertions that with Bureau oversight the "sellers" will acknowledge and mitigate impacts. Unfortunately, there is no factual grounding for this grand assumption, and there is no disclosure to demonstrate how a business or individual would demonstrate harm. Such was the problem in 1994, when DWR and the sellers told people without irrigation and residential well water that they couldn't prove it was the water sales or existing conditions. The environment also needs a voice in this water marketing scheme, but there isn't a method or plan to provide it. The EA rightly acknowledges that, "It is recognized that an increase in groundwater pumping will affect the rate of groundwater recharge during balanced conditions, which will affect stream flow," (p.11) but fails to suggest how this could be avoided, monitored, or mitigated. Also missing in this regard in the EA/FONSI are:

1. What is the definition of "balanced conditions" in the numerous regions where both CVP and non-CVP groundwater substitution is proposed and who will define it?
2. What are the existing conditions in the areas of origin in 2013 (let alone at the baseline), which must start no sooner that when the CalFed Record of Decision was approved in August 2000?
3. Because the Bureau , DWR, buyers, and sellers continue these multi-year, serial water transfers from the Sacramento Valley, without the benefit of comprehensive environmental review, how has climate change and local use already affected streams, fish, terrestrial species, and groundwater, to name just a few critical areas with significant impacts from the Project?

The EA noticeably omits painfully obvious and significant impacts in the current Project EA/FONSI that were previously disclosed by the Bureau in the *2010/2011 Water Transfer Program* EA/FONSI. For example:

- Surface water and groundwater interact on a regional basis, and, as such, gains and losses to groundwater vary significantly geographically and temporally. In areas where groundwater levels have declined, such as in Sacramento County, streams that formerly gained water from groundwater now lose water to the groundwater system through seepage (*2010/2011 Water Transfer Program* EA at p. 3-12).
- *Groundwater substitution transfers would alter ground water levels and potentially affect natural and managed seasonal wetlands and riparian communities, upland habitats and wildlife species depending on these habitats.* As a part of groundwater substitution transfers, the willing sellers would use groundwater to irrigate crops and decrease use of surface water. Pumping additional groundwater would decrease groundwater levels in the vicinity of the sellers' pumps. Natural and managed seasonal wetlands and riparian communities often depend on surface water/groundwater interactions for part or all of their water supply. Under the Proposed Action, subsurface drawdown related to groundwater substitution transfers could result in hydrologic changes to nearby streams and marshes, potentially affecting these habitats. Reduced groundwater elevations could also affect trees that access groundwater as a source of water through taproots in addition to extensive horizontal roots that use soil moisture as a water source. Decreasing groundwater levels could reduce part of the water base for species within these habitats (EA at p. 3-53 and 3-54).

Have these impacts dissipated, or were they not disclosed in the Project EA/FONSI?

The reader is directed to the Bureau and DWR's *Draft Technical Information for Water Transfers* in 2013 to discover the *minimal* objectives and required elements of the monitoring and mitigation component of the Project. "Water transfer proponents transferring water via groundwater substitution transfers must establish a monitoring program capable of identifying any adverse transfer related effects before they become significant." However, the reader (and possibly the sellers) are left wondering what exactly is "a monitoring program capable of identifying any adverse transfer related effects before they become significant," since there are no standards or particular guidance to manage and analyze the very complex hydrologic relationships internal to groundwater and its connection to surface waters.

Certainly the public has no idea or ability to comment, which fails the full disclosure mandate in NEPA and CEQA. Page 38of the *Draft Technical Information for Water Transfers* in 2013 briefly lists, "Potentially significant impacts identified in a water transfer proposals [that] must be avoided or mitigated for a proposed water transfer to continue, including:"

- Contribution to long-term conditions of overdraft;
- Dewatering or substantially reducing water levels in nonparticipating wells;
- Measurable contribution to land subsidence;
- Degradation of groundwater quality that substantially impairs beneficial uses or violates water quality standards; and
- Affecting the hydrologic regime of wetlands and/or streams to the extent that ecological integrity is impaired.

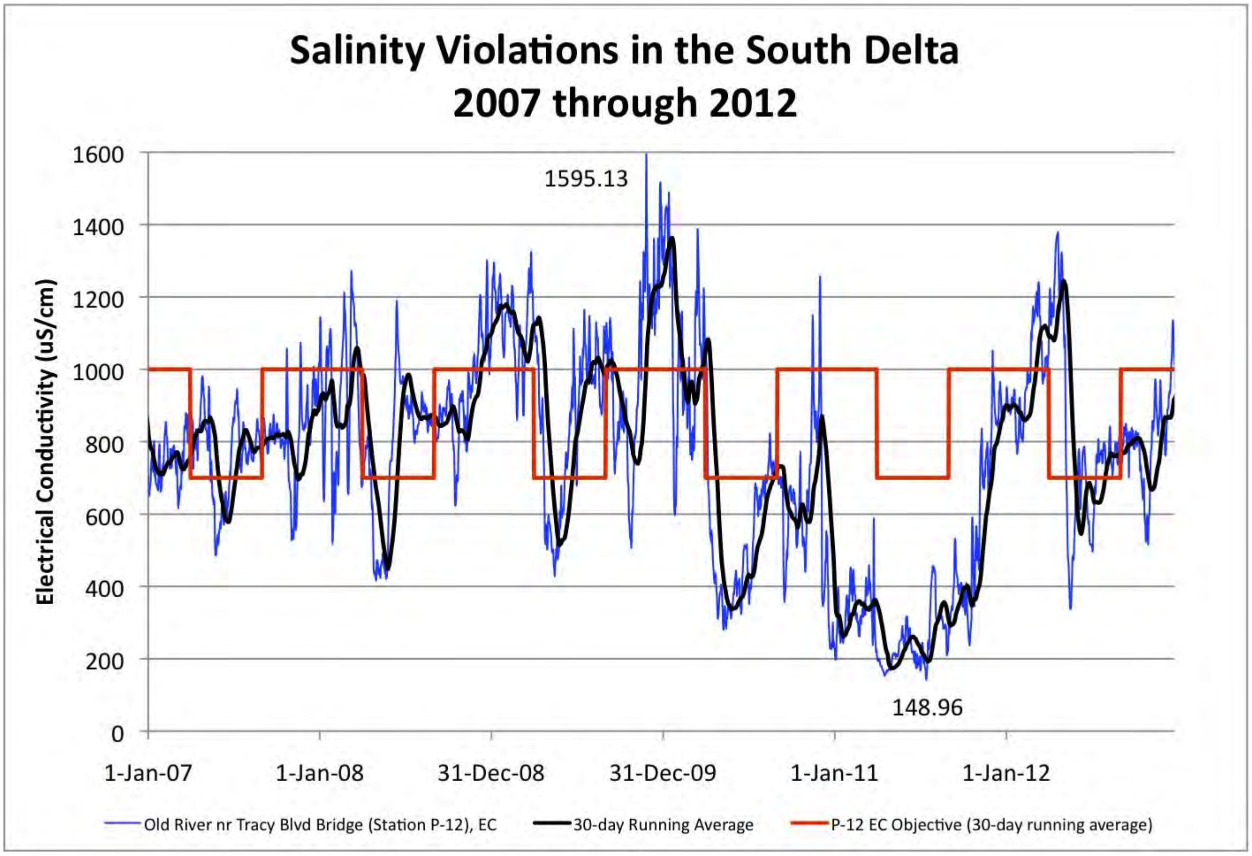
The *Draft Technical Information for Water Transfers* in 2013 continues with suggestions to curtail pumping from lower bowls, and pay higher energy costs to ease the impacts to third party wells owners (p. 38-39). While this bone thrown at mitigation is appreciated, the glaring omissions are notable. The *Draft Technical Information for Water Transfers* in 2013 completely fails to mention, even at a very general level, how individual well owners who may be harmed by the Project, will determine and prove where the impacts to their wells are coming from, that water quality and health could become a significant impact for impacted wells, users, and streams. The onus for coping with and disclosing potential impacts is deflected onto the nonparticipating public, species, and environment. How does this meet the requirements of NEPA and CEQA? Since wetlands and streams would require human observation or adequate monitoring to report an impact, how will, "Affecting the hydrologic regime of wetlands or streams to the extent that ecological health is impaired," be avoided or mitigated without standards and requirements from the Bureau and DWR? (*Draft Technical Information for Water Transfers* p. 38) There also appears to be no consideration for species monitoring, just "practices" or "conservation measures" to "minimize impacts to terrestrial wildlife and waterfowl," (*Draft Technical Information for Water Transfers* pp. 16, 20, 22-24).

The EA/FONSI and the *Draft Technical Information for Water Transfers* in 2013 don't appear to weigh the significance of avoidance of impacts, pre-Project mitigation, during Project mitigation, or post-Project mitigation. This fails to create objective standards and merely differs responsibility to the "willing sellers," a broadly unsuspecting public, and a voiceless environment.

Another example of the inadequacy of the proposed monitoring is that the draft EA fails to include any coordinated, programmatic plan to monitor stream flow of creeks and rivers located in proximity to the "willing sellers" that will evacuate more groundwater than has been used historically. The potential for immediate impacts would be very close to water sellers' wells, but the long term impacts could be more subtle and geographically diverse. What precautions has the Bureau and DWR made for the cumulative impacts that come not only from this one-year Project, but in combination with the water sales from the last dozen years and those that are planned by the Bureau into the future (see lists in Sections G, 4 & 5 below)? Bureau and DWR water transfers are not just one- or two-year transfers, but many serial actions in multiple years by the agencies, sellers, and buyers without the benefit of comprehensive environmental analysis under NEPA and CEQA.

As discussed above, adequate monitoring is vital to limit the significant risks posed by the Project to the health of the region's groundwater, streams, and fisheries (more discussion below). Moreover, to the extent this Project is conceived as an ongoing hardship program that will provide knowledge for future groundwater extraction and fallowing, its failure to include adequate monitoring protocols is even more disturbing and creates the risk of significant long-term, perhaps irreversible impacts from the Project.

a. The Bureau's assertion that the Project may be modified or halted in the event of significant adverse impacts to hydrologic resources is an empty promise in light of the wholly inadequate EA disclosure, and proposed monitoring for the *2013 Water Transfer Program.* Knowing that the Bureau and DWR deliberately and repeatedly violate the a major requirement like the X2 standard in the Delta does little to instill confidence from AquAlliance in the vague, non-specific monitoring program and mitigation criteria proposed in the EA/FONSI and associated documents..



Source: Tim Stroshane, May 2013

The *2010/2011 Water Transfer Program* has been incorporated by reference in the Project EA. AquAlliance found repeated illustrations of potential for significant injury to other groundwater users, water quality, streams, flora and fauna, and the soil profile in the *2010/2011 Water Transfer Program* (p. 3-12, 3-23, 3-24, 3-53, 3-54). Chapter Three contained numerous examples that illustrated the need for an EIS since there is insufficient, comprehensive planning for, let alone preparation to mitigate, adverse environmental impacts:

- *Acquisition of water via groundwater substitution or cropland idling would change the rate and timing of flows in the Sacramento River compared to the No Action Alternative.*
- *In Figure 3.2-2, groundwater substitution pumping results in a change in the groundwater/surface water interaction characteristics. In this case, the water pumped*

from a groundwater well may have two impacts that reduce the amount of surface water compared to pre-pumping conditions. These mechanisms are:

  - *Induced leakage. The lowering of the groundwater table causes a condition where the groundwater table is lower than that the water level in the surface water. This conditions causes leakage out of the surface water.*
  - *Interception of groundwater. The placement of groundwater substitution pumping may intercept groundwater that may normally have discharged to the surface water (i.e., water that has already percolated into the ground may be pumped out prior the water reaching the surface water and being allowed to enter the "gaining" stream).*

- *The changes in groundwater flow patterns (e.g., direction, gradient) due to increased groundwater substitution pumping may result in changes in groundwater quality from the migration of reduced quality water.*
- *Groundwater substitution transfers would alter ground water levels and potentially affect natural and managed seasonal wetlands and riparian communities, upland habitats and wildlife species depending on these habitats.*
- *Rice land idling transfers would reduce habitat and forage for resident and migratory wildlife populations.*
- *Water transfers could change reservoir releases and river flows and potentially affect special status fish species and essential fish habitat.*
- *Water transfers could affect fisheries and aquatic ecosystems in water bodies, including Sacramento and American River systems, the Sacramento-San Joaquin Delta, San Luis Reservoir, and DWR and Metropolitan WD reservoirs in southern California.*
- *Increased groundwater pumping for groundwater substitution transfers would increase emissions of air pollutants.*

The Bureau thus recognizes the potential for significant decline in groundwater levels in the Project's EA as it did in the proposed *2010/2011 Water Transfer Program* (EA at p. 3-23, 3-24, 3-53, 3-54). The acknowledgements alone are sufficient to require a full EIS, but, regrettably, the Bureau has returned with the Project EA in 2013, instead of the EIS for which it ostensibly held scoping meetings in January 2011. Moreover, as detailed below, the monitoring proposed by the *2013 Water Transfer Program* remains inadequate leaving the public and environment with no guarantee that adverse impacts will be discovered at all (or be discovered in time to avoid significant environmental impacts).

Glenn County will experience groundwater substitution if the Project moves forward. Glenn County realized that its management plan and ordinances were not sufficient for the challenges presented by the *2010/2011 Water Transfer Program* and cautioned that "[s]ince the groundwater management plan is relatively new and not fully implemented, the enforcement and conflict resolution process has not been vigorously tested," (2010) Subsequently, Glenn County updated their Ordinance 1237 and amended their *Groundwater Management to Groundwater Coordinated Resource Management Plan* (Glenn County Plan) in 2012, so it remains new and untested.. AquAlliance finds the Glenn County inadequate to protect humans and the environment, since it states that, "The County does not hereby intend to regulate, in any manner, the use of groundwater; unless safe yield is exceeded or there is a threat to public health, welfare, or safety, but intends to adopt monitoring programs that will allow for the effective management of groundwater availability (groundwater level), groundwater quality, and indications of land subsidence." Moreover, the Glenn County Groundwater Management Plan does not have any provisions to monitor or protect the environment, will in no way protect the common Tuscan aquifer that is beyond Glenn County's border, and will protect no one or the environment that that is outside its jurisdictional boundary. The *2013 Water Transfer Program* EA fails to disclose the inadequacies of this and other local ordinances and plans.

Ordinance 1237, which updated the *Groundwater Management to Groundwater Coordinated Resource Management Plan* does not contain a definition of "safe yield," but defers it to the BMO method (Glenn County Plan at p.5) The BMO method is found on Glenn County's web site and was written by Toccoy Dudley in 2000 while he still worked for DWR. This method was created in an attempt to provide a fig leaf for a massive obstacle: safe yield is extremely difficult to determine. "In early 1999 the GCWAC began to focus on a countywide ordinance that did not attempt to control groundwater use, including export, as long as the aquifer system was not harmed and safe yield was not exceeded. But estimating safe yield appeared to be nearly impossible to accomplish given the inherent difficulties in determining safe yield and that no funding was available to do the required studies."
(http://www.glenncountywater.org/management_plan.aspx)

Monitoring based on the Glenn County Plan is clearly inadequate to the task because enforcement remains cumbersome and voluntary. "In the Glenn County structure, if a BMO threshold is exceeded, the process sets into motion a series of events. First the TAC reports on the regional extent and magnitude of the non-compliance to the WAC. The TAC then starts a fact-finding process to identify the cause(s) of the non-compliance and makes recommendations to the WAC on how to resolve the situation. The WAC then tries to resolve the problem in the affected area by negotiations with the locals if at all possible. Some of the possible actions that may be taken by the WAC might be to coordinate the following voluntary actions in the affected area." (Dudley, Basin Management Objective (BMO) Method Of Groundwater Basin Management, 2000 p.8)

The Bureau omitted discussion of the adequacy of the Glenn County Plan or any other county's plan, in the *2013 Water Transfer Program*, but we are pleased that at a minimum the *Draft Technical Information for Water Transfers in 2013* identifies local ordinances in Table 3-1 (p. 27). We believe that this is appropriate juncture to refer to some of the commitments that the Bureau is making for itself and the sellers in the EA. A review of county-of-origin ordinances reveals that they are inadequate to the task because of the absence of enforceable measures that could protect human and environmental health within each county:

- "The objectives of this process are: to mitigate adverse environmental effects that occur; to minimize potential effects to other legal users of water; to provide a process for review and response to reported third party effects; and to assure that a local mitigation strategy is in place prior to the groundwater transfer. The seller will be responsible for assessing and minimizing or avoiding adverse effects resulting from the transfer within the source area of the transfer." (EA at p. 25)

- "Each district will be required to confirm that the proposed groundwater pumping will be compatible with state and local regulations and groundwater management plans. " (EA at p.25) What consideration is made for the inadequacy of a local ordinance that could lead to a serious impact to the human environment and the environment overall?
- "For purposes of this EA, Reclamation assumes that stream flow losses due to groundwater pumping to make water available for transfer are 12 percent of the amount pumped." (EA at p. 25) Where are the supporting data? How will this be mitigated?

Since the Project's EA fails to disclose limitations or inadequacies with local ordinances (also see AquAlliance's Attachments A & B), it is helpful that Butte County's Department of Water and Resource Conservation explains that local plans are simply not up to the task of managing a regional resource:

> Each of the four counties that overlie the Lower Tuscan aquifer system has their own and separate regulatory structure relating to groundwater management. Tehama County, Colusa, and Butte Counties each have their own version of an export ordinance to protect the citizens from transfer-related third party impacts. Glenn County does not have an export ordinance because it relies on Basin Management Objectives (BMOs) to manage the groundwater resource, and subsequently to protect third parties from transfer related impacts. Recently, Butte County also adopted a BMO type of groundwater management ordinance. Butte County, Tehama County and several irrigation districts in each of the four counties have adopted AB3030 groundwater management plans. All of these groundwater management activities were initiated prior to recognizing that a regional aquifer system exists that extends over more than one county and that certain activities in one county could adversely impact another. Clearly the current ordinances, AB3030 plans, and local BMO activities, which were intended for localized groundwater management, are not well suited for management of a regional groundwater resource like that theorized of the Lower Tuscan aquifer system.[5]

c. The EA asserts that, "The potential for subsidence is small if the groundwater substitution pumping is small compared to overall pumping in a region." (p. 24) This is misleading at best, and incorrect at worst. The potential for subsidence in a given clay and slit deposit is small only when groundwater levels can be guaranteed to remain above the lowest water levels caused by past droughts. As more water is pumped from an aquifer because of increased usage of groundwater supplies, the potential for subsidence is increased, not decreased, and if existing pumping brings water levels near to their lowest historical lows, then substitution pumping indeed has the potential to induce subsidence.

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[5] Butte County Department of Water and Resource Conservation, *Needs Assessment Tuscan Aquifer Monitoring, Recharge, and Data Management Project*,.2007.

The EA goes on stating, “The minimization measures in Section 3.2.2.3 require all groundwater substitution transfers to monitor for subsidence or provide a credible analysis why it would be unlikely.” (p. 24) Subsidence is difficult (if not impossible) to detect in the short term. Elastic deformations that are recoverable upon aquifer recharge are readily detected by proper measurement techniques, but these reversible motions are not subsidence. Subsidence is by definition an irreversible mechanical response that permanently lowers the ground surface and that permanently decreases aquifer capacity. Because of the low permeability of soil deposits that are susceptible to subsidence, these permanent effects are commonly widely separated in time from the actual pumping that causes them to begin, and thus only long-term monitoring can accurately identify subsidence.

Or in simple terms, the absence of evidence of subsidence when pumping is initiated provides little or no evidence of whether subsidence is actually occurring. Only when irreversible damage is done over the long-term is the effect of groundwater extraction obvious.

Determining a credible basis for subsidence potential can be extremely difficult and expensive. Such an analysis would commonly require determination of historical low groundwater levels, the likelihood of future increases in groundwater extraction, and the composition of the subsurface layers that comprise the aquifer. If these tasks were easy, they would have been performed already, and the fact that the Bureau cannot provide credible evidence to rule out subsidence is an implicit admission that such credibility is difficult or impossible to obtain in practice.

The EA has responded to AquAlliance’s proposal for real-time monitoring for land subsidence (AquAlliance, et. al, 2010). (EA at p. 24) We believed at the time that this would be a step forward that could reveal immediate subsidence problems. We have subsequently learned is that real-time subsidence monitoring is a misnomer. While it is possible to monitor ground surface elevation, performing this with due degree of precision is not easy or inexpensive in practice. And since such ground-surface monitoring often only provides real-time estimates of elastic (i.e., reversible) surface elevation changes, at best it yields only a hint of the potential damage that can occur in the long term.

Third-party independent verification, perhaps by scientists from the U.S. Geological Survey, should be incorporated by DWR and the Bureau into the Project description of the *2013 Water Transfer Program*. We applaud the initiation of a regional GPS network in the Sacramento Valley but remain concerned about the existing extensometers in the Sacramento Valley that measure land subsidence, and a Global Positioning System land subsidence network established by one county (*2010/2011 Water Transfer Program* EA at p. 13). The remaining responsibility is again deferred to the “willing sellers.” Unfortunately, voluntary monitoring by pumpers does not strike us as a responsible assurance given the substantial uncertainties involved in regional aquifer responses to extensive groundwater pumping in the Sacramento Valley. Admonishing sellers not to cause problems is a deferral of responsibility by the Bureau and DWR.

There is a noticeable absence of discussion regarding delayed subsidence, which we broach above, that should also be monitored according to the findings of Dr. Kyran Mish, Presidential Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma. Dr. Mish notes: "It is important to understand that *all* pumping operations have the potential to produce such settlement, and when it occurs with a settlement magnitude sufficient enough for us to notice at the surface, we call it *subsidence*, and we recognize that it is a serious problem (since such settlements can wreak havoc on roads, rivers, canals, pipelines, and other critical infrastructure)." (Mish 2008) Dr. Mish further explains that "[b]ecause the clay soils that tend to contribute the most to ground settlement are highly impermeable, their subsidence behavior can continue well into the future, as the rate at which they settle is governed by their low permeability." *Id.* "Thus simple real-time monitoring of ground settlement can be viewed as an *unconservative* measure of the potential for subsidence, as it will generally tend to underestimate the long-term settlement of the ground surface." *Id.* (emphasis added).

The *2010/2011 Water Transfer Program* EA acknowledged the existence and cause of serious subsidence in one area of the valley. "The area between Zamora, Knights Landing, and Woodland has been most affected (Yolo County 2009). Subsidence in this region is generally related to groundwater pumping and subsequent consolidation of aquifer sediments," (EA p. 3-13). This fact alone illustrates the need for more extensive analysis throughout the export areas in an EIS.

d. The *2013 Water Transfer Program* EA fails to require streamflow monitoring. The 2009 DWB EA/FONSI deferred the monitoring and mitigation planning to "willing sellers," but even that requirement has been completely eliminated. We can't emphasize enough the importance of frequent and regular streamflow monitoring by either staff of the project agencies or a third, independent party such as the USGS, paid for by Project transfer surcharges mentioned above. It is clear from existing scientific studies and the EA that the Project may have significant impacts on the aquifers replenishment and recharging of the aquifers (EA at pp. 10 – 12, 27), so the *2013 Water Transfer Program* should therefore require extensive monitoring of regional streams. The radius for monitoring should be large, not the typical two to three miles as usually used by DWR and the Bureau. Though not presented for the Project's EA or the *2010-2011 Water Transfers Program*, the *Stony Creek Fan Aquifer Performance Testing Plan,* which is a much smaller project, recognized that there may be a drawdown effect on the aquifer by considering results from a DWR Northern District spring 2007 production well test (Water Transfer Program EA/FONSI p. 28). However, it did not assess the anticipated scope of that effect—or even what level of effect would be considered acceptable. Moreover, the results from that test well indicate that the recharge source for the solitary production well "is most likely from the foothills and mountains, to the east and north"—which at a minimum is more than fifteen miles away. (Stanton, Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California).

The Butte County Department of Water and Resource Conservation has identified streams that must be monitored to determine impacts to stream flows that would be associated with pumping the Lower Tuscan Aquifer. These "[s]treams of interest" are located on the eastern edge of the Sacramento Valley and include: Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and Little Dry Creek (The Butte County DWRC 2007). The department described the need and methodology for stream flow gauging:

> The objective of the stream flow gaging is to determine the volume of surface water entering into or exiting the Lower Tuscan Aquifer along perennial streams that transect the aquifer formation outcropping for characterization of stream-aquifer interactions and monitoring of riparian habitat. Measurement of water movement into or out of the aquifer will allow for testing of the accuracy of the Integrated Water Flow Model, an integrated surface water-groundwater finite differential model developed for the eastern extent of the Lower Tuscan aquifer.
>
> Two stream gages will be installed on each of five perennial streams crossing the Lower Tuscan Formation to establish baseline stream flow and infiltration information. The differences between stream flow measurements taking upstream and downstream of the Lower Tuscan Formation are indications of the stream-aquifer behavior. Losses or gains in stream volume can indicate aquifer recharge or discharge to or from the surface waters. *Id.*

As is evident in the following conclusory assertions, the draft EA/FONSI fails to define the radius of influence associated with the aquifer testing and thus entirely fails to identify potential significant impacts to salmon:

> An objective in planning a groundwater substitution transfer is to ensure that groundwater levels recover to their typical spring high levels under average hydrologic conditions. Because groundwater levels generally recover at the expense of stream flow, the wells used in a transfer should be sited and pumped in such a manner that the stream flow losses resulting from pumping peak during the wet season, when losses to stream flow minimally affect other legal users of water. (EA at p. 11.

As mentioned above, streamflow monitoring is not a requirement of the Project, which is unfathomable. Monitoring of flow on streams associated with the Lower Tuscan Formation is particularly important to the survival of Chinook salmon which use these "streams of interest" to spawn and where salmon fry rear. Intensive groundwater pumping would likely lower water table elevations near these streams of interest, decreasing surface flows, and therefore reducing salmon spawning and rearing habitat through dewatering of stream channels in these northern counties. This would be a significant adverse impact of the Project and is ignored by the Project's EA/FONSI.

A similar effect has been observed in the Cosumnes River, where "[d]eclining fall flows are limiting the ability of the Cosumnes River to support large fall runs of Chinook salmon," (Fleckenstein, et al 2004). This is a river that historically supported a large fall run of Chinook Salmon. *Id.* Indeed, "[a]n early study by the California Department of Fish and Game . . . estimated that the river could support up to 17,000 returning salmon under suitable flow conditions." *Id.*, citing CDFG 1957 & USFWS 1995. But "[o]ver the past 40 years fall runs ranged from 0 to 5,000 fish according to fish counts by the CDFG (USFWS 1995)," and "[i]n recent years, estimated fall runs have consistently been below 600 fish, according to Keith Whitener," (Fleckenstein, *et al*. 2004). Indeed, "[f]all flows in the Cosumnes have been so low in recent years that the entire lower river has frequently been completely dry throughout most of the salmon migration period (October to December)." *Id.*

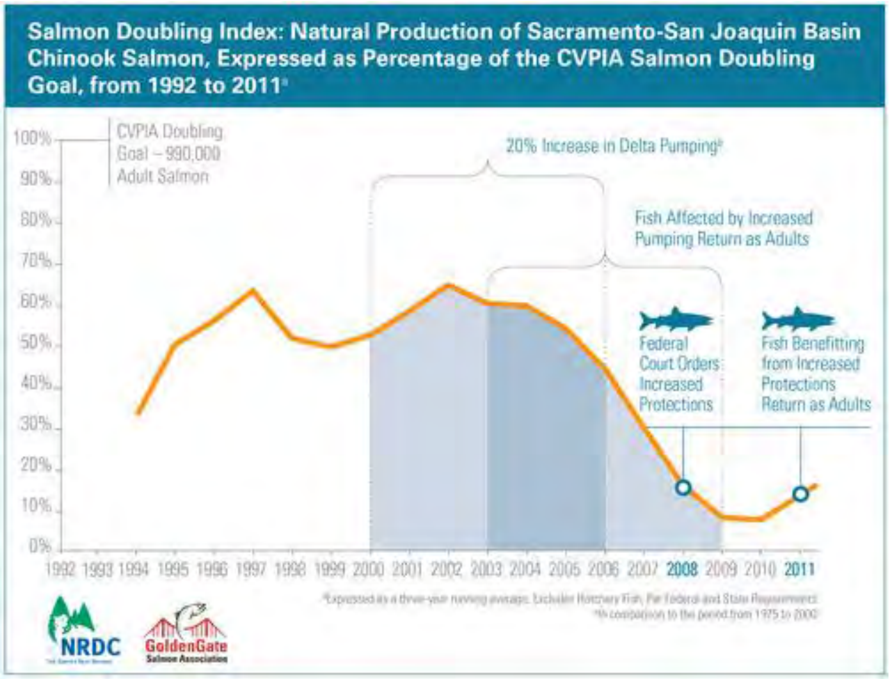
Research indicates that "groundwater overdraft in the basin has converted the [Cosumnes River] to a predominantly losing stream, practically eliminating base flows…." (Fleckenstein, *et al*. 2004). And "investigations of stream-aquifer interactions along the lower Cosumnes River suggest that loss of base flow support as a result of groundwater overdraft is at least partly responsible for the decline in fall flows." *Id.* Increased groundwater withdrawals in the Sacramento basin since the 1950s have substantially lowered groundwater levels throughout the county." *Id.*

The draft EA acknowledges the potential for impacts to special status fish species from altered river flows and commits to maintaining flow and temperature requirements already in place (p. 12). AquAlliance would like to have greater assurance of a commitment considering, as noted above, that the Bureau and DWR fail to meet the X2 standard in the Delta regularly and repeatedly. The Bureau and DWR should make X2 compliance and streams of interest monitoring in real time part of their permit amendment applications to the SWRCB in June 2013. If stream levels are affected by groundwater pumping, then pumping would cease.

Unfortunately, the draft EA fails to anticipate possible stream flow declines in important salmon rearing habitat in the *2013 Water Transfer Program* area. Many important streams, such as Mud Creek, are located within the *2013 Water Transfer Program* and flows through probable Tuscan recharge zones, yet are not mentioned in the EA (also see comments above regarding Rock Creek). While a charged aquifer is likely to add to base flow of this stream, a de-watered aquifer would pull water from the stream. According to research conducted by Dr. Paul Maslin, Mud Creek provides advantageous rearing habitat for out-migrating Chinook salmon (1996). Salmon fry feeding in Mud Creek grew at over twice the rate by length as did fry feeding in the main stem of the Sacramento River. *Id.*

Another tributary to the Sacramento River, Butte Creek, also hosts spring-run Chinook salmon, a threatened species under the Endangered Species Act. 64 Fed. Reg. 50,394 (Sept. 16, 1999). Butte Creek contains the largest remaining population of the spring-run Chinook and is designated as critical habitat for the species. *Id.* at 50,399; 70 Fed. Reg. 52,488, 52,590-91 (Sept. 2, 2005). Additionally, Butte Creek provides habitat for the threatened Central Valley steelhead. *See* 63 Fed. Reg. 13,347 (Mar. 19, 1998); 70 Fed. Reg. at 52,518. While Butte Creek was mentioned in the *2010/2011 Water Transfer Program's* EA (p. 2-11, 3-4, 3-49, 3-57), it is only mentioned for identification purposes in the Project's EA. In the *2010/2011 Water Transfer Program's* EA, the only protection afforded this vital tributary are statements that cropland idling will not occur adjacent to it, yet that was contradicted on page 3-19. The Bureau should not overlook the importance of rearing streams, and should not proceed with this Project unless and until adequate monitoring and mitigation protocols are established.

Existing mismanagement of water in California's rivers, creeks, and groundwater has already caused a precipitous decline in salmon abundance. There is no mention of the fall-run salmon numbers in the main stem Sacramento River or its essential tributaries despite the fact that their numbers dropped precipitously in 2007, 2008, and 2009 and have not come close to the numbers found over a decade ago. The graph below illustrates natural production of Sacramento-San Joaquin Basin Chinook salmon and is expressed as a percentage of the CVPIA Salmon Doubling Goal, from 1992 to 2011 as a three-year running average. The numbers exclude hatchery fish, which complies with federal and state requirements.



Graph courtesy of NRDC and Golden Gate Salmon

A May 15, 2013 article underscores the past and present impacts from Bureau and DWR mismanagement of the CVP and SWP.

> After two closed salmon fishing seasons in 2008 and 2009, and a token season in 2010, fishermen are fishing again, but we remain far below the abundant runs required by law," said Zeke Grader, executive director of Pacific Coast Federation of Fishermen's Association and GGSA board member. "Stronger Delta pumping restrictions are paying off but we have to finish the job and get these salmon runs rebuilt." The groups say these results are only "marginally

> better" than the 12 percent of salmon produced in 2011, when NRDC and GGSA released the first analysis of the Central Valley Chinook salmon population goals. The CPVIA specifically directs the U.S. Department of the Interior to protect, restore, and enhance fish in the Central Valley of California. That means rebuilding salmon populations from 495,000 to 990,000 wild adult fish by 2002, according to Grader. "This year our industry will only get a fraction of what our state and federal governments are supposed to be producing," said John McManus, executive director of GGSA. "We're having a hard time living on 22 percent of the legally required salmon population. Balance could be restored by reallocating a fairly small amount of water which would give us healthy salmon runs, healthy local food, healthy communities and a healthy economy." Central Valley Chinook salmon declined drastically from 2003 through 2010, reaching a record low of 7 percent of the required population level, according to McManus. This decline in the fishery corresponded with a 20 percent increase in water diversions from salmon habitat over levels from the preceding quarter century. The largest water exports from the Delta in California history took place from 2003 to 2006 and in 2011. Although the Central Valley salmon numbers have increased since the unprecedented collapse of 2008-2009, forecasts suggest 2013's salmon returns will again fall far below what the law requires. (Bacher)

The following chart provides a valuable summary that compliments the article and graph immediately above and demonstrates how the Bureau and DWR failure to meet required standards.

Year (Y)	Three-Year* Running Average as a Percentage of CVPIA Production Goal	Year (Y)	Three-Year* Running Average as a Percentage of CVPIA Production Goal
1994	32.05%	**2004**	59.26%
1995	49.82%	**2005**	53.80%
1996	55.57%	**2006**	44.15%
1997	62.85%	**2007**	29.85%
1998	51.38%	**2008**	15.90%
1999	49.29%	**2009**	8.04%
2000	52.13%	**2010**	7.41%
2001	57.88%	**2011**	13.25%
2002	64.33%		

*$(Y + Y_{Y-1} + Y_{Y-2})/3$

Table courtesy of Golden Gate Salmon Association

As noted above, the EA casually asserts that maintaining flow and temperature requirements in the main stem will be sufficient to protect aquatic species. (EA at pp. 12, 13, 20) We question that assurance and present factual data compiled by The Bay Institute in 2012 that contradicts the Bureau's conclusory statement. (TBI at pp. 7-12) The EA/FONSI also fails to consider the impacts of 190,906 AF of water transfers and groundwater substitution on the tributaries. How much additional pumping does the Project represent, given CVP and SWP contractual commitments, available reservoir supplies, and other environmental restrictions south of the Delta? The EA and DWR's missing environmental review are silent on this.

Unsupported assertions, that impacts to aquatic species will be below a level of significance, are arbitrary and capricious and lack foundational data. (EA at pp. 10, 12, 17) Habitat values are also essential to many other special status species that utilize the aquatic and/or riparian landscape including, but not limited to, giant garter snake, bank swallow, greater sandhill crane, American shad, etc. Where is the documentation of the potential impacts to these species?

In addition to the direct decline in the salmon populations is the reverberating indirect influence on the food chain that may significantly impact species such as killer whales.

3. The EA fails to address the significant unknown risks raised by the *2013 Water Transfer Program*'s proposed groundwater extraction.

The EA fails to identify and address the significant unknown risks associated with this Project. There are substantial gaps in scientists' understanding of how the aquifer system recharges.

The EA fails to reveal the scientifically known and unknown characteristics of the Lower Tuscan aquifer. Expert opinion and experience is offered by Professor Karin Hoover from CSU Chico who asserts that: "[T]o date there exists no detailed hydrostratigraphic analysis capable of distinguishing the permeable (water-bearing) units from the less permeable units within the subsurface of the Northern Sacramento Valley. In essence, the thickness and extent of the water-bearing units has not been adequately characterized." (2008 p. 1)

Though the Project fails to disclose the limitations in knowledge of the geology and hydrology of the northern counties, it was disclosed in 2008 in the EA for the *Stony Creek Fan Aquifer Performance Testing Plan* (Testing Plan EA). It revealed that there is also limited understanding of the interaction between the affected aquifers, and how that interaction will affect the ability of the aquifers to recharge. The Testing Plan EA provides:

> *The Pliocene Tuscan Formation lies beneath the Tehama Formation in places in the eastern portion of the SCF Program Study Area, although its extent is not well defined. Based on best available information, it is believed to occur at depths ranging between approximately 300 and 1,000 feet below ground surface. It is thought to extend and slope upward toward the east and north, and to outcrop in the Sierra Nevada foothills. The Tuscan Formation is comprised of four distinct units: A, B C and D (although Unit D is*

> *not present within the general project area). Unit A, or Upper Tuscan Formation, is composed of mudflow deposits with very low permeability and therefore is not important as a water source. Units B and C together are referred to as the Lower Tuscan Formation. Very few wells penetrate the Lower Tuscan Formation within the SCF Program study area.*

(The Testing Plan EA/FONSI at p. 23). The Tehama Formation, however, generally behaves as a semi-confined aquifer system and the EA contains no discussion of its relationship with the adjoining formations. Nor is there any discussion of the role of the Pliocene Tehama Formation as "the primary source of groundwater produced in the area," (DWR 2003).

The EA/FONSI fails to offer any in-depth analysis of the groundwater basins for both CVP and non-CVP groundwater substitution transfers, of the aquifers within the basins, and which strata in the aquifers in the basins will be most likely affected by the *2013 Water Transfer Program*'s proposed extraction of groundwater. This detailed information is also not found in the *Draft Technical Information for Water Transfers in 2013*. The *2010/2011 Water Transfer Program's* EA did disclose information about the Sacramento Valley Groundwater Basin, but there is no direct reference to this in the Project's EA. It must be emphasized that neither the Project nor the *2010/2011 Water Transfer Program's* EAs revealed any understanding of aquifer strata or hydrostratigraphy.

In addition, the Project's EA added the Anderson Cottonwood Irrigation District (ACID) to the CVP groundwater substitution transfers, which resides in a different groundwater basin. The Redding Basin is mentioned on page 21 of the EA, but nowhere is there a description of the basin, its potential sub-basins, strata, or hydrostratigraphy. What is presented are numerous conclusory statement attributed to ACID that assert that their part of the Project will not create impacts, but these are without demonstrable data and analysis. (EA at p. 23) The draft Project EA/FONSI fails to define the radius of influence associated with ACID's groundwater extraction and thus entirely fails to identify potential significant impacts to tributaries, domestic and agricultural wells, as well as possible special status species. The *Redding Basin Water Resources Management Plan Environmental Impact Report* determined that there was an existing deficit of water need with Shasta County in 2005 and a greater deficit would exist by 2030. (p. 1-6) This begs the questions, why is ACID transferring river water out of the Sacramento Valley and substituting groundwater that could be used for local needs, and why didn't the Bureau consider and present this information in the Project's EA? Liability is a crucial component of potential third party impacts. As noted in this paragraph, the Project's deficient EA does not reveal any information about the current status of the ground water basin, which indicates that there is not enough known about the aquifer to judge liability for damage from pumping. How will the Bureau and ACID rectify this for other ground water dependent users and the environment?

AquAlliance incorporates by reference the comments we submitted September 28, 2011 for the *Draft Environmental Assessment/Initial Study and Finding of No Significant Impact/Mitigated Negative Declaration for the Anderson-Cottonwood Irrigation District Integrated Regional Water Management Program – Groundwater Production Element Project.*

Thousands of domestic wells are in the upper layers of the target area-of-origin aquifers, but they are not even considered in the EA. In addition, the EA provides no assessment of the interrelationship of varying basins, sub-basins, or strata in the target aquifers in the Sacramento Valley.

The EA fails to provide basic background information regarding the recharge of groundwater in the different basins and sub-basins. The Project's EA excludes disclosure of this crucial information, but the *2010/2011 Water Transfer Program's* EA states, "Groundwater is recharged by deep percolation of applied water and rainfall infiltration from streambeds and lateral inflow along the basin boundaries," (*2010/2011 Water Transfer Program's* EA p. 3-10). We asked in 2010 and ask again here, how did the Bureau conclude that applied water leads to recharge of the aquifer? Where are the supporting data? This claim is unsubstantiated by any of the work that has been performed to date. For example, the RootZone water balance model used by a consultant with Glenn Colusa Irrigation District, Davids Engineering, was designed to simulate root zone soil moisture. It balances incoming precipitation and irrigation against crop water usage and evaporation, and whatever is left over is assigned to "deep percolation." Deep percolation in this case means below the root zone, which is anywhere from a few inches to several feet below the surface, depending on the crop. There is absolutely no analysis that has been performed to ensure that applied water does, indeed, recharge the aquifer. For example, if the surface soils were to dry out, water that had previously migrated below the root zone might be pulled back up to the surface by capillary forces. In any case, the most likely target of the "deep percolation" water in the Sacramento Valley is the unconfined, upper strata of the aquifer and possibly the Sacramento River. The Project's EA has not demonstrated otherwise.

A public hearing concerning the Monterey Agreement was held in Quincy on November 29, 2007, hosted by DWR. At the hearing Barbara Hennigan presented the following testimony: "So for the issues of protecting the water quality, protecting the stream flow in the Sacramento, one of the things that we have learned is that the Sacramento River becomes a permanently losing stream at the Sutter Buttes. When I first started looking at the water issues that point was at Grimes south of the [Sutter] buttes, now it is at Princeton, moving north of the buttes. As the Sacramento becomes a losing stream farther and farther north because of loss of the Lower Tuscan Aquifer, that means that it [sic], there will be less water that the rest of the State relies on," (http://www.water.ca.gov/environmentalservices/docs/mntry_plus/comments/Quincy.txt). How and when will the Bureau and DWR address this enormously important condition and amplify the risk to not only to the Northstate, but the entire State of California?

4. The EA contains numerous errors and omissions regarding groundwater resources.

There are numerous errors, omissions, and negligence in addressing existing conditions before and with the Project in Section 3, Affected Environmental and Environmental Consequences.

The failure to address stated problematic conditions and the lack of accuracy in this section of so many elemental issues and facts raises questions about the content of the entire EA and FOSI. A partial list of statements and questions follows.

- On pages 15 and 21 of the EA, the Sierra Nevada [mountain range] and "Pacific Coast Range" are identified, but there is no mention of the southern Cascade Range that is a prominent geologic feature of the northern Sacramento Valley, the genesis of the Sacramento River, and a significant contributor to the hydrology of the region.
- We are so pleased that the Bureau added the McCloud and the Pit rivers as "major tributaries" to the Sacramento River, as we requested in comments for the *2010/2011 Water Transfer Program*, but we note that the Project's EA still fails to mention Battle, Mill, Big Chico, and Butte creeks, but now also excludes mention of Putah and Stony creeks in Section 3. These omissions again reflect an odd lack of understanding of the Cascade Range and the Sacramento River hydrologic region.
- The *2010/2011 Water Transfer Program's* EA states quite straightforwardly on page 3-12 that, "Surface water and groundwater interact on a regional basis, and, as such, gains and losses to groundwater vary significantly geographically and temporally. In areas where groundwater levels have declined, such as in Sacramento County, streams that formerly gained water from groundwater now lose water to the groundwater system through seepage." Both the *2010/2011 Water Transfer Program's* EA and the Project's EA fail to expand upon what was initiated in this quotation: What is the geographic extent of this far-reaching and hydrologically essential pre-project understanding and how that has changed already from the baseline that we continue to believe is the year 2000? This *alone* requires substantive environmental review under NEPA and CEQA.
- *Id.* Page 3-12. "Groundwater production in the basin has recently been estimated to be about 2.5 million acre-feet or more in dry years." What is the citation for this assertion?
- *Id.* Page 3-12. "Historically, groundwater levels in the Basin have remained steady, declining moderately during extended droughts and recovering to pre-drought levels after subsequent wet periods. DWR extensively monitors groundwater levels in the basin. The groundwater level monitoring grid includes active and inactive wells that were drilled by different methods, with different designs, for different uses. Types of well use include domestic, irrigation, observation, and other wells. The total depth of monitoring grid wells ranges from 18 to 1,380 feet below ground surface." As presented above, groundwater levels have been changing, historically. Since the Bureau and DWR have access to a monitoring grid, for NEPA and CEQA compliance, they must present current facts, not general statements that relate to social science.
- *Id.* Page 3-12. "In general, groundwater flows inward from the edges of the basin and south parallel to the Sacramento River. In some areas there are groundwater depressions associated with extraction that influence local groundwater gradients." Where are the groundwater depressions? How have they affected groundwater gradients? How will the Project exacerbate a negative existing condition?
- *Id.* Page 3-12. "Prior to the completion of CVP facilities in the area (1964-1971), pumping along the west side of the basin caused groundwater levels to decline. Following construction of the Tehama-Colusa Canal, the delivery of surface water and reduction in

groundwater extraction resulted in a recovery to historic groundwater levels by the mid to late-1990s." Please provide the citation(s).

- *Id.* Pg 3-15 "According to the SWRCB, there are no elevated concentrations of arsenic or selenium in the Sacramento Groundwater Basin." The GAMA domestic well Project, Tehama County Focus Area, 2009, Arsenic in Domestic and Public Wells indicates variable levels of arsenic in the cited basin. The study found that, "Fourteen percent of the wells [in the Tehema County focus area] had concentrations of both arsenic and iron above their associated CDPH MCLs or secondary MCLs."
- *Id.* Page 3-15. "The State Water Code (Section 1745.10) requires that for short term water transfers, the transferred water may not be replaced with groundwater unless the following criteria are met (SWRCB 1999)…"
  - No matter how the Bureau and DWR attempt to present the Project as a "short-term water transfer," it is factually one of a series of actions in multiple years by the agencies, sellers, and buyers without the benefit of comprehensive environmental analysis under NEPA and CEQA as AquAlliance revealed in comments for the *2010/2011 Water Transfer Program* EA/FONSI and the Project's EA/FONSI.
  - *Id.* Page 3-16. "California Water Code Section 1810 and the CVPIA protect against injury to third parties as a result of water transfers. Three fundamental principles include (1) no injury to other legal users of water; (2) no unreasonable effects on fish, wildlife or other in-stream beneficial uses of water; and (3) no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred. These principles must be met for approval of water transfers." Without monitoring and mitigation plans presented for review, the public has no means with which to determine the effectiveness of lack of effectiveness of the Bureau's decision to defer all responsibility in the areas of origin onto the "willing sellers" and the unsuspecting public and environment. The Bureau, at minimum, must at least *disclose*
  - How the Project will prevent "[i]njury to other legal users of water" including the environment?
  - How the Project will prevent "[u]nreasonable effects on fish, wildlife or other in-stream beneficial uses of water?"
  - And how the Project will prevent "[u]nreasonable effects on the overall economy or the environment in the counties from which the water is transferred?"

The disclosures and analyses contained in the *2010/2011 Water Transfer Program* EA/FONSI, its appendices, and the Project's EA/FONSI are inadequate to satisfy the California Water Code requirements and the Bureau's requirements under the CVPIA and NEPA. DWR has clearly failed its obligations under CEQA by providing no disclosure or analysis at all.

E. Other resource impacts flowing from corrected chains of cause and effect are unrecognized in the EA and should be considered in an EIS instead.

Regarding surface water reservoir operations in support of the *2013 Water Transfer Program*, we have several questions and concerns:

- Regarding fisheries, do the Bureau and DWR intend to comply with the State Water Resources Control Board's Water Rights Orders 90-05 and 91-01 in order to provide temperature control at or below 56 degrees Fahrenheit for anadromous fish, their redds, and hatching wild salmonid fry, and to provide minimum instream flows of 3,250 cubic feet per second (cfs) between September 1 and February 28, and 2,300 cfs between March 1 and August 31? How will the Bureau and DWR comply with Fish and Game Code Section 5937—to keep fish populations below and above their dams in good condition, as they approve transfers of CVP water from willing CVP and non-CVP contractors to willing buyers? Please reflect on our comments and fish population data above, which demonstrate that the SWP and CVP have a horrendous record since 2000 keeping fish alive, let alone thriving or recovering.
- Regarding public health and safety, the *2010/2011 Water Transfer Program's* EA negligently denies the potential for impacts (p.3-1) and the Project's EA doesn't even bring up the topic. Fluctuating domestic wells can lead to serious contamination from heavy metals and non-aqueous fluids. Additionally, there are numerous hazardous waste plumes in Butte County, which could easily migrate with the potential increased groundwater pumping proposed for the Project. Because the Bureau fails to disclose basic standards for the mitigation and monitoring requirements, it is unknown if hazardous plumes in the areas of origin will be monitored or not. Please note the attached map from the State Water Resources Control Board (2008) that highlights areas vulnerable to groundwater contamination throughout the state. A significant portion of both the areas of origin and the receiving areas are highlighted. When the potential for serious health and safety impacts exists, NEPA and CEQA require that this must be disclosed and analyzed.

In general, the *2013 Water Transfer Program* EA/FONSI—and by logical implication, DWR's actions—consistently avoids full disclosure of existing conditions and baseline data, rendering the Bureau's justifications for the *2013 Water Transfer Program* at best incoherent, and at worst, dangerous to groundwater dependent communities and businesses, domestic well owners, and vulnerable fisheries in tributary streams of the Sacramento River hydrologic region.

F. The *2013 Water Transfer Program* is likely to have a cumulatively significant impact on the environment.

The draft EA/FONSI does not reveal that the current Project is part of a much larger set of plans to develop groundwater in the region, to develop a "conjunctive" system for the region, and to integrate northern California's groundwater into the state's water supply. These are plans that the Bureau, together with DWR, sellers, and other have pursued and developed for many years. Indeed, one of the plans—the short-term phase of the Sacramento Valley Water Management

Program—is the subject of an ongoing scoping process for a Programmatic EIS that has not yet been completed.[6]

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3) (emphasis added).

As provided in details below, instead of assessing the cumulative impacts of the proposed action as part of the larger program that even the Bureau has recognized should be subject to a programmatic EIS (but for which no programmatic EIS has been completed), the Bureau has attempted to separate this program and approve it through another inadequate EA. Further, the Bureau has failed to take into account the cumulative effects of other groundwater and surface water projects in the region, the development of "conjunctive" water systems, and the anticipated further integration of Sacramento Valley surface and ground water into the state water system.

The Bureau's attempts to frame the *2013 Water Transfer Program* as an isolated *de minimis* project is a shell game, whereby an analysis of the cumulative impacts of individual actions is avoided in direct contravention of NEPA. *See Blue Mountains Biodiversity Project v. United States Forest Service*, 161 F.3d 1208, 1215 (9th Cir. 2008).

G. The Environmental Assessment Fails to Meet the Requirements of NEPA.

Even if an EIS was not clearly required here, which we believe it is, the draft EA/FONSI prepared by the Bureau violates NEPA on its own. As discussed above, the draft EA does not provide the analysis necessary to meet NEPA's requirements and to support its proposed finding of no significant impact. Further, as outlined above, the draft document fails to provide a full and accurate description of the proposed Project, its purpose, its relationship to myriad other water transfer and groundwater extraction projects, its potentially significant adverse effects on salmon

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[6] *Id* page 3.

critical habitat in streams of interest that are tributaries to the Sacramento River, and an assessment of the cumulative environmental impacts of the *2013 Water Transfer Program* when considered together with past, present, and reasonably foreseeable projects, plans, and actions of not only the Bureau and DWR, but also with the past, present, and reasonably foreseeable projects, plans, and actions of others.

Additionally, the draft EA/FONSI fails to provide sufficient evidence to support its assertions that the *2013 Water Transfer Program* would have no significant impacts on the human or natural environments, so neither decision makers nor the public are fully able to evaluate the significance of the *2013 Water Transfer Program*'s impacts. These informational failures complicate AquAlliance's efforts to provide meaningful comments on the full extent of the potential environmental impacts of the Project and on appropriate monitoring and mitigation measures. Accordingly, many of the AquAlliance's comments include requests for additional information.

1. The EA Fails to Consider a Reasonable Range of Alternatives.

NEPA's implementing regulations call for analysis of alternatives is "the heart of the environmental impact statement," 40 C.F.R. §1502.14, and they require an analysis of alternatives within an EA. *Id.* §1408.9. The statute itself specifically requires federal agencies to:

> *study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning available uses of resources.*

42 U.S.C. §4332(2)(E). Here, because the Bureau's EA considers only the proposed Project and a "No Action" alternative, the EA violates NEPA.

The case law makes clear that an adequate analysis of alternatives is an essential element of an EA, and is designed to allow the decision maker and the public to compare the environmental consequences of the proposed action with the environmental effects of other options for accomplishing the agency's purpose. The Ninth Circuit has explained that "[i]nformed and meaningful consideration of alternatives … is … an integral part of the statutory scheme." *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228 (9th Cir. 1988) (holding that EA was flawed where it failed adequately to consider alternatives). An EA must consider a reasonable range of alternatives, and courts have not hesitated to overturn EAs that omit consideration of a reasonable and feasible alternative. *See People ex rel. Van de Kamp v. Marsh*, 687 F.Supp. 495, 499 (N.D. Cal. 1988); *Sierra Club v. Watkins*, 808 F.Supp. 852, 870-75 (D.D.C. 1991).

Here, there are only two alternatives presented: the No Action and the Proposed Action. The lack of *any* alternative action proposal is unreasonable and is by itself a violation of NEPA's requirement to consider a reasonable range of alternatives.

Even more significantly, there are numerous other alternative ways to ensure water is allocated reliably when California experiences dry hydrologic years. We described several elements of reasonable alternatives above. These are the alternatives that should have been presented for the Bureau's draft EA/FONSI on the *2013 Water Transfer Program* to comply with NEPA. 42 U.S.C. § 4332(2)(E).

2. The EA Fails to Disclose and Analyze Adequately the Environmental Impacts of the Proposed Action

The discussion and analysis of environmental impacts contained in the EA is cursory and falls short of NEPA's requirements, because it lacks a clear and well-described narrative for the proposed *2013 Water Transfer Program*. Please recall that the EA doesn't contain a "purpose" statement. This obscures realistic chains of cause and effect, which in turn prevent accurate and comprehensive accounting of environmental baselines and measurement of the DWB's potential impacts. NEPA's implementing regulations require that an EA "provide sufficient evidence and analysis for determining whether to prepare an [EIS]." 40 C.F.R. §1508.9(a). For the reasons discussed above, the EA fails to discuss and analyze the environmental effects of the water transfers and groundwater substitution proposed by the *2013 Water Transfer Program*. The Bureau must consider and address the myriad environmental consequences that are likely to flow from this proposed agency action.

Along with our significant concerns about the adequacy of the proposed monitoring, the draft EA/FONSI also fails to explain what standards will be used to evaluate the monitoring data, and on what basis a decision to modify or terminate the pumping would be made. In light of the document's silence on these crucial issues, the draft EA/FONSI's conclusion that there will not be significant adverse impacts withers quickly under scrutiny.

3. The EA Fails to Analyze Cumulative Impacts Adequately.

The Ninth Circuit Court makes clear that NEPA mandates "a useful analysis of the cumulative impacts of past, present and future projects." *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). Indeed, "[d]etail is required in describing the cumulative effects of a proposed action with other proposed actions." *Id.* The very cursory cumulative effects discussion in the EA plainly fails to meet this standard.

As discussed throughout these comments, the proposed Project does not exist in a vacuum, is another transfer program in a series of many that have also been termed either "temporary," "short term," "emergency," or "one-time" water transfers, and is cumulative to numerous broad programs or plans to develop regional groundwater resources and a conjunctive use system. The *2013 Water Transfer Program* is also only one of several proposed and existing projects that affect the regional aquifers. The existence of these numerous related projects makes an adequate analysis of cumulative impacts especially important.

4. The Bureau Has Segmented the Project Over Many Years

The Bureau's participation in planning, attempting to execute, and sometimes executing the following programs, plans and projects has circumvented the requirements of NEPA. DWR's failure to conduction comprehensive environmental review has segmented a known project for decades, which means that the Bureau is also failing to comply with state law as the CVPIA mandates. (EA at p. 10) Such segments include:

- The Sacramento Valley Water Management Agreement was signed in 2002 and the need for a programmatic EIS/EIR was clear and the process was initiated, but never completed.[7]
- Sacramento Valley Integrated Regional Water Management Plan (2006).
- The Sacramento Valley Water Management Plan. (2007)
- The Stony Creek Fan Partnership Orland Project Regulating Reservoir Feasibility Investigation.
- GCID's *Stony Creek Fan Aquifer Performance Testing Plan* to install seven production wells in 2009 that will extract 26,530 AF of groundwater as an experiment.
- GCID's Lower Tuscan Conjunctive Water Management Program (Bureau provided funding).
- GCID's water transfers in 2008 and in 2010.
- California Drought Water Bank for 2009.
- The Bureaus of Reclamation's 2010/2011 Water Transfer Program of 395,910 af of CVP and non-CVP water with 154,237 AF of groundwater substitution (EA/FONSI p. 2-4 and 3-107) and
- The planned 2012 water transfers of 76,000 af of CVP water all through ground water substitution.
- The Bureaus of Reclamation's 600,000 AF, North-to-South Water Transfer Program. EIS/EIR pending.
- The Bay Delta Conservation Plan.

5. The Bureau Has Failed to Consider the Cumulative Impact of Other Groundwater Development and Surface Water Diversions Affecting the Region

In addition to the improper segmentation evident by the Project EA/FONSI and the long list of projects and plans in Section 4 above, the assessment of environmental impacts is further deficient because the Bureau has failed to consider the cumulative impacts of the proposed groundwater extraction when taken in conjunction with other projects proposed for the development of groundwater and surface water.

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[7] *Id* p. 3

The Bureau, its contractors, and its partner DWR are party to numerous current and reasonably foreseeable water programs that are related to the water transfers contemplated in the Project EA including, but not limited to, the following:

- Sacramento Valley Integrated Regional Water Management Plan (2006)
- Sacramento Valley Regional Water Management Plan (January 2006)
- Stony Creek Fan Conjunctive Water Management Program
- Sacramento Valley Water Management Agreement (Phase 8, October 2001)
- Draft Initial Study for 2008-2009 Glenn-Colusa Irrigation District Landowner Groundwater Well Program
- Regional Integration of the Lower Tuscan Groundwater Formation into the Sacramento Valley Surface Water System Through Conjunctive Water Management (June 2005) (funded by the Bureau)
- Stony Creek Fan Aquifer Performance Testing Plan for 2008-09
- Annual forbearance agreements (2008 had an estimated 160,000 acre feet proposed).

We briefly describe some of their key elements here.

a) Stony Creek Fan Conjunctive Water Management Program. The SCF Aquifer Plan is part of and in furtherance of the Stony Creek Fan Conjunctive Water Management Program ("SCF Program"). This program is being carried out by GCID, Orland-Artois and Orland Unit Water Association.

The long-term objective of the SCF Program is the development of a "regional conjunctive water management program consisting of a direct and in-lieu recharge component, a groundwater production component, and supporting elements…" (SVWMA: Project 8A Stony Creek Fan Conjunctive Water Management Program ("SVWMA Project 8A"), at 8A-1). The potential supply from such a program was estimated at 50,000 af per year to 100,000 af per year. *Id.*

The SCF Program has three phases: (1) a feasibility study; (2) a demonstration project; and (3) project implementation. Phase I of the SCF Program has already been completed. The SCF Aquifer Plan described in a draft EA/FONSI is part of Phase II of the larger SCF Program. Phase III of the SCF Program will implement the program's goal of integrating test and operational production wells into the water supply systems for GCID, Orland-Artois, and Orland Unit Water Association for long-term groundwater production in conjunction with surface water diversions.

The Bureau is well aware of the SCF Program, but declined to analyze the environmental effects of the program as a whole, and simply considered the effects of an isolated component of the larger program. Indeed, the Bureau awarded a grant to GCID to fund the SCF Program. The Bureau's grant agreement states that the SCF Program "target[s] the Lower Tuscan Formation and possibly other deep aquifers in the west-central portion of the Sacramento Valley … as the source for all or a portion of the additional groundwater production needed to meet [the SCF Partners'] respective integrated water management objectives." BOR Assistance Agreement No.

06FG202103 at p. 2. The agreement further provides that “[a]dditional test wells and production wells will be installed within the Project Area.” *Id.*

b) The SCF Program is a Component of the Sacramento Valley Water Management Program. The Sacramento Valley Water Management Program (Phase 8) (“SVWMP”) also includes the SCF Program as one of its elements. (SVWMA Project 8A at pp. 8A-1 to 8A-13).

The SVWMP recognizes that the SCF Program “has the potential to improve operational flexibility on a regional basis resulting in measurable benefits locally in the form of predictable, sustainable supplies, *and improved reliability for water users’ elsewhere in the state*.” *Id.* at p. 8A-2 (emphasis added). By piecemealing this program improperly and analyzing only the small component of the SCF Program, the Bureau has failed to assess the environmental impacts associated not just with the anticipated conjunctive use of the groundwater, but also the effect of the anticipated export of water to other regions of the state.

Additionally, ten years ago, on August 5, 2003, the Bureau published a notice in the Federal Register announcing its intention to prepare a programmatic EIS to analyze the short-term phase of the SVWMP. 68 Fed. Reg. 46218, 46219 (Aug. 5, 2003). Like the SVWMP, this “Short-term Program” for which the Bureau stated its intent to conduct a programmatic EIS included implementation of the SCF Program. *Id.* at 46219, 46220.

c) The SCF Program is Also a Component of the Sacramento Valley Integrated Regional Water Management Program. The Bureau has been working with GCID and others to realize the Sacramento Valley Integrated Regional Water Management Program (“SVIRWMP”). SVIRWMP is comprised of a number of sub-regional projects, including the SCF Program. *See* SVIRWMP, Appendix A at A-5; BOR Assistance Agreement No. 06FG202103. Here again, even though the SCF Aquifer Plan is clearly a necessary component of the SCF Program – which is in turn a component of the SVIRWMP – the draft EA/FONSI failed to even acknowledge, let alone assess, the cumulative impacts of these related projects.

Most obviously, the draft EA wholly fails to assess the impact of the Bureau’s *Sacramento Valley Regional Water Management Plan (2006)* (SVRWMP) and the forbearance water transfer program that the Bureau and DWR facilitate jointly. As noted above, the Programmatic EIS for the 2002 Sacramento Valley Water Management Agreement or Phase 8 Settlement was initiated, but never completed, so the SVRWMP was the next federal product moving the Phase 8 Settlement forward. The stated purpose of the Phase 8 Settlement and the SVRWMP are to improve water quality standards in the Bay-Delta and local, regional, and statewide water supply reliability. In the 2008 forbearance program, 160,000 af was proposed for transfer to points south of the Delta. To illustrate the ongoing significance of the demand on Sacramento Valley water, we understand that GCID alone entered into “forbearance agreements” to provide 65,000 af of water to the San Luis and Delta Mendota Water Authority in 2008, 80,000 af to State Water Project contractors in 2005, and 60,000 af to the Metropolitan Water District of Southern California in 2003.

Less obvious, but certainly available to the Bureau, are the numerous implementation projects that Phase 8 signatories are pursuing, such as Glenn Colusa Irrigation District's (GCID) 2008 proposal to divert groundwater pumped from private wells to agricultural interests in the District. *See* Attach. (GCID Proposed Negative Declaration, GCID Landowner Groundwater Well Program for 2008-09). Additionally, the draft EA does not consider the cumulative effect of the Lower Tuscan Integrated Planning Program, a program funded by the Bureau that will "integrate the Lower Tuscan formation aquifer system into the management of regional water supplies." Grant Agreement at p. 4. This program, as described by the Bureau, will culminate in the presentation of a proposed water management program for the Lower Tuscan Formation for approval and implementation by the appropriate authorities. Clearly, the cumulative impact of this program and the *2013 Water Transfer Program*'s proposed groundwater extraction should have been assessed.

d) There are serious concerns raised by the *2012 Water Transfer Program* to engage in conjunctive management of groundwater and surface water that are not even mentioned, let alone addressed, in the Project EA. For example, in 1994, following seven years of low annual precipitation, Western Canal Water District and other irrigation districts in Butte, Glenn and Colusa counties exported 105,000 af of water extracted from the Tuscan aquifers to buyers outside of the area. This early experiment in the *conjunctive use* of the groundwater resources – conducted without the benefit of environmental review – caused a significant and immediate adverse impact on the environment (Msangi 2006). Until the time of the water transfers, groundwater levels had dropped but the aquifers had sustained the normal demands of domestic and agricultural users. The water districts' extractions, however, lowered groundwater levels throughout the Durham and Cherokee areas of eastern Butte County (Msangi 2006). The water level fell and the water quality deteriorated in the wells serving the City of Durham (Scalmanini 1995). Irrigation wells failed on several orchards in the Durham area. One farm never recovered from the loss of its crop and later entered into bankruptcy. Residential wells dried up in the upper-gradient areas of the aquifers as far north as Durham.

Finally, with the myriad projects and programs that are ignored in the *2010/2011 Water Transfer Program's* EA and the Project's EA that have never been analyzed cumulatively, only the *2010/2011 Water Transfer Program's* EA discloses that there could be a *devastating* impact to groundwater: "The reduction in recharge due to the decrease in precipitation and runoff in the past years in addition to the increase in groundwater transfers would lower groundwater levels. Multi-year groundwater acquisition under cumulative programs operating in similar areas of the Sacramento Valley could further reduce groundwater levels. Groundwater levels may not fully recover following a transfer and may experience a substantial net decline in groundwater levels over several years. This would be a substantial cumulative effect," (EA p. 3-108). While the honesty is refreshing, the lack of comprehensive monitoring, mitigation, and project cessation mechanisms is startling. It is also noteworthy that this admission is not included in the Project's EA. This alone warrants the preparation of an EIS.

Here again, the current document does not discuss or analyze these potential impacts, their potential scope or severity, or potential mitigation efforts. Instead, it relies on the existence of local ordinances, plans, and oversight with the monitoring and mitigation efforts of individual "willing sellers" to cope with any adverse environmental effects. However, as we have shown above, for example, the Glenn County management plan is untested, does not provide adequate protection and monitoring, and relies on "voluntary" enforcement of the region's important groundwater resources. To further clarify the inadequacy of relying on local plans and ordinances, Butte County's Basin Management Objectives have no enforcement mechanism and Butte County's Chapter 33, while it requires CEQA review for transfers that include groundwater, has never been tested. There is thus very limited local protection for groundwater within a county, and no authority or mechanism to influence pumping in a different county from a shared groundwater basin.

6. The *2013 Water Transfer Program* is likely to serve as precedent for future actions with significant environmental effects.

As set forth above, this Project is part of a broader effort by the Bureau and DWR to develop groundwater resources and to integrate groundwater into the state system. For these reasons, the *2013 Water Transfer Program* is likely to "establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration" (40 C.F.R. §1508.27(b)(6)), and should be analyzed in an EIS.

7. The *2013 Water Transfer Program* has potential adverse impacts for a threatened species.

As the Bureau of Reclamation is well aware, the purpose of the ESA is to conserve the ecosystems on which endangered and threatened species depend and to conserve and recover those species so that they no longer require the protections of the Act. 16 U.S.C. § 1531(b), ESA § 2(b); 16 U.S.C. § 1532(3), ESA §3(3) (defining "conservation" as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary"). "[T]he ESA was enacted not merely to forestall the extinction of species (i.e., promote species survival), but to allow a species to recover to the point where it may be delisted." *Gifford Pinchot Task Force v. U.S. Fish & Wildlife Service*, 378 F3d 1059, 1069 (9th Cir. 2004). To ensure that the statutory purpose will be carried out, the ESA imposes both substantive and procedural requirements on all federal agencies to carry out programs for the conservation of listed species and to insure that their actions are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. 16 U.S.C. § 1536. *See NRDC v. Houston*, 146 F.3d 1118, 1127 (9th Cir. 1998) (action agencies have an "affirmative duty" to ensure that their actions do not jeopardize listed species and "independent obligations" to ensure that proposed actions are not likely to adversely affect listed species). To accomplish this goal, agencies must consult with the Fish and Wildlife Service whenever their actions "may affect" a listed species. 16 U.S.C. § 1536(a)(2); 50 C.F.R. § 402.14(a). Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to "mean all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States." 50 C.F.R. § 402.02.

The giant garter snake ("GGS") is an endemic species to Central Valley California wetlands. (Draft Recovery Plan for the Giant Garter Snake ("DRP") 1). The giant garter snake, as its name suggests, is the largest of all garter snake species, not to mention one of North America's largest native snakes, reaching a length of up to 64 inches. Female GGS tend to be larger than males. GGS vary in color, especially depending on the region, from brown to olive, with white, yellow, or orange stripes. The GGS can be distinguished from the common garter snake by its lack of red markings and its larger size. GGS feed primarily on aquatic fish and specialize in ambushing small fish underwater, making aquatic habitat essential to their survival. Females give birth to live young from late July to early September, and brood size can vary from 10 to up to 46 young. Some studies have suggested that the GGS is sensitive to habitat change in that it prefers areas that are familiar and will not typically travel far distances.

The Project's EA failure to discuss GGS is arbitrary and capricious. 1) Either the EA assertion on page 12 is incorrect stating that, "Idling rice fields would reduce the use of farm equipment…" in reference to emissions to air or the EA is failing to disclose impacts to GGS from fallowing. If there are plans to fallow, there will be potentially significant impacts to GGS and if fallowing won't occur, emissions to air will not be reduced as claimed. Please clarify this. 2) Moving on, GGS depend on more than rice fields in the Sacramento Valley.[8] "The giant garter snake inhabits marshes, sloughs, ponds, small lakes, low gradient streams, other waterways and agricultural wetlands such as irrigation and drainage canals and rice fields, and the adjacent uplands. Essential habitat components consist of (1) adequate water during the snake's active period, (early spring through mid-fall) to provide a prey base and cover; (2) emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat…" (Id at p. 3) What analysis has occurred that removes GGS from consideration for potential significant impacts? If the 2013 Water Transfer Program will only use groundwater substitution to make river water sales possible, how will that affect streams, wetlands, and emergent, herbaceous wetland vegetation? How will it be monitored?

The Bureau's Biological Assessment for the 2009 DWB disclosed that one GGS study in Colusa County revealed the "longest average movement distances of 0.62 miles, with the longest being 1.7 miles, for sixteen snakes in 2006, and an average of 0.32 miles, with the longest being 0.6 miles for eight snakes in 2007." (BA at p.16) However, in response to droughts and other changes in water availability, the GGS has been known to travel up to 5 miles in only a few days,

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[8] **Programmatic Consultation with the U.S. Army Corps of Engineers**
404 Permitted Projects with Relatively Small Effects on the Giant Garter Snake within Butte, Colusa, Glenn, Fresno, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter and Yolo Counties, California

but the impacts on GGS survival and reproduction from such extreme conditions are unknown due to the deficiency in data and analysis.

Flooded rice fields, irrigation canals, streams, and wetlands in the Sacramento Valley can be used by the giant garter snake for foraging, cover and dispersal purposes. The Bureau's 2009 Biological Assessment acknowledged the failure of Bureau and DWR to complete the Conservation Strategy that was a requirement of the 2004 Biological Opinion. (BA at p. 19-20) To date it is still not done. What possible excuse delayed this essential planning effort?

The *2010/2011 Water Transfer Program* also proposed to delete or modify other mitigation measures previously adopted as a result of the EWA EIR process to substantially reduce significant impacts, but without showing they are infeasible. For example, the Bureau and DWR proposed to delete the 160 acre maximum for "idled block sizes" for rice fields left fallow rather than flooded and to substitute for it a 320 acre maximum. (See 2003 Draft EWA EIS/EIR, p. 10-55; 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 4.) There is no evidence to support this change. In light of the agencies failure to complete the required Conservation Strategy mentioned above and the data gathered in the Colusa County study, how can the EA suggest that doubling the fallowing acreage is in any way biologically defensible? The agencies additionally propose to delete the mitigation measure excluding Yolo County east of Highway 113 from the areas where rice fields may be left fallow rather than flooded, except in three specific areas. (See 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 2.) What is the explanation for this change? What are the impacts from this change?

Deleting these mitigation measures required by the EWA approval would violate NEPA and CEQA's requirements that govern whether, when, and how agencies may eliminate mitigation measures previously adopted under NEPA and CEQA. (See *Napa Citizens for Honest Government v. Napa County Board.*

The *2010/2011 Water Transfer Program* failed to include sufficient safeguards to protect the giant garter snake and its habitat. The EA concluded, "The frequency and magnitude of rice land idling would likely increase through implementation of water transfer programs in the future. Increased rice idling transfers could result in chronic adverse effects to giant garter snake and their habitats and may result in long-term degradation to snake populations in the lower Sacramento Valley. In order to avoid potentially significant adverse impacts for the snake, additional surveys should be conducted prior to any alteration in water regime or landscape," (p. 3-110). To address this significant impact the Bureau proposed relying on the 2009 DWB Biological Opinion, which was a one-year BO. The expired BO highlighted the Bureau and DWR's avoidance of meeting federal and state laws stating, "This office has consulted with Reclamation, both informally and formally, approximately one-half dozen times over the past 8 years on various forbearance agreements and proposed water transfers for which water is made available for delivery south of the delta by fallowing rice (and other crops) or substituting other crops for rice in the Sacramento Valley. Although transfers of this nature were anticipated in our biological opinion on the environmental Water Account, that program expired in 2007 and, to our knowledge, no water was ever made available to EWA from rice fallowing or rice substitution. The need to consult with such frequency on transfers involving water made available from rice fallowing or rice substitution suggests to us a need for programmatic environmental compliance documents, including a programmatic biological opinion that addresses the additive effects on giant garter snakes of repeated fallowing over time, and the long-term effects of potentially large fluctuations and reductions in the amount and distribution of rice habitat upon which giant garter snakes in the Sacramento Valley depend," (p.1-2). AquAlliance agrees with the U.S. Fish and Wildlife Service that programmatic environmental compliance is needed under the Endangered Species Act, NEPA, CEQA, and the California Endangered Species Act.

It is conspicuously noticeable that GGS are not mentioned even if fallowing is not used although the statement from the EA on page 12 leaves some confusion. Increased groundwater extraction will impact the aquatic and terrestrial environment that GGS depend upon. The Bureau should also prepare an EIS because the *2013 Water Transfer Program* will, in combination with all its past and reasonably foreseeable plans, programs, and projects, likely have significant environmental effects on the Giant Garter Snake, a listed threatened species under the federal Endangered Species Act and California Endangered Species Act. 40 C.F.R. §1508.27(b)(9).

In addition to GGS, as discussed above, unsupported assertions, that impacts to aquatic species will be below a level of significance, ring hollow and lack foundational data (EA at pp. 10, 12, 17). Habitat values are also essential to many other special status species that utilize the aquatic and/or riparian landscape including, but not limited to, giant garter snake, bank swallow, greater sandhill crane, American shad, and more. Where is the documentation of the potential impacts to these species?

II. Purpose and Need Issues of the *2013 Water Transfer Program*

A. The Purpose and Need Section of the EA/FONSI fails to specify the policy framework upon which the *2013 Water Transfer Program* is based.

As mentioned many times, the Project's EA/FONSI fails to provide a statement of purpose, and the need statement on page 4 is cursory at best. Avoiding the requirements of NEPA, and for DWR – CEQA, for the *2013 Water Transfer Program* does not reflect the actual environmental effects of the proposal—which are similar to the proposed 1994 Drought Water Bank and for which a final Program Environmental Impact Report was completed in November 1993. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but it was never undertaken. Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate. So, the 2009 DWB Notice of Exemption and complete avoidance of CEQA review for the *2013 Water Transfer Program* reflects an ongoing end-run around established water law and CEQA.

We question the merits of and need for the *2013 Water Transfer Program* itself. The need for transfers reflects less on the type of water year than on the failures by the Agencies to pursue a sensible water policy framework, given that California has a Mediterranean climate with major fluctuations in precipitation and long periods of drought (Anderson, 2009). AquAlliance believes that the Agencies continue to avoid the inconvenient truths about California's climate, the current and future needs from climate change, and go too far to help a few junior water right holders. The Project intends to directly benefit the areas of California whose water supplies are the least reliable by operation of state water law. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The EA/FONSI fails to provide a statement of purpose and the need statement on page 4 is cursory at best. At a minimum, a purpose statement must be presented in the EA and clearly identified. The purpose and need statements should also include specific criteria and a delineation of priorities that the Project must adhere to, but they are absent.

The EA/FONSI makes no attempt to place the *2013 Water Transfer Program* into the context of the 2009 California Water Plan that the state most recently completed, which contains many recommendations for increasing regional water self-sufficiency, but it appears that this plan is largely on the shelf now. Pursuing watershed self-sufficiency would be a proactive and sustainable through the many types of water years, which is why many coastal communities are aggressively meeting this challenge. It is distressing to see that the Bureau and the state of California resist such as strategy and continue to pursue multi-year, serial, "temporary" water transfers and large engineering projects that are prohibitively costly and low in water and environmental benefits. This is not a sustainable water policy for California.

The missing purpose section and weak need sections of the Project's EA/FONSI, the *2010/2011 Water Transfer Program*, *and the 2009 Governor's drought emergency declaration* cry out for a cogent policy framework. What is the state doing to facilitate regional water self-sufficiency for these areas with the least reliable water rights and how is the Bureau assisting or motivating such action? Instead, the state and federal response to another dry year falls back on the continuation of multi-year, serial, "temporary" water transfers.

B. The *2013 Water Transfer Program* is not needed because the state's current allocation system—in which the federal Bureau of Reclamation participates—wastes water profligately.

The incentive from the state's lax system of regulation of California's State Water Project and Central Valley projects is to deliver the water now, and worry about tomorrow later. Indeed, the State Water Resources Control Board (SWRCB) has been AWOL for decades. In response to inquiries from the Governor's Delta Vision Task Force in 2009, the SWRCB acknowledged that while average runoff in the Delta watershed between 1921 and 2003 was 29 million acre-feet annually, the 6,300 active water right permits issued by the SWRCB is approximately 245 million acre-feet. In other words, **water rights on paper are 8.4 times greater than the real water in California streams diverted to supply those rights on an average annual basis.** *And the SWRCB acknowledges that this "water bubble" does not even take account of the higher priority rights to divert held by pre-1914 appropriators and riparian water right holders, of which there are another 10,110 disclosed right holders.* Many more remain undisclosed.

Like federal financial regulators failing to regulate the shadow financial sector, subprime mortgages, Ponzi schemes, and toxic assets of our recent economic history, the state of California has been derelict in its management of scarce water resources. As we mentioned above we are supplementing these comments on this matter of wasteful use and diversion of water by incorporating by reference the 2011 complaint to the State Water Resources Control Board of the California Water Impact Network the California Sportfishing Protection Alliance, and AquAlliance on public trust, waste and unreasonable use and method of diversion as additional evidence of a systematic failure of governance by the State Water Resources Control Board, the Department of Water Resources and the U.S. Bureau of Reclamation, filed with the Board on April 21, 2011 (attached).

We question the Bureau and DWR's desire for the Project, since reservoir levels throughout California are quite decent and groundwater is and will be necessary to support river and stream flows, aquatic and terrestrial species, and economic activity in the areas origin as California grapples with unpredictable, but well known, precipitation patterns and climate change. Don Pedro Reservoir on the Tuolumne River is at 98 percent of historic average. (CDEC, May 20, 2013)[9] The CVP's Millerton is at 99% and Folsom is at 90%. *Id* These two reservoirs must provide water to the agricultural San Joaquin River Exchange Contractors first, and they have among the most senior rights on that river. Rice growers in the Sacramento Valley are receiving full deliveries from the CVP's Shasta reservoir (88% of historic average) and their Yuba River water supplies. *Id* The CVP's own New Melones Reservoir on the Stanislaus River, which contributes to Delta water quality as well as to meeting eastern San Joaquin Valley irrigation demands, is at 91 percent of normal for this time of year. *Id*

Moreover, the SWP's terminal reservoirs at Pyramid (104 percent of average) and Castaic (93 percent of average) Lakes are slightly above and below normal levels for this time of year, presumably because DWR has been releasing water from Oroville (96% historic average) for delivery to these reservoirs. *Id*

We acknowledge that the snowpack is very poor this year.[10] The fact that reservoirs of the CVP and SWP with more senior responsibilities in the water rights hierarchy are doing so well, but

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[9] http://cdec.water.ca.gov/cdecapp/resapp/getResGraphsMain.action

[10] http://cdec.water.ca.gov/snow/

admittedly there is so little to refill them, certainly suggests caution for deliveries. Still, given what is known, these reservoir levels indicate that most major cities and most Central Valley farmers are very likely to have enough water for this year. The demands by junior water rights holders, who expect to receive little water this year, do so because of the low priority of their water service contracts within the Central Valley Project—their imported surface supplies are therefore less reliable in dry times. It is the normal and appropriate functioning of California's system of water rights law that makes it so.

The efforts of the Bureau and DWR to initiate water sales from the Sacramento, Feather, and Yuba rivers with groundwater substation are only intended to benefit the few western San Joaquin Valley farmers whose contractual surface water rights have always been less reliable than most—and whose lands are the most problematic for irrigation. Since these growers have chosen to harden demand by planting permanent crops, a very questionable business decision, will the Bureau please explain why this "tail" in water rights is wagging the dog? Compounding the insanity of growing perennial crops in a desert is the result where in excess of 1 million acres of irrigated land in the San Joaquin Valley and the Tulare Lake Basin are contaminated with salts and trace metals like selenium, boron, arsenic, and mercury. This water drains back—after leaching from these soils the salts and trace metals—into sloughs and wetlands and the San Joaquin River, carrying along these pollutants. Retirement of these lands from irrigation usage would stop wasteful use of precious fresh water resources and help stem further bioaccumulation of these toxins that have settled in the sediments of these water bodies.

The *2013 Water Transfer Program* would exacerbate pumping of fresh water from the Delta, which has already suffered from excessive pumping over the last 12 years. Pumped exports cause reverse flows to occur in Old and Middle Rivers and can result in entrainment of fish and other organisms in the pumps. Pumping can shrink the habitat for Delta smelt as well, since less water flows out past Chipps Island through Suisun Bay, which Delta smelt often prefer. AquAlliance shares the widely held view that operation of the Delta export pumps is the major factor causing the Pelagic Organism Decline (POD) and in the deteriorating populations of fall-run Chinook salmon. The State Water Resources Control Board received word in early December that the Fall Midwater Trawl surveys for September and October 2012 showed horrendous numbers for the target species. The indices for longfin smelt, splittal, and threadfin shad reveal the lowest in history.[11] Delta smelt, striped bass, and American shad numbers remain close to their lowest levels. *Id*

New capital facilities should be avoided to save on costly, unreliable, and destructive water supplies that new dams and massive, 40-foot diameter "peripheral tunnels" represent. Moreover, these facilities would need new water rights; yet the most reliable rights in California are always the ones that already exist—and of those, they are the ones that predate the California State Water Project and the federal Central Valley Project. We should apply our current rights far more efficiently—and realistically—than we do now. California should instead pursue a "no-

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[11] http://www.dfg.ca.gov/delta/data/fmwt/Indices/index.asp

regrets" policy incorporating aggressive water conservation strategies, careful accounting of water use, research and technological innovation, and pro-active investments.[12]

III. General Comments

1. Where are the materials required in the Criteria Checklist for Complete Written Transfer Proposals, Appendix 1 of the 1993 *Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project Improvement Act (Title XXXIV of Public Law 102-575)*? In particular, where are the following: "Comprehensive ground-water basin study or evaluation of ground-water supplies demonstrating transfer will have no significant long-term adverse impacts on ground-water conditions, inter-related surface streams, or other ground-water supplies in Project service area; OR Comprehensive evaluation of the potential impact on ground-water supplies accompanied by an adopted ground-water management plan?"
   (3) Location map of ground-water well(s) to be utilized.
   (4) Drillers log for ground-water well(s) to be utilized.
   (5) Provide location of other ground-water wells in Project service area.
   (6) Identify and document area(s) normally irrigation by wells."
2. How is the EA cumulative total for transfers, 190,906 AF, reached (p. 29)? The direct Project impacts are listed as 37,505 AF (EA at p. 9), the non-CVP groundwater substitution is 92,806, non-CVP reservoir water is 95,000, and other non-CVP water is 3,100 (EA at p. 31). It would help the public understand the proposed Project if the total quantity of water involved in the Project wasn't so opaque.
3. The following paragraph in the EA raises numerous questions and concerns.

   > "Reclamation approves transfers consistent with provisions of state law and/or the CVPIA that protect against injury to third parties as a result of water transfers. Several important CVPIA principles include requirements that the transfer will not violate the provisions of Federal or State law, will have no significant adverse effect on the ability to deliver CVP water, will be limited to water that would have been consumptively used or irretrievably lost to beneficial use, will have no significant long-term adverse impact on groundwater conditions, and will not adversely affect water supplies for fish and wildlife purposes. Reclamation will not approve any transfer of water for which these basic principles have not been adequately addressed." (EA at p. 10)

   a. How is water for the Project considered, "[c]onsumptively used or irretrievably lost to beneficial use," with groundwater substitution in the Sacramento Valley? Page 4 of the *Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project*

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[12] See especially, Pacific Institute, *More with Less: Agricultural Water Conservation and Efficiency in California, A Special Focus on the Delta*, September 2008; Los Angeles Economic Development Corporation, *Where Will We Get the Water? Assessing Southern California's Future Water Strategies*, August 2008, and Lisa Kresge and Katy Mamen, *California Water Stewards: Innovative On-farm Water Management Practices*, California Institute for Rural Studies, January 2009.

Improvement Act (Title XXXIV of Public Law 102-575) define irretrievable loss to beneficial use as "[d]eep percolation to an unusable groundwater aquifer (e.g., saline sink or a groundwater aquifer that is polluted to the degree that water from the aquifer cannot be directly used." The groundwater basins that are part of the Project do not fit this definition.

b. The groundwater pumped for the Project is a substitute and would not have been used consumptively except for the sale of river water. This violates section H of the *Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project Improvement Act (Title XXXIV of Public Law 102-575)* (p. 4)

If the Project is approved, it flies in the face of CVPIA requirements.

4. Shasta County is not listed in the Affected Environment section although Anderson Cottonwood Irrigation District is participating in the proposed Project (EA at p. 21). If the Bureau intended to identify the counties by groundwater basin, the EA must call out the Redding Basin and Shasta County.

IV. Conclusion

The Bureau's *2010/2011 Water Transfer Program's* EA/FONSI stated on page 3-16:

> *California Water Code Section 1810 and the CVPIA protect against injury to third parties as a result of water transfers. Three fundamental principles include (1) no injury to other legal users of water; (2) no unreasonable effects on fish, wildlife or other in-stream beneficial uses of water; and (3) no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred.*

The current Project's EA/FONSI presents this differently:

- "Reclamation approves transfers consistent with provisions of state law and/or the CVPIA that protect against injury to third parties as a result of water transfers." (EA at p.12)
- "[w]ill not adversely affect water supplies for fish and wildlife purposes." (EA at p.12)
- Adds, "[w]ill have no significant long-term adverse impact on groundwater conditions…" (EA at p. 12)
- Omits, "[n]o unreasonable effects on the overall economy or the environment in the counties from which the water is transferred." 2020/2011 Water Transfer Program EA at p. 3-16)

We unreservedly state to you that the two draft EA/FONSIs, since the *2010/2011 Water Transfer Program's* EA/FONSI is incorporated by reference, appear to describe a project, since they are quite similar, that would fail all of the tests required by the CVPIA and state law as currently described. The *2010/2011 Water Transfer Program* had and the *2013 Water Transfer Program* clearly has the potential to affect the human and natural environments, both within the

Sacramento Valley as well as in the areas of conveyance and delivery. It is entirely likely that injuries to other legal users of water, including those entirely dependent on groundwater in the Sacramento Valley, will occur if this project is approved. Groundwater, fishery and wildlife resources are also likely to suffer harm as instream users of water in the Sacramento Valley as well as terrestrial habitat upon which fishery and wildlife resources depend. And the economic effects of the proposed Project are at best poorly understood through the EA/FONSI. To its credit, at least the Bureau studied the proposed project, while DWR has completely avoided CEQA, thereby enabling the agency to ignore these potential impacts outside a courtroom.

Taken together, the Bureau and DWR treat these serious issues carelessly in the EA/FONSI, the *Draft Technical Information for Water Transfers in 2013* and in DWR's specious avoidance of CEQA review. In so doing, the Agencies deprive decision makers and the public of their ability to evaluate the potential environmental effects of this Project and violate the full-disclosure purposes and methods of both the National Environmental Policy Act and the California Environmental Quality Act.

Sincerely,

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References Cited

Anderson, Michael. 2009. *Future California Droughts in a Climate Change World.*

Bacher, Dan. 2013. *Bay-Delta salmon population just one fifth of mandated goal.* http://www.indybay.org/newsitems/2013/05/15/18736849.php

Bureau of Reclamation. 1993. *Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project Improvement Act (Title XXXIV of Public Law 102-575).*

Bureau of Reclamation, et al. 2003. *Environmental Water Account*, Draft EIS/EIR.

Bureau of Reclamation 2006. Sacramento Valley Regional Water Management Plan. p. 5-8 to 5-10.

Bureau of Reclamation 2009. Drought Water Bank Environmental Assessment.

Butte Basin Water Users Association 2007. *2007 Butte Basin Groundwater Status Report* p. 23 and 30.

Butte Basin Water Users Association 2008. *2008 Butte Basin Groundwater Status Report*

Butte County 2007. Summary of Spring 07 Levels.

Butte County Department of Water and Resource Conservation 2003. *Urban Water Demand Forecast.*

Butte County DWRC June 2007. *Tuscan Aquifer Monitoring, Recharge, and Data Management Project*, Draft.

Butte County DWRC 2013. *Groundwater Status Report, 2012 Water Year.*
    a) Esquon Subinventory Unit report
    b) Pentz Subinventory Unit report
    c) Vina Subinventory Unit

California State Water Resources Control Board 2009. *GAMA Domestic Well Project, Tehama County Focus Area.*

California Water Impact Network, et al 2011. Complaint for Declaratory and Injunctive Relief.

CH2Mhill 2006, *Sacramento Valley Regional Water Management Plan*, Figure 1-4.

Dudley, Toccoy et al. 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update.*

Dudley, Toccoy 2007. Letter to Lester Snow as presented to the Butte County Board of Supervisors as part of agenda item 4.05.

DWR 2008. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

DWR 2009. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

Fleckenstein, Jan; Anderson, Michael; Fogg, Graham; and Mount, Jeffrey 2004. *Managing Surface Water-Groundwater to Restore Fall Flows in the Cosumnes River*, Journal of Water Resources Planning and management, opening page of article.
Friend, Scott 2008. *City of Chico General Plan Update Existing Conditions Report;* Pacific Municiple Consulting.

Glenn County. Board of Supervisors. 2001. California Ordinance No. 1115, Ordinance Amending the County Code, Adding Chapter 20.03, Groundwater Management.

Glenn County. Management Plan: Development of a Locally Driven Groundwater Management Plan Ordinance #1115 amended by ordinance 1237 (2912). Accessed May 15, 2013 at: http://www.glenncountywater.org/management_plan.aspx.

Glenn-Colusa Irrigation District 2008-2009. *Initial Study And Proposed Negative Declaration Landowner Groundwater Well Program*.

Governor's Advisory Drought Planning Panel 2000. *Critical Water Shortage Contingency Plan*.

Hennigan, Barbara 2007. Testimony, Monterey Agreement hearing in Quincy, California. (http://www.water.ca.gov/environmentalservices/docs/mntry_plus/comments/Quincy.txt).
Hennigan, Robert 2010. Personal communication with Barbara Vlamis on January 17, 2010.

Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

Lippe, Gaffney, Wagner LLP. 2009. Letter to DWR regarding the Drought Water Bank Addendum.

Maslin, Paul E., et. al, 1996. *Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon: 1996 Update*.

Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.

Msangi, Siwa and Howit, Richard E. 2006. *Third Party Effects and Asymmetric Externalities in Groundwater Extraction: The Case of Cherokee Strip in Butte County, California.* International Association of Agricultural Economists Conference, Gold Coast, Australia.

Natural Resources Defense Council and Golden Gate Salmon Association. 2012. *Salmon Doubling Index: Natural Production of Sacramento-San Joaquin Basin Chinook Salmon, Expressed as Percentage of the CVPIA Salmon Doubling Goal, from 1992 to 2011*. http://goldengatesalmonassociation.com/wp-content/uploads/2012/06/Salmon-Graph-11-12-12.jpg

Sacramento County Water Agency. 2011. *Ground Water Management Plan.*

Scalmanini, Joseph C. 1995. *VWPA Substatiation of Damages*. Memo. Luhdorff and Scalmanini Consulting Engineers.

Shasta County Water Agency. 2007. *Redding Basin Water Resources Management Plan Environmental Impact Report*.

Shutes, Chris et al. 2009. *Draft Environmental Assessment DeSabla – Centerville Project (FERC No. 803)*. Comments. California Sportfishing Protection Alliance.

Spangler, Deborah L. 2002. *The Characterization of the Butte Basin Aquifer System, Butte County, California*. Thesis submitted to California State University, Chico.

State Water Resources Control Board. 2008. *Hydrogeologically Vulnerable Areas*. http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf

Staton, Kelly 2007. *Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California*. California Department of Water Resources.

The Bay Institute. 2012. *Fresh Water Flows in the Central Valley A primer on their importance, status, and projected changes under the BDCP*.

The Natural Heritage Institute, et al. 2012 *Feasibility Investigation of Re-Operation of Shasta and Oroville Reservoirs in Conjunction with Sacramento Valley Groundwater Systems to Augment Water Supply and Environmental Flows in the Sacramento and Feather Rivers*.

USFWS 1999. Draft Recovery Plan for the Giant Garter Snake.

USFWS 2006. Giant Garter Snake Five Year Review: Summary and Evaluation.

USFWS 2008 Biological Opinion for Conway Ranch.

USFWS 2009 Biological Opinion for the Drought Water Bank.

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RE: Comments and Recommendations on U.S. Bureau of Reclamation and San Luis & Delta-Mendota Water Authority Draft Long-Term Water Transfer DRAFT EIS/EIR, dated September 2014

This letter provides comments and recommendations on the information provided in the September 2014 Draft Long-Term Water Transfer Environmental Impact Statement/ Environmental Impact Report (Draft EIS/EIR) prepared by the U.S. Bureau of Reclamation (BoR) and San Luis & Delta-Mendota Water Authority (SLDMWA). This document evaluates the potential impacts of alternatives over a 10-year period, 2015 through 2024, for transferring Central Valley Project (CVP) and non-CVP water from north of the Sacramento-San Joaquin Delta (Delta) to CVP contractors south of the Delta. These transfers require the use of CVP and State Water Project (SWP) facilities. This Draft EIS/EIR evaluated impacts of alternatives for water transfers made available through groundwater substitution, cropland idling, crop shifting, reservoir release, and conservation.

This letter focuses mostly on the groundwater substitution element of the transfers for the Sacramento Valley groundwater basin and proves comments and recommendations regarding the potential impacts, technical information submitted, and monitoring and mitigation measures. Comments and recommendations are also provided regarding the biological resources, crop idling/crop shifting when those resources or activities impact or are impacted by the groundwater substitution transfers. This letter has two parts. The first part comments on the Draft Long-Term Water Transfer Draft EIS/EIR. The second part provides additional technical information on surface water–groundwater interactions that are relevant to the evaluation of potential impacts from the proposed water transfers, monitoring during the transfers and designing and implementing mitigation measures.

I. Comments and Recommendations on the Draft Long-Term Water Transfer DRAFT EIS/EIR

The Draft EIS/EIR evaluated a number of potential environmental impacts from the groundwater substitution transfers using a finite element groundwater model, SACFEM2013. The potential impacts evaluated include: groundwater levels; surface water flow; water quality; biological resources, including vegetation, wildlife and fisheries; and the associated cumulative effects and impacts. Two mitigation measures, WS-1 and GW-1, are provided for monitoring and mitigating potential impacts from groundwater substitution transfers. I will provide comments and recommendations on these topics following seven comments and recommendations on general issues, assumptions and methods that are used throughout the Draft EIS/EIR.

General Comments

1. The Draft EIS/EIR has an underlying assumption that specific information on each proposed transfer will be evaluated in the future by the Bureau of Reclamation, the California Department of Water Resources (DWR), perhaps the California State Water Resources Control Board (SWRCB), and local agencies, presumably the County, or other designated local agency (Sections 1.5, 3.1.4.1-WS-1 and 3.3.4.1-GW-1). The Draft EIS/EIR relies on the results of the SACFEM2013 groundwater modeling effort to validate the conclusion of less than significant and reasonable impacts that cause no injury from the groundwater substitution transfer pumping. This conclusion is reached based on model simulation results, and assumption of implementation of mitigation measures WS-1 and GW-1. However, the Draft EIS/EIR provides only limited information on the wells to be used in the groundwater substitution transfers (see Table 3.3-3), and no information on non-participating wells that may be impacted. Information that is still needed to evaluate the potential impacts simulated by the groundwater modeling and the potential significance of the groundwater substitution transfer pumping includes, but isn't limited to:

a. proposed transfer wells locations that are sufficiently accurate to allow for determination of distances between the wells and areas of potential impact,
b. the distances between the transfer wells and surface water features,
c. the number of non-participating wells in the vicinity of the transfer wells that may be impacted by the pumping,
d. the distance between the transfer wells and non-participant wells that may be impacted by the transfer pumping, including domestic, public water supply and agricultural wells,
e. the number of non-participating wells in the vicinity of the transfer wells that can be expected to be pumped to provide public water supply or irrigation water during the same period as the transfer pumping,
f. the amount of well interference anticipated at each of the non-participating domestic, public water supply and agricultural wells in the vicinity of transfer wells,
g. the aquifers that the non-participating wells in the vicinity of the transfer wells are drawing groundwater from,
h. groundwater level hydrographs near the non-participating and participating transfer wells, to document the pre-transfer trends and fluctuations in groundwater elevations in order to evaluate the current conditions and serve as a reference for monitoring impacts from transfer pumping,
i. the identity and locations of wells that will be used to monitor groundwater substitution transfer pumping impacts, the aquifers these wells are monitoring, frequency for taking and reporting measurements, and the types and methods for monitoring and reporting,
j. groundwater level decline thresholds at each monitoring well that require actions be taken to reduce or cease groundwater substitution transfer pumping to prevent impacts from excessive drawdown, including impacts to non-participating wells, surface water features, fisheries, vegetation and wildlife, other surface structures, and regional economics.

This list addresses only the minimum of information needed about the groundwater wells and does not address other elements of the groundwater substitution transfer, which I will discuss under separate sections, including the WS-1 and GW-1 mitigation measures, the SACFEM2013 groundwater modeling effort, and stream depletion impacts.

I recommend the Draft EIS/EIR be revised to include the additional well information and monitoring requirements listed above. I recommend that mitigation measures WS-1 and GW-1 be revised to provide specific requirements for monitoring, thresholds of significance, and actions to be taken when the thresholds are exceeded.

2. The only maps provided by the Draft EIS/EIR that show the location of the groundwater substitution transfer wells, and the rivers and streams potentially impacted are the simulated drawdown Figures 3.3-26 to 3.3-31, which are at a scale of approximately 1 inch to 18 miles on letter size paper. These figures show clusters of wells and several rivers, creeks and canals. A few are labeled, but apparently not all of the streams and creeks evaluated for groundwater substitution impacts are shown. Figures 3.7-1 and 3.8-2 show the major rivers and reservoirs evaluated in the biological analyses, and Tables 3.7-2, 3.7-3, and 3.8-3 list up to 34 small rivers or creeks that were apparently evaluated for stream depletion using the SACFEM2013 groundwater model. Without river/stream/creek labels on the drawdown figures at a scale that allows for reasonable measurement and review, it is difficult to determine the anticipated drawdown at the 34 small rivers and creeks or other important habitat areas.

   The Fisheries Section 3.7, and Vegetation and Wildlife Section 3.8 provide discussions of the potential impacts from groundwater substitution transfer induced stream depletion (Sections 3.7.2.1.1, 3.8.2.1.1 and 3.8.2.1.4). The Well Acceptance Criteria of Table B-1 in Appendix B of the October 2013 joint DWR and BoR document titled *Draft Technical Information for Preparing Water Transfer Proposals* (DTIPWTP) lists in the table footnotes eight major and three minor surface water features tributary to the Delta that are affected by groundwater pumping. Apparently, the Well Acceptance Criteria in Table B-1 will be applied to these eleven surface water features as part of mitigation measure GW-1. Whether the Well Acceptance Criteria will also be applied to the creeks listed in Tables 3.7-2, 3,7-3 and 3.8-2 is not specifically stated in the Draft EIS/EIR or GW-1.

   The lack of maps with sufficient detail to see the relationship between the wells and the surface water features prevents adequate review of the Draft EIS/EIR analysis to determine whether mitigation measures WS-1 and GW-1 will be effective at mitigating pumping impacts. As I will discuss in Part 2 of this letter, the distance between a surface water feature and a pumping well is a critical parameter in estimating the rate and duration of stream depletion. Maps are needed of each seller's service area at a scale that allows for reasonably accurate measurement of distances between the groundwater substitution transfer wells and surface water features, other non-participating wells, proposed monitoring wells, fisheries, vegetation and wildlife areas, critical surface structures, and regional economic features.

   I recommend the Draft EIS/EIR be revised to provide additional maps of each seller's service area at a scale that allows for reasonably accurate measurement of distances between the groundwater substitution transfer wells and surface water features listed in Tables 3.7-2, 3.7-3, 3.8-3 and B-1 as well as other non-listed surface water dependent features such as wetlands and riparian areas, non-participating wells, the proposed monitoring wells, wildlife areas, critical surface structures, regional economic features, and other structures that might be impacted by groundwater substitution pumping.

3. The Draft EIS/EIR evaluated a number of potential environmental impacts from the groundwater substitution transfers using the finite element groundwater model SACFEM2013. The results of the modeling effort were used in the assessment of the

potential biological resource impacts from reductions in surface water flow caused by groundwater substitution transfer pumping (pages 3.7-18 to 3.7-30, and 3.8-49 to 3.8-67). The Draft EIS/EIR assumes that SACFEM2013 model results are sufficiently accurate to justify removing most of the small creeks from a detailed effects analysis (Table 3.7-3 and 3.8-3).

Statements are given that the mean monthly reduction in the Sacramento, Feather, Yuba and American rivers will be less than 10 percent (pages 3.7-25 and 3.8-49) and that other stream requirements of flow magnitude, timing, temperature, and water quality would continue to be met. However, actual SACFEM2013 model results on anticipated changes in flow, temperature and water quality are not provided for all of the surface water features that may be potentially impacted by the groundwater substitution transfer projects. Creeks that passed a preliminary screening, Tables 3.7-3 and 3.7-4, were selected to be modeled by water year type for stream depletion that exceeds 1 cubic feet per second (cfs) and 10% reduction in mean monthly flow. Results of the modeling effort are presented in Tables 3.8-4 to 3.8-7.

The Draft EIS/EIR notes that not all surface water features were evaluated because some lacked sufficient historical flow data, or they were too small to model (page 3.7-20). The Draft EIS/EIR then assumes that the pumping impacts to un-modeled small surface water features are similar to nearby modeled features. No maps with sufficient detail are provided to allow for determination of the spatial relationship between the modeled and un-modeled surface water features, or the relationship between the groundwater substitution transfer wells and the modeled and un-modeled surface water features (see comment no. 2). The distance between a well and a surface water feature is a critical parameter in determining the rate and timing of surface water depletion resulting from groundwater pumping. The validity of the assumption that the un-modeled surface water features will respond similarly to the modeled is dependent on the distance between them and their respective distances to the pumping transfer well(s). I will discuss in more detail in Part 2 the importance of distance in the calculation of stream depletion.

The Draft EIS/EIR also provides Figures B-5 and B-6 of Draft EIS/EIR Appendix B that graph in aggregate the changes in stream-aquifer interactions, presumably equal to changes in stream flow, based on the SACFEM2013 simulations. While these graphs are interesting for several reasons, they don't provide information specific to each seller service area on flow losses expected in each river and creek. No figures are provided that show the longitudinal- or cross-sections of channel where impacts are expected, or the rate of stream depletion in each channel section. Maps with rates and times of stream depletion by longitudinal channel section are needed to allow for an adequate review of the Draft EIR/EIS conclusion of less than significant and reasonable impacts with no injury. These maps are also needed to evaluate the specific locations for monitoring potential impacts.

Statements are made in Section 3.7 that reductions in surface flow due to groundwater substitution pumping would be observed in monitoring wells in the region as required by mitigation measure GW-1. Thus detailed maps that show the locations of the monitoring wells and the areas of potential impact along with the rates and seasons of anticipated stream depletion are needed for each service area. These maps are also needed to allow for evaluation of the cumulative effects whenever pumping by multiple sellers can impact the same resource. Without site-specific information on expected locations and changes in flow at each potentially impacted surface water feature, it's difficult to evaluate the adequacy of any monitoring effort.

I recommend the Draft EIS/EIR be revised to provide additional information on the anticipated changes in surface water flow, temperature, water quality and channel geomorphology for each river, creek and surface water feature in the areas of groundwater substitution transfer pumping. In addition, I recommend that maps showing the along channel longitudinal sections, the maximum anticipated changes in flow rate, water temperature, water quality, and the timing of the maximum anticipated rate of stream depletion due to groundwater substitution transfer pumping be provided at an appropriate scale to allow for adequate measurement and review in the Draft EIS/EIR, and for use in the WS-1 and GW-1mitigation monitoring programs.

4. The results of the SACFEM2013 simulation are used to evaluate stream depletion quantities and impacts for vegetation and wildlife resources that are dependent on surface water (Sections 3.7 and 3.8), and to determine the expected lowering of groundwater levels in the areas of transfer pumping (Section 3.3). The groundwater substitution transfer pumping simulation was run from water year (WY) 1970 to WY 2003 and assumed 12 periods of groundwater substitution transfer at various annual transfer volumes as shown in Figure 3.3-25. The apparent Draft EIS/EIR baseline for analysis of groundwater pumping impacts ends with WY 2003 because of limitations of the CalSim II surface water operations model. The CalSim II model was jointly developed by DWR and BoR and is used to determine available export capacity of the Delta. The WY 2003 time limitation was adopted in the SACFEM2013 groundwater-modeling effort apparently because of the desire to combine the simulation of groundwater impacts with estimating the timing of when groundwater substitution water could be transferred through the Delta (Section 3.3.2.1.1). The description of the SACFEM2013 modeling effort states that the volume of groundwater pumping was determined by "comparing the supply in the seller service area to the demand in the buyer service area" (page 3.3-60).

   While this is an interesting modeling exercise, and much can be learned from it, the simulations didn't evaluate the impacts of pumping the maximum annual amount proposed for each of the 10 years of the project. It is important that with any simulation used to analyze potential project impacts that the maximum levels of stress, pumping, proposed by the project be simulated at each of the project locations for the entire duration of the project. This is especially important whenever the simulations are used to justify the conclusion that project impacts will be less than significant, reasonable and cause no injury. Because the groundwater modeling effort didn't include the most recent 11 years of record, it appears to have missed simulating the most recent periods of groundwater substitution transfer pumping and other groundwater impacting events, such as recent changes in groundwater elevations and groundwater storage (DWR, 2014b), and the reduced recharge due to the recent periods of drought. Without taking the hydrologic conditions during the recent 11 years into account, the results of the SACFEM2013 model simulation may not accurately depict the current conditions or predict the effects from the proposed groundwater substitution transfer pumping during the next 10 years.

   Although the Draft EIS/EIR project description is specific on the volumes and periods of groundwater substitution transfer pumping as shown in Tables 2-4 and 2-5, the write-up of the groundwater modeling effort aggregated the volume pumped (Sections 3.3.2.4.2 and B.4.3.1.2 in Appendix B). The simulated volume of groundwater pumped doesn't reach the maximum being requested by the project in any individual year or for all ten years (Figures B-4 in Appendix B and 3.3-25). Note, the annual groundwater substitution transfer amounts shown in Figure B-4 in Appendix B are not the same as the amounts simulated by the SACFEM2013 model as shown in Figure 3.3-25. The presentation of the SACFEM2013 model results in Sections 3.3.2.4.2 and B.4.3.1.2 don't tabulate or provide detailed maps by seller service area on the pumping rates, cumulative pumped volumes, pumping times and durations, or which aquifers were pumped in the simulations. The model documentation doesn't provide the maximum drawdown or the expected centers of maximum drawdown for each seller service area.

The documentation of the SACFEM2013 model results should also discuss the variations in potential impacts that might result from pumping transfer wells other than those simulated. If the groundwater simulation didn't pump all of the transfer wells listed in Table 3.3-3 for each seller at their maximum rate, then the modeling documentation should describe how the impacts from the simulation should be evaluated for the non-simulated transfer wells and for those well simulated at less than maximum pumping. For example, if the modeling effort provides the pumping time and distance drawdown characteristics of each well this information can be used to estimate the drawdown at different distances, pumping rates, and durations of pumping (see pages 238 to 244 in Driscoll, 1986). The Draft EIS/EIR should provide the time-drawdown and distance-drawdown hydraulic characteristics for each groundwater substitution transfer well so that non-simulated impacts can be estimated. The Draft EIS/EIR should then describe a method(s) for estimating the drawdown at different distances, rates and durations of pumping so that non-participant well owners can estimate and evaluate the potential impacts to their well(s) from well interference due to the pumping of groundwater substitution transfer well(s).

Because the rate of stream depletion is scaled to pumping rate and because the model documentation doesn't indicate the pumping locations, rates, volumes, times or durations that produced the pumped volumes shown in Figure 3.3-25, or the stream depletions shown in Figures B-5 and B-6 in Appendix B, there is uncertainty whether the SACFEM2013 modeling simulated the maximum rate of stream depletion for the proposed 10-year project. The annual volume of groundwater pumping shown in Figure 3.3-25 are less than the maximum requested, and pumping for a continuous 10 years was not simulated. This suggests that the stream-interaction values or stream depletion(?) shown in Figures B-5 and B-6 of Appendix B are not the maximum level of impact that might occur from the 10-year project.

Without information on the rate, timing and duration of the groundwater pumping, there can be no evaluation of whether the annual simulated impacts are representative of the two pumping seasons listed in Table 2-5, or just a single 3-month pumping season. Whenever the simulated annual pumping rate was greater than the single season maximum of 163,571 acre-feet (AF), two seasons of pumping are required, but the percentage in each season is unknown. If the simulated pumping time represents only one season or a mixture of the two seasons, then the simulation may not reflect the actual timing and/or duration of maximum groundwater substitution pumping impacts proposed in Table 2-5. If a simulation doesn't evaluate the project under existing conditions or simulate the maximum stress allowed by the project description, then it raises a question of whether the Draft EIS/EIR adequately evaluated the projects potential impacts. Without thorough documentation of the SACFEM2013 groundwater impact simulation, it is difficult to review and analyze the model's predictions for potential impacts from each seller's groundwater substitution transfer project, or use the model results in designing and setting impact thresholds for the groundwater monitoring required in mitigation measure GW-1.

I recommend the Draft EIS/EIR be revised to provide a more complete description of the SACFEM2013 groundwater modeling effort, including tabulation of the groundwater substitution pumping rates, volumes, durations,

and dates for each simulated well; the hydraulic characteristics of each well simulated; the aquifer(s) pumped by each simulation well; the impacts from the maximum proposed pumping, annually and during the 10-years of the proposed project; sufficiently detailed maps of the well locations in each seller's service area that non-participants and the public can use to identify any well's relationship to the groundwater substitution transfer wells and understand the potential impacts to groundwater levels. I recommend the Draft EIS/EIR provide, for each transfer well, the pumping time and distance drawdown characteristics such that drawdown for durations, distances and rates of pumping other than those simulated can be estimated. I recommend the Draft EIS/EIR also provide an explanation of why the simulation is representative of the current (2014) conditions, how the simulation can be used to assess current and future conditions, and how the simulation can be used to evaluate, monitor and set impact thresholds for future impacts from the 10-year project at the maximum groundwater substitution transfer pumping volumes listed in Tables 2-4 and 2-5.

5. The Draft EIS/EIR was written from the perspective of the process of transferring surface waters through the Delta. This surface water point of view has carried over into some of the analyses of impacts and mitigations for groundwater pumping. For example, the discussions of potential impacts to surface water users, fisheries, and other stream dependent biological resources are thought of as occurring "downstream" of the groundwater substitution wells. While it is correct that groundwater pumping can impact down gradient resources, pumping can also affect up gradient and lateral resources. A pumped well creates a depression in the surrounding aquifer, often referred to as a "cone of depression." Thus, the area of impact around a pumping well is not a single point, but a region whose extent is sometimes called the "area, radius or zone of influence." The length of stream affected by groundwater pumping is related to the distance between the well and the stream (Figures 16 and 29 from Barlow and Leake, 2012; Exhibits 1.1 and 1.2). Miller and Durnford (2005) noted that for an ideal aquifer and stream at longer durations of pumping, when the stream depletion rate approaches the well pumping rate, 50% the stream depletion occurs within a stream reach length of twice the distance between the stream and well, and 87% of the depletion occurs within a reach length of 10 times the stream to well distance. Obviously, for non-ideal aquifers and streams the length of stream depleted will vary from the ideal, but this illustrates that stream depletion caused by a pumping well is not focused at one point, but occurs along a length of stream with impacts that occur upstream and downstream from the point on the stream that is typically closest to the well.

   Because groundwater is generally flowing, the water table or piezometric surface has a slope. This slope causes the cone of depression around a pumping well to elongate along the direction of regional flow. The elongated cone of depression is often referred to as a "capture zone" (Frind and others, 2002) and determining its extent is a basic part of a pump and treat groundwater cleanup program (USEPA, 2008a). This "capture zone" is related to stream depletion capture because the pumping well intercepts groundwater that would eventually discharge to surface water or be used by surface vegetation. If the "capture zone" extents far enough it may cross a surface water feature and induce greater seepage. However, unlike the capture needed for a contaminant plume, stream depletion can occur without the actual molecule of water that enters the well having to originate from the stream (Figure 29; Exhibit 1.2).

   The stream depletion occurs when groundwater is either intercepted before reaching the stream or seepage from the stream is increased. This water only has to backfill the change in storage caused by pumping, it doesn't have to enter the well. The "capture zone" also extends upgradient to the recharge area that's the normal source of water flowing past the well. The aquifer recharge that flows past the pumping well may be derived from a wide mountain front area, it could be a section of another river that crosses the the "capture zone", or an overlying area of agricultural irrigation. In a complex hydrogeologic setting, numerical modeling that utilize particle tracking is needed to define where a pumping well is recharged and where it may deplete surface water features (Frind and others, 2002; Franke and others, 1998).

The concepts of a wide zone of influence and an elongated "capture zone" are important for the Sacramento Valley groundwater substitution transfers projects because the analysis and monitoring of potential pumping impacts requires a multidirectional evaluation. It can't be assumed that stream depletion impacts from pumping occur only downstream from the point on the stream closest to the pumping well. Any monitoring of the effects of groundwater substitution pumping on surface or ground water levels, rates and areas of stream depletion, fisheries, vegetation and wildlife impacts, and other critical structures needs to cover a much wider area than what is needed for a direct surface water diversion. This is a fundamental issue with the Draft EIS/EIR. The environmental analyses, monitoring requirements and mitigation measures appear to be developed without adequately considering the multidirectional, wide extent of potential impacts from groundwater substitution transfer pumping.

I recommend the Draft EIS/EIR be revised to address the wide extent of potential impacts for groundwater substitution transfer pumping. This should include conducting numerical modeling of the groundwater basin using particle tracking to determine which surface water features and other structures are potentially impacted by the pumping of each transfer well and to determine the extent of stream depletion along each potentially impacted surface water feature. The monitoring and mitigation measures WS-1 and GW-1 should also be revised to account for a wide area of potential impact from groundwater substitution transfer pumping.

6. The Draft EIS/EIR is written with the assumption that project specific evaluation for each seller agency will be done at a later time by the BoR and/or DWR, and at the local level (see Section 3.3.1.2.3, mitigation measure GW-1 in Section 3.3.4.1, and Section 3.1 in the DTIPWRP). The Draft EIS/EIR lists in Table 3.3-1 and Table 3-1 of the DTIPWRP the Groundwater Management Plans (GMP), agreements and county ordinances that regulate the sellers at a local level. The Draft EIS/EIR discusses only two county ordinances, the Colusa Ordinance No. 615 and Yolo Export Ordinance No. 1617, one agreement, the Water Forum Agreement in Sacramento County, and one conjunctive use program, the American River Basin Regional Conjunctive Use Program. The Table 3-1 in the DTIPWRP lists short descriptions of the county ordinances related to groundwater transfers, if one exists. These descriptions don't always identify the actual ordinance number that applies to a groundwater substitution transfer, but sources for additional information are provided in the table.

   The DTIPWRP (page 27) and GW-1 (page 3.3-88) instructs the entity participating in a groundwater substitution transfer that they are responsible for compliance with local groundwater management plans and ordinances. Except for the brief discussion of the two ordinances, one agreement, and one conjunctive use program listed above, the Draft EIS/EIR doesn't describe the requirements of local GMPs, ordinances, and agreements listed in Tables 3.3-1 (page 3.3-8) and Table 3-1 (page 27). Thus, the actual groundwater substitution transfer project permit requirements, restrictions, conditions, or exemptions required for each seller service area by BoR, DWR, and one or more County GMP or groundwater ordinance will apparently be determined at a future date. It follows that any actual monitoring requirements, mitigation measures, thresholds of significance required by BoR, DWR or local governing agencies will also be determined at a future date. The mechanism for the public to participate in the determination of the actual groundwater substitution transfer project permit requirements, restrictions, conditions, mitigation measures or exemptions isn't specified in the Draft EIS/EIR.

Addition information is needed on what the local regulations require for exporting groundwater out of each seller's groundwater basin. The Draft EIS/EIR needs to discuss how the local regulations ensure that the project complies with California Water Code (WC) Sections 1220, 1745.10, 1810, 10750, 10753.7, 10920-10936, and 12924 (for more detailed discussion of these Water Codes see Draft EIS/EIR Section 3.3.1.2.2). Although the Draft EIS/EIR doesn't document, compare or evaluate the requirements of all local agencies that have authority over groundwater substitution transfers in each seller service area, the Draft EIS/EIR concludes that the environmental impacts from groundwater substitution transfer pumping by each of the sellers will either be less than significant and cause no injury, or be mitigated to less than significant through mitigation measures WS-1, and GW-1 with it's reliance on compliance with local regulations. Because the spatial limits of groundwater substitution pumping impacts are controlled by hydrogeology, hydrology, and rates, durations and seasons of pumping, the impacts may not be limited to the boundaries of each seller's service area, GMPs, or County. There is a possibility that a seller's groundwater substitution area of impact will occur in multiple local jurisdictions, which should results in project requirements coming from multiple local as well as state and federal agencies. The Draft EIS/EIR doesn't discuss which of the multiple local agencies would be the lead agency, how an agreement between agencies would be reached, or how the requirements of the other agencies will be enforced. The Draft EIS/EIR only briefly mentions the Northern Sacramento Valley Integrated Regional Water Management Plan (IRWMP) (page 3.3-91 and -92) and doesn't mention the American River IRWMP (http://www.rwah2o.org/rwa/programs/irwmp/), the Yuba County IRWMP (http://yubairwmp.org/the-plan-irwmp/content/irwmp-plan), or the Yolo County IRWMP (http://www.yolowra.org/irwmp.html). The Draft EIR/EIS doesn't provide information on the water management requirements of the IRWMP covering each seller service area or how the groundwater substitution transfers will be accounted for in the IRWMP process.

Because the Draft EIS/EIR requires that each individual transfer project meet the requirements of Water Code sections listed above, and because it assumes that each of the sellers will separately comply with all federal, state and local regulation, GMPs, IRWMPs, ordinances or agreements, the Draft EIS/EIR should provide an analysis of how these local regulations, GMPs, ordinances or agreements will ensure each seller's project achieves the goals of no injury, less than significant and reasonable impacts. Each seller's project analysis should identify what future analyses, ordinances, project conditions, exemptions, monitoring and mitigation measures are required to ensure that each of the seller's project meets or exceed the goals of the Draft EIS/EIR.

I recommend the Draft EIS/EIR be revised to include a discussion and comparison of the local regulations, GMPs, IRWMPs, ordinances and agreements that govern each of the seller's proposed groundwater substitution transfers. I recommend each analysis demonstrate that each seller's project will meet or exceed the environmental protection goals of the Draft EIS/EIR. I recommend an analysis that compares local and regional management plans,

ordinances, regulations, and agreements with the monitoring and mitigation measures in the Draft EIS/EIR to identify any additional mitigation measures needed to ensure compliance with local, regional, state and federal regulations. I recommend an analysis that includes: (1) a discussion on how the local lead agency will be determined; (2) how multiagency jurisdictions will be enforced; (3) how conflicts between different local, regional, state and federal regulatory jurisdictions will be resolved; and (4) how public participation will occur.

7. The Draft EIS/EIR provides only one groundwater elevation map of the Sacramento Valley groundwater basin, Figure 3.3-4, which shows contours from wells screened from a depth greater than 100 feet to less than 400 feet below ground surface (bgs) (>100 to < 400 feet bgs) and only for the northern portion of the proposed groundwater substitution transfer seller area. The Draft EIS/EIR doesn't provide maps showing groundwater elevations, or depth to groundwater, for groundwater substitution transfer seller areas in Placer, Sutter, Yolo, Yuba, and Sacramento counties.

   The DWR provides on a web site a number of additional groundwater level and depth to groundwater maps at: http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Well%20Depth%20Summary%20Maps.

   For example, there are maps that show the change in groundwater levels from the spring of 2004 to spring of 2014 for shallow screened wells (<200 feet bgs), intermediate wells (>200 to <600 feet bgs), deep wells (>600 feet bgs), and well screened in the >100 to < 400 feet bgs interval. In addition, the DWR web site has a series of well depth summary maps for Butte, Colusa, Glenn, and Tehama counties, and the Redding Basin that show the density of wells screened at less than 150 feet bgs, and between 150 and 500 feet bgs, along with contours of the depth to groundwater in the summer of 2013. There are also numerous other groundwater elevation contour maps on DWR's web page, going back to 2006. Historical and recent groundwater elevation and depth contours maps for Placer, Sutter, Yolo, Yuba, and Sacramento counties may be available from the groundwater substitution transfer sellers, other water agencies in those counties, the IRWMP documents, or technical reports on groundwater management (for example, Northern California Water Association, 2014a, b, and c).

   Historic change and current groundwater contour maps are critical to establishing an environmental baseline for the groundwater substitution transfers. This information is needed to evaluate the impacts from groundwater substitution transfers because it establishes the present groundwater basin conditions and document the changes and trends in groundwater levels in the last 10-plus years, which were not simulated by the SACFEM2013 modeling.

   Information on the depth to shallow groundwater is critically important because of the analysis of impacts to vegetation and wildlife in Section 3.8 assumed, based on the results of the SACFEM2013 model, that the current depth to shallow groundwater is greater than 15 feet bgs for most of the Sacramento Valley groundwater basin (page 3.8-32). Because the simulation showed a condition of greater than 15 feet depth to groundwater, the Draft EIS/EIR concluded that impacts from lowering of the shallow water table as a result of the groundwater substitution transfer pumping would be less than significant (page 3.8-47).

   This assumption however appears to conflict with the DWR shallow well depth summary maps (DWR, 2014a) that show contours of the depth to groundwater in wells less than 150 feet bgs in the summer 2013. These maps show extensive areas around the Sutter Buttes and to the north were the depth to groundwater is less than 10 feet and 20 feet (Exhibit 2.1). These maps also show extensive areas where the depth to groundwater is less than 40 feet, a depth significant to some tree species such as the valley oak (page 3.8-32). There is also a recent trend of lower groundwater levels in a number of areas in the Sacramento Valley as shown on the DWR 2004 to 2014 groundwater change maps for shallow, intermediate, deep aquifer zones available from the web site listed above (DWR, 2014b). Exhibit 2.1 has a composite map of the shallow zone well depth maps and traces of the shallow zone 2004 to 2014 groundwater elevation change contours.

These groundwater elevation, depth and changes in elevation maps are important for documenting baseline groundwater conditions. The recent trend of decreased groundwater levels should be included in the analysis of groundwater substitution pumping impacts because the drawdowns shown in Figures 3.3-26 to 3.3-31 will interact with existing conditions, and may cause additional long-term decreases in groundwater levels. The Draft EIS/EIR's assessment of the impacts from groundwater substitution transfer pumping to existing and future wells, fisheries, vegetation and wildlife, and surface structures should factor in these recent trends in groundwater levels and not rely solely on SACFEM2013 model simulations that ended in 2003. In addition, the hydrographs in Appendix E that show the SACFEM2013 model results should identify wells near the selected 34-hydrograph locations where groundwater level measurements have been taken and show these actual groundwater levels on the hydrographs. Currently the public is left with the task of finding groundwater level data near the 34 selected hydrograph locations and then validating the simulation results by making comparisons between the simulated water levels and the actual water levels. This model validation task should be part of the Draft EIS/EIR.

I recommend the Draft EIS/EIR be revised to include maps of recent groundwater levels and depths to groundwater along with changes in groundwater levels and depths for at least the last 11 years for all of the counties where the seller agencies propose a groundwater substitution transfer project. I recommend that the Draft EIS/EIR be revised to provide additional verification of the SACFEM2013 model results by comparing them to measured groundwater levels in the vicinity of the 34 selected modeling hydrograph locations. I also recommend the hydrographs of actual water level measurements in the vicinity be included on the simulation hydrographs, so that the public can review the accuracy of the simulation. I recommend contour maps showing the current depth to groundwater be made from actual shallow groundwater measurements and that these contours be shown on maps of the surface water features identified and evaluated in Draft EIS/EIR Sections 3.3-Groundwater, 3.7-Fisheries (Table 3.7-3), and 3.8-Vegegation and Wildlife (Table 3.8-3). I recommend that the SACFEM2013 simulation drawdowns be combined with the current (2014) groundwater elevations for each groundwater substitution transfer aquifer to show the cumulative impacts of the 10-year project on existing groundwater elevations.

Groundwater Model SACFEM2013

A finite element groundwater model, SACFEM2013, was used to evaluate the potential for changes in groundwater levels and stream depletion from groundwater substitution transfer pumping during the 10-year period of the project. The results of the simulations were used to evaluate the impacts to fisheries, vegetation and wildlife (Section 3.7 and 3.8). Section 3.3.2.1 discusses the use of the model for estimating regional groundwater level declines due to groundwater substitution pumping. Figures 3.3-26 to 3.3-31 provide simulated changes in groundwater elevation or head for three intervals, up to 35 feet bgs, 200 to 300 feet bgs, and 700 to 900 feet bgs. Figures 3.3-32 to 3.3-40 and Appendix E provide hydrographs of model simulations for 34 selected locations shown on the simulated groundwater elevation change maps. Sections 3.7.2.1.1, 3.7.2.1.3, 3.7.2.4.1, 3.8.2.1.1, 3.8.2.1.4, and 3.8.2.4.1 provide discussion on the potential impacts of groundwater substitution transfer pumping on fisheries, vegetation and wildlife resources from a drop in the shallow groundwater table and depletion of stream flows.

The SACFEM2013 model was set up to simulate transient flow conditions from WY 1970 to WY 2010 (page 3.3-60). Historic data from 1970 to 2003 were use to estimate the potential impacts from groundwater substitution transfers during the 10-year period of the project. The simulation terminated at 2003 because that was the last simulation period available for the CalSim II model, a planning model designed to simulate operations of the CVP and SWP reservoirs and water delivery systems. Additional SACFEM2013 model documentation is given in Appendix D, which provides information on the model gridding, layering, assumptions and calculation methods. Several of the model designs and parameters selected likely influenced the model's ability to predict future impacts from the 10-year groundwater substitution transfer project. Those include: the time period of the model, the assumptions about the amount and frequency of groundwater substitution pumping, the model's nodal spacing, estimates of aquifer properties, the number of streams simulated, streambed parameters, and specified-flux boundaries. There are at least two other groundwater simulation models developed for the Sacramento Valley, a U.S. Geological Survey model, USGS-CVHM (Faunt, ed., 2009) and a DWR-C2VSim model (Brush and others, 2013a and 2013b).

A comparison between the SACFEM2013 and these two other models provides an interesting assessment of how these three models estimated the hydrogeologic character and conditions of the Sacramento Valley. A comparison also demonstrates that there is no one correct groundwater model, that models with different parameter distributions can achieve reasonable calibration. With models of differing hydrogeologic characteristics, the predictions of future impacts by each model should be expected to differ. Determining which of the models accurately predicts future impacts requires the validation of each model's prediction with new field data. The Draft EIS/EIR mitigation measures for groundwater substitution transfer pumping shouldn't assume that the SACFEM2013 model results are all that is needed to demonstrate no injury and less than significant impacts from the proposed project. Validation of the model-based conclusion of no impacts requires collection of new field data and comparison to simulation predictions throughout and beyond the 10-year project.

A comparison of portions of the SACFEM2013 simulation for the Draft EIS/EIR with the two other models is given below.

8. *Period of Modeled Historic Groundwater Conditions* – Although the model simulation period ended in 2003, the Draft EIS/EIR indicates that the model was run to 2010, but the results were not provided. From the model write-up it is unknown whether the latest groundwater elevations were a factor in the modeling effort. The simulation hydrographs in Appendix E terminate in 2004. Apparently, the hydrologic conditions for the latest 10 years are not included because the Draft EIS/EIR doesn't discuss how the model simulations agree with the current baseline conditions. Specifically, the change in groundwater elevation between 2004 and 2014 as document by DWR (2014b) in a series of three maps. I've

provided in attached Exhibits 3.1 to 3.3 maps that are composites of DWR's 2004 to 2014 groundwater change maps with Draft EIS/EIR Figures 3.3-29, 3.3-30 and 3.3-31, the SACFEM2013 1990 hydrologic conditions simulations of drawdown by zone. The 1990 hydrologic condition was selected for comparison because the sequence of groundwater pumping events is the closest match to the actual pumping requested in the Draft EIS/EIR. Note that the depth intervals of the two sets of maps don't exactly coincide, but they are generally grouped as shallow, intermediate and deep aquifers.

Exhibits 3.1 to 3.3 show that the simulated changes in groundwater elevation from the 10-year groundwater substitution transfer project appear to widen the existing groundwater depressions. The pumping depression southwest of Orland will expands to the east and northeast, as will the depression in the Williams area. A pumping depression will develop in the Live Oaks area and to the east. In the southeastern Sacramento area, the pumping depression from the 10-year project will apparently extent southeastward beyond the limits of the Sacramento Valley transfer project boundary. Combining the existing areas of recent sustained groundwater drawdown with the additional drawdown from the groundwater substitution transfer pumping could slow the recovery of groundwater elevations. The 10-year project pumping east of Orland may connect the two existing groundwater depressions around Orland and Chico to create one large depression. Because the DWR 2004 to 2014 groundwater change maps don't extend completely to the southern portions of the Sacramento Valley groundwater substitution transfer area in Placer, Sutter, Yolo, Yuba, and Sacramento counties, no evaluation can be made about the impact of 10 years of groundwater substitution transfer pumping on existing groundwater conditions in those or adjacent areas.

I recommended the Draft EIS/EIR be revised to discuss how the SACFEM2013 simulations incorporate the changes in groundwater level from 2004 to 2014 in assessing the potential impacts from the proposed 10 years of groundwater substitution transfer pumping. I recommended this discussion include evaluation of the rate and duration of groundwater level recovery that factors in the existing (2014) groundwater levels. I also recommend the Draft EIS/EIR be revised to discuss how during the 10 years of project transfers through the Delta will be made with a CalSim II model that's only current to the year 2003.

9. *Simulation Pumping Volume and Frequency* - The model simulated a series of groundwater pumping events in 12 out of the 34 years of simulation (page 3.3-60). The logic of a multiyear, variable hydrology simulation was that it allowed for evaluation of the cumulative effects of pumping in previous years (page 3.3-61). Figure 3.3-25 shows the simulated periods of groundwater substitution transfer pumping. The 1990 simulation period most closely matches the multiyear pumping being requested by the 10-year project. The 1990 simulation period included groundwater pumping 7 out of 10 years, with pumping values ranging from approximately 95,000 acre-feet per year (AFY) to approximately 262,000 AFY, as measured from Figure 3.3-35. Note the actual pumping rates, volumes, and pumping durations were not provided in the simulation documentation. Apparently, none of the modeled groundwater substitution pumping simulation periods was given the actual maximum groundwater substitution pumping value of 290,495 AFY as calculated from Table 2-5. The time-weighted annual average pumping rate for the 1990 simulation period is approximately 126,900 AF, as measured from Figure 3.3-35. This represents approximately 44% of the maximum pumping rate requested in the Draft EIS/EIR (126,900 AF/290,495 AF = 0.437). Therefore the SACFEM2013 Draft EIS/EIR simulations may only represent a portion of the project's potential impacts from groundwater substitution transfer pumping.

I recommend the Draft EIS/EIR be revised to discuss how the SACFEM2013 simulations provide a full and accurate estimation of the potential impacts from the groundwater substitution transfer pumping throughout the 10-year project. I also recommend the Draft EIS/EIR be revised to include SACFEM2013 simulations at the maximum requested annual volume of 290,495 AF for each of the 10 years of pumping.

10. *Simulation Grid Size* - The SACFEM2013 documentation states that the grid used for groundwater substitution transfer simulations has 153,812 nodes and 306,813 elements (page D-3 of Appendix D). The model nodal spacing varies from 410 feet to 3,000 feet, with an approximate nodal spacing of 1,640 feet along streams and flood bypasses. While this nodal spacing is reasonable for regional groundwater simulations, the results of the simulations may not provide the detail needed to evaluate drawdown interference between the groundwater substitution transfer wells and adjacent non-participating wells. Information is needed on the locations of the groundwater substitution transfer wells and the adjacent non-participating wells in order to determine whether the current simulation grid spacing can accurately estimate well interference. The Draft EIS/EIR analysis of groundwater substitution pumping impacts should be based on an appropriate model grid spacing to establish accurate maximum thresholds for well interference caused by the transfer well pumping. The Draft EIS/EIR should provide sufficient information that an owner of a non-participating well can determine accurately the maximum anticipated increase in drawdown at their well during the 10 years of groundwater substitution transfer pumping. Whether this amount of increased drawdown is significant at each non-participating well is a matter of the current well design and groundwater conditions at each well. The Draft EIS/EIR should establish values for the maximum allowable well interference drawdown from groundwater substitution transfer pumping, which should be based on the costs and inconvenience of lowering the water level. The Draft EIS/EIR should establish the economic costs and level of injury that are reasonable for a non-participating well owner to assume and will keep the impacts from the 10-year project in compliance with the no injury rule as required by WC Section 1706, 1725 and 1736 (Section 1.3.2.3).

    I recommend the Draft EIS/EIR be revised to discuss how the maximum thresholds for water level drawdown due to well interference from groundwater substitution transfer pumping will be established for non-participating wells, and provide a process for assigning a threshold to each non-participating well, along with monitoring requirements and specific mitigation measures should the threshold be exceeded. The Draft EIS/EIR also should be revised to provide the threshold values for well system repair costs used in set the maximum allowable well interference drawdown, along with the documentation and analysis of why the well interference drawdown and cost thresholds are considered reasonable and result in no injury to non-participating well owners, and comply with the Water Code.

11. *Simulation Hydrogeologic Parameter Values* - The SACFEM2013 model was developed with seven layers of varying thickness that extend from the shallow water table to the base of fresh water. The USGS-CVHM model has ten layers, while the DWR-C2VSim model has 3 layers. All of the models assume that the uppermost layer, layer 1, was unconfined and the lower layers are confined aquifer. The hydrogeologic parameters values differ for each of these models as shown in a summary table in Exhibit 4.1. Both the CVHM and C2VSim models divided the Central Valley in to 21 subregions (Figure 3, Brush and others, 2013a; Exhibit 4.4). The SACFEM2013 doesn't use subregions from the Sacramento Valley model. As discussed below, the SACFEM2013 appears to use the same distribution of the

horizontal hydraulic conductivity, Kh, for all model layers (Figure D-4 of Appendix D). Both the CVHM and the C2VSim models appear to have more varied hydraulic conductivity distributions then SACFEM2013.

Development of the SACFEM2013 simulations used horizontal hydraulic conductivity values derived from the well logs of large-diameter irrigation wells. Shallow and low-yielding wells, less than 100 gallons per minute (gpm), and domestic-type wells were not used (page D-12 of Appendix D). The values of specific capacity (gallons per minute per foot of drawdown) from the DWR well completion reports were used to estimate transmissivity around a well using an empirical equation for confined aquifer developed from Jacob's modified non-equilibrium equation (see equation 8 page D-13 and Appendix 16D of Driscoll, 1986 in Exhibit 4.6). Transmissivity was converted to Kh by assuming the aquifer thickness was equal to the length of the well screen interval. These well Kh values were then averaged using a geometric mean with surrounding wells within a critical distance of 6 miles. The results of the geometric mean averaging were then gridded using a kriging to produce Kh values across the modeled area (Figure D-4 in Appendix D). The transmissivity of each model layer was then calculated at each node by multiplying the kriged geometric mean value of Kh by the aquifer layer thickness. The vertical hydraulic conductivity, Kv, was calculated by assuming a uniform Kh:Kv ratio of 50:1 for layer 1 and 500:1 for layers 2 to 7.

The CVHM model (Faunt, ed., 2009) used the percentage of coarse-grained material from well logs and boreholes as the primary variable in a sediment texture analysis of the Central Valley, which was divided into nine textural provinces and domains (Figures A10 to A14; Exhibits 4.7a to 4.7i). The Sacramento Valley has three textural domains, Redding, eastern, and western Sacramento domains (page 30, Faunt, ed., 2009). The coarse-grained fraction was correlated to horizontal (Kh) and vertical (Kv) conductivity (page 154, Faunt, ed., 2009). The Kh values were estimated using kriging and a weighted arithmetic mean, a type of power mean, whereas the Kv value estimates used either a harmonic or geometric mean. Faunt (ed., 2009) notes that the arithmetic mean is most influenced by the coarser-grained material, whereas the fine-grained material more heavily weights both the harmonic and geometric means. Figure C14 (Exhibit 4.7j) shows the relationship between the percentage of coarse-grained deposits and hydraulic conductivity for the different types of means. For the Sacramento Valley the texture-weighted power-mean value was -0.5, a value midway between the harmonic and geometric means (Table C8, Exhibit 4.3).

Table C8 lists the end member hydraulic conductivity values used in the CVHM model with those for the Sacramento Valley ranging from 670 feet/day (ft/day) for coarse-grained to 0.075 ft/day for fine-grained. The table also lists field and laboratory values of Kh and Kv for coarse and fine-grained deposits. The Redding textural domain has the highest percentage of coarse-grained material of the three in Sacramento Valley, a mean of 39 percent, with the western portion becoming coarser with depth (page 30, Faunt, ed., 2009). The western and eastern Sacramento domains are finer-grained, with the eastern mean at 32 percent coarse-grained deposits, and the western mean at 25 percent. Figure A15B(A?) (Exhibit 4.7k) shows the cumulative distribution of kriged sediment textures for each layer of the CVHM model for the Sacramento Valley. Figures A12A to A12E (Exhibits 4.7c to 4.7g) show the distribution of coarse-grained deposits in CVHM groundwater model layers 1, 3, Corcoran Clay, 6 and 9 for the Sacramento and San Joaquin Valleys. Isolated coarser-grained deposits that occur in layer 1 are associated with the Sacramento River, distal parts of fans from the Cascade Range and northern Sierra Nevada, and the American River (page 30, Faunt, ed., 2009; Figure A14, Exhibit 4.7i). Although the texture maps, Figures A12A to A12E of CVHM, and the hydraulic conductivity distribution map of Figure D4 of SACFEM2013, show different characteristic of each model's hydraulic conductivity, they can be compared by their visual complexity. The CVHM texture also varies by model layer, whereas the SACFEM2013 apparently applied the same Kh distribution to each layer. The CVHM western and eastern Sacramento domains appear to have smaller coarse-grained areas than the SACFEM2013 higher hydraulic conductivity areas (Figures A12, C14 and A15 in Exhibits 4.7c, 4.7j, and 4.7k versus D4 in Appendix D). Figure 12E (Exhibit 4.7g) shows layer 9 with high percentages of coarse-grained deposits that have higher Kh values (Figure C14) in the western parts of the Redding (10) and northern western portion of the western Sacramento (11) province. Whereas Figure D4 of SACFEM2013 shows these same areas as having the lowest Kh values, suggesting finer-grained textures dominate.

The C2Vsim model divided the Sacramento Valley into seven subregions, as did the USGS-CVHM model. Like the USGS model, hydraulic conductivity varies with the three model layers for the Sacramento Valley. The spatial variability of the Kh and Kv values for the C2VSim model is greater than with the SACFEM2013 model (compare Figures 34 and 35 from Brush and others, 2013a in Exhibits 4.8a to 4.8f to Figures D4 of Appendix D). Table 5 of Brush and others, 2013a (Exhibit 4.2) shows the range of model parameters for the saturated groundwater portion of the C2VSim model. Kh values range from 2.2 ft/day to 100 ft/day, and Kv from 0.005 ft/day to 0.299 ft/day. The highest Kh value for the C2VSim model is less than for SACFEM2013 (100 ft/day vs 450 ft/day), while the lowest values are lower (0.005 ft/day vs <0.1 ft/day).

I recommend the Draft EIS/EIR discuss the uncertainty in aquifer hydraulic parameter estimations for the groundwater substitution transfer pumping simulations and the sensitivity of the model results to the uncertainty in the groundwater hydraulic parameters. I recommend the Draft EIS/EIR discuss how the uncertainty in hydraulic conductivity parameters influences: (1) estimates of potential stream depletion (Section 3.3), (2) evaluations of fisheries impacts (Section 3.7), (3) evaluations of vegetation and wildlife impacts (Section 3.8), and (4) the screening procedures that removed a number of the small streams from further environmental impact analysis (Table 3.7-3 and 3.8-3).

12. *Simulation Groundwater Storage Parameters* - The SACFEM2013 simulations assigned to the upper unconfined model layer 1 a uniform specific yield (Sy) value of 0.12 (dimensionless) (page D-14 in Appendix D; Exhibit 4.1). For the confined model layers 2 to 7 a uniform specific storage, Ss, value of 6.5 x 10^{-5} per foot (ft) was used (page D-14 of Appendix D; Exhibit 4.1). Both the CVHM and C2VSim simulations used a range of values of Sy and Ss that were more variable than SACFEM2013 (Exhibits 4.1, 4.8n, and 4.8o). The CVHM simulation used a range of Sy and Ss values, (CVHM Table C8, Exhibits 4.3). The CVHM simulation also used a range of Ss values for coarse-grain elastic and fine-grained elastic and inelastic deposits to simulating subsidence from groundwater pumping. The C2VSim simulations used a range of Sy values for model layer 1 and separate ranges of Ss values for layers 2 and 3 (C2VSim Table 5, Exhibits 4.2; Exhibits 4.8g to 4.8i). The C2VSim and CVHM models assigned a range of coefficients for elastic (Sce) and inelastic (Sci) deposits used in simulating subsidence (Exhibits 4.1, 4.8j to 4.8m). Note, the Ss values are multiplied by the aquifer thickness at each model node at to obtain the dimensionless value of storativity (S) for confined aquifers (S = Ss x thickness), which is similar to the dimensionless Sy parameter for an unconfined aquifer.

    I recommend the Draft EIS/EIR discuss the uncertainty in aquifer storage parameter estimations for the groundwater substitution transfer pumping simulations and the sensitivity of the model results to the uncertainty in the groundwater storage parameters. I recommend the Draft EIS/EIR discuss how

uncertainty in groundwater storage parameters influences: (1) estimates of potential stream depletion (Section 3.3), (2) evaluations of fisheries impacts (Section 3.7), (3) evaluations of vegetation and wildlife impacts (Section 3.8), and (4) the screening procedures that removed a number of the small streams from further environmental impact analysis (Table 3.7-3 and 3.8-3).

13. *Simulation River and Stream Parameters* - All three models simulated the interactions between the groundwater and streams or rivers. The rate and direction of movement of water between streams and shallow groundwater is governed by the vertical hydraulic conductivity of the streambed, Kvb, thickness of the streambed, m, the wetted perimeter of the stream, w, and the difference in elevation between groundwater table and stream. The hydraulic parameters of a streambed are combined into a term called conductance, C, which is calculated as the product of Kvb times the wetted perimeter divided by the streambed thickness (C = [Kvb x w]/m).

    The SACFEM2013 simulations assigned all eastern streambeds draining from the Sierra Nevada a Kvb value of 6.56 ft/day (2 meters/day), except the Bear River and Big Chico Creek, whose values were unstated (page D-7 of Appendix D). For all western streambeds draining the Coast Ranges, a higher value of Kvb at or above 16.4 ft/day (5 meters/day) was assigned. Figure 3.3-24 in the Draft EIS/EIR shows the SACFEM2013 groundwater boundary and the simulated rivers and streams. This map may not be showing all of the small streams evaluated in the simulation based on the streams listed in Tables 3.7-3 and 3.8-3 (also see general comment no. 2).

    The streambed Kvb values used in CVHM simulation are shown in Figure C26 (Exhibit 5.3). The values of Kvb for the Sacramento Valley varying from approximately 0.04 ft/day to 5.6 ft/day are shown in Figure C26. Results of the CVHM simulation of surface water-groundwater interactions, gains and losses, from 1961 to 1977 are compared to measured and simulated stream gauge values in Figures C19A and C19B (Exhibits 5.4a and 5.4b).

    The C2VSim simulations also used varying values for streambed Kvb ranging from 0 to 44 ft/day with a mean of 1.8 ft/day and lake bed Kvb of 0.67 ft/day (page 100, Brush and others, 2013a; Exhibit 5.1). Simulated streambed conductance values are shown in Figure 40 of Brush and others, 2013a (Exhibit 5.2).

    I recommend the Draft EIS/EIR discuss the uncertainty in streambed parameter estimations for the groundwater substitution transfer pumping simulations and the sensitivity of the model results to the uncertainty in the hydraulic characteristics of the streambeds. I recommend the Draft EIS/EIR discuss how uncertainty in the hydraulic characteristics of the streambeds influences: (1) estimates of potential stream depletion (Section 3.3), (2) evaluations of fisheries impacts (Section 3.7), (3) evaluations of vegetation and wildlife impacts (Section 3.8), and (4) the screening procedures that removed a number of the small streams from further environmental impact analysis (Table 3.7-3 and 3.8-3).

14. *Groundwater Flow Between Sub-regions* - Of the three previously discussed regional groundwater models for the Sacramento Valley, only the reports for the C2VSim simulation provided information on the volume of groundwater that flows laterally among groundwater subregions. The C2VSim simulation results show that groundwater flow between subregions has changed significantly in some areas (Figures 81A to 81C of Brush and others, 2013a and Figure 39 of Brush and others, 2013b; Exhibits 6.1a to 6.1c and 6.2). The SACFEM2013 simulations results presented in the Draft EIS/EIR don't provide information on the exchange between subregion areas used in simulations by the USGS (Faunt, ed.,

2009) and DWR (Brush and others, 2013a and 2013b). Therefore, the flow of groundwater between the subregions and/or counties of the 10-year project's groundwater substitution transfer sellers wasn't evaluated for potential impacts on neighboring areas. The loss or gain of groundwater from neighboring subregions should be evaluated in the Draft EIS/EIR.

Accounting for subsurface flow among subregions is an important part of the water balance because it is measures of the amount of impact that groundwater pumping in one subregion has on it's neighboring subregions. The subsurface inter-basin movement of groundwater is an important element in the analysis of the environmental impacts from the 10-year groundwater substitution transfer projects because the groundwater substitution transfer pumping by sellers in one region can have a significant impact on the groundwater levels, storage and stream depletion in adjacent regions.

The C2VSim simulations calculated the volume of groundwater that flowed between the subregions and presented the results for three decades, 1922-1929, 1960-1969, and 2000-2009, and for the total simulation period, 1922-2009. Tables 10 through 13 (Brush and others, 2014a; Exhibits 6.3a to d) provide the sum of inter-region groundwater flow for each model subregion, but not the individual values of flow among adjoining subregions. Figures 81 and 39 (Exhibits 6.1a to 6.1c and 6.2) give the simulated annual volume of inter-region flow for the three decades and from 1922 to 2009. An estimate of a portion of the long-term changes in groundwater storage in each subregion can be made by comparing the change in annual volume and flow direction between sub-regions.

For example, in the 1922 to 1929 simulation period subregion 9 (Sacramento-San Joaquin Delta received 81,000 AFY of groundwater flow from adjoining subregions 6, 8, 10 and 11 (Exhibit 6.1a). By 1969 the simulation shows that subregion 9 was still receiving a small volume, 2,000 AFY, of groundwater flow from subregion 6, but losing approximately 56,000 AFY to subregions 8, 10, and 11 (Exhibit 6.1b). A change in groundwater storage from 1929 to 1969 in the Delta of 135,000 AFY; from a plus 81,000 AFY to a minus 54,000 AFY. For 2002-2009, the simulation shows that the Delta still receiving a small volume, 4,000 AFY, of groundwater flow from subregion 6, but now losing 137,000 AFY to subregions 8, 10 and 11 (Exhibit 6.1c). A loss in storage in the Delta of 214,000 AFY from 1929. The 2000-2009 simulation period shows that subregion 8 is receiving a large portion of the groundwater flow out of the Delta, 112,000 AFY, a reversal in groundwater flow direction and a cumulative annual loss to the Delta from 1922-1929 of 147,000 AFY. Subregion 8 in turn loses 17,000 AFY of groundwater flow to subregion 7 in 2000-2009, and receives 123,000 AFY from subregion 11 (Exhibit 6.1c). A reversal of 1922-1929 when subregion 8 received 1,000 AFY from subregions 7 and gave 1,000 AFY to subregion 11.

The 10-year transfer project proposes under the groundwater substitution to pump up to approximately 75,000 AFY from subregions 7 and 8, Table 2-5. This additional pumping will likely cause additional groundwater to flow from the subregion 9, the Delta, and subregion 11 into subregion 8, and eventually to subregion 7. Similar shifts in direction and annual volumes of groundwater flow have occurred with the other Central Valley subregions. The changes direction and volume of flow between the Delta and surrounding subregions appear to be the largest shift in groundwater flow for in Sacramento Valley area.

I recommend the Draft EIS/EIR be revised to evaluate the subsurface flows between subregions in Sacramento Valley due to the proposed groundwater substitution transfer pumping. I recommend the Draft EIS/EIR be revised to include groundwater model simulations that account for the rates, volumes, times, and changes in direction of groundwater flow between the seller pumping areas and the surrounding non-participating regions. I recommend the Draft

EIS/EIR also analysis the short- and long-term impacts from the changes in subregional groundwater flow caused by the 10-year transfer project.

Mitigation Measure WS-1

15. The purpose of mitigation measure WS-1 as stated in Draft EIS/EIR Section 3.1.4.1 is to mitigate potential impacts to CVP and SWP water supplies from stream depletion caused by groundwater substitution transfer pumping. The stream depletion factor (BoR-SDF) is imposed by the BoR and DWR because they *will not move transfer water if doing so violates the no injury rule* (page 3.1-21). The no injury rule is discussed in Section 1.3.2.3 and cites CA WC Sections 1725, 1736 and 1706. The language from WC 1736 that also requires transfers to not result in unreasonable effects to fish, wildlife, or other instream beneficial uses is discussed in the subsequent Section 1.3.2.4.

    Draft EIS/EIR Sections 3.1.2.4.1 (page 3.1-15) and 3.1.6.1 (page 3.1-21) discuss the impacts from groundwater substitution transfers on surface water. On page 3.1-16 the Draft EIS/EIR states that groundwater recharge, presumably greater because of groundwater substitution pumping, occurring during higher flows would decrease flow in surface waterways. During periods of high flow, the decrease in surface flow won't affect water supplies or the ability to meet flow or quality standards. The document also states that if groundwater recharge occurs during dry periods, presumably occurring when groundwater substitution transfers are needed, groundwater recharge would decrease flows and affect BoR and DWR operations. BoR and DWR would then need to either decrease Delta exports or release additional flows from surface storage to meet the required standards. These statements are followed by seemly conflicting statements that:

    > *Transfers would not affect whether the water flow and quality standards are met, however, the actions taken by Reclamation and DWR to meet these standards because of instream flow reductions due to the groundwater recharge could affect CVP and SWP water supplies.* (page 3.1-16)
    >
    > *Increased releases from storage would vacate storage that could be filled during wet periods, but would affect water supplies in subsequent years if the storage is not refilled.* (page 3.1-17)

    The potential for the reduction in surface water storage to eventually cause reductions in streamflow and water quality isn't clearly addressed in the Draft EIS/EIR.

    > *Overall, the increased supplies delivered from water transfers would be greater than the decrease in supply because of streamflow depletion; however, the impacts from streamflow depletion may affect water users that are not parties to water transfers. On average, the losses due to groundwater and surface water interaction would result in approximately 15,800 AF of water annually compared to the No Action/No Project Alternative, or approximately a loss of 0.3 percent of the supply.* (page 3.1-18)
    >
    > *In a period of multiple dry years (such as 1987-1992), the streamflow depletion causes a 2.8 percent reduction in CVP and SWP supplies, or 71,200 AF.* (page 3.1-18)
    >
    > *To reduce these effects, Mitigation Measure WS-1 includes a streamflow depletion factor to be incorporated into transfers to account for the potential water supply impacts to the CVP and SWP. Mitigation Measure WS-1 would reduce the impacts to less than significant.* (page 3.1-18)

    Additional information on the requirements of WS-1 appears to be contained in the October 2013 joint DWR and BoR document titled *Draft Technical Information for Preparing Water Transfer Proposals* (DTIPWTP) because the discussion in that document's Section 3.4.3

on estimating the effects of transfer operations on streamflow says that a default BoR-SDF of 12 percent will be applied *"unless available monitoring data analyzed by Project Agencies supports the need for the development of a transfer proposal site-specific SDF"* (page 33). The document also states that:

> *Although real time streamflow depletion due to groundwater substitution pumping for water transfers cannot be directly measured, impacts on streamflow due to groundwater pumping can be modeled. Project Agencies have applied the results from prior modeling efforts to evaluate potential groundwater transfers in the Sacramento Valley to establish an estimated average streamflow depletion factor (SDF) for transfers requiring the use of Project Facilities.*

I have several comments on this analysis of stream depletion impacts and mitigation measure WS-1:

a. Sections 2.3.2.2 and 2.3.2.3 discuss potential groundwater substitution and crop idling transfers and the limitations on the timing of the transfers. Transfers typically occur from July to September, but could also occur from April to June if conditions in the Delta allow for transfer. Surface water to be used in groundwater substitution and crop idling transfers would be stored during April to June if the condition of the Delta is unacceptable for transfer.

   My understanding of the BoR-SDF in mitigation measure WS-1 is that at the same time transfer surface waters are flowing towards the Delta, a portion of that water is assigned to the waterway to "offset" or compensate for stream depletion caused by groundwater substitution pumping. The Draft EIS/EIR doesn't seem to address the issue of how to compensate for groundwater substitution pumping impacts occurring before or after the transfer water flows to the Delta, the long-term losses caused by the pumping in subsequent years, and cumulative impacts from multiple years of pumping by all sellers. Yet the Draft EIS/EIR acknowledges that stream depletion is cumulative and a cumulative increase in depletion can be significantly greater than with a single event (Section 4.3.1.2 in Appendix B). The SACFEM2013 simulation shows that stream depletion will continue for a number of years after the groundwater substitution pumping event (Figures B-4, B-5 and B-6 in Draft EIS/EIR Appendix B). Mitigation measure WS-1 doesn't appear to fully address how mitigation will occur for stream depletion impacts from groundwater substitution pumping during entire duration of the impact.

   I recommend mitigation measure WS-1 be revised to clearly address how reductions in stream flows caused by groundwater substitution transfer pumping will be mitigated to less than significant for all of the times when stream depletion is occurring, including the time before and after the water is physically transferred; long-term impacts; and cumulative impacts from multiple sellers over multiple years of participating in groundwater substitution transfers.

b. Although mitigation measure WS-1 doesn't state that its implementation is linked to the October 2013 DTIPWTP (that linkage is part of mitigation measure GW-1), the DTIPWTP discusses the use of the BoR-SDF in the methodology for determining the amount of water available for groundwater substitution transfer, and the effects of the groundwater substitution pumping on streamflow in Section 3.4 (page 31). Item 5 on page 31 gives the formula for using four steps in determining the amount of transferable water, one of which is subtraction of the estimated streamflow reduction. Section 3.4.3 states on page 33 of the DTIPWTP that:

> *Although real time streamflow depletion due to groundwater substitution pumping for water transfers cannot be directly measured, impacts on streamflow due to groundwater pumping can be modeled. Project Agencies have applied the results from prior modeling efforts to evaluate potential groundwater transfers in the Sacramento Valley to establish an estimated average streamflow depletion factor (SDF) for transfers requiring the use of Project Facilities.*
>
> *Project Agencies will apply a 12 percent SDF for each project meeting the criteria contained in this chapter unless available monitoring data analyzed by Project Agencies supports the need for the development of a transfer proposal site-specific SDF.*
>
> *Project Agencies are developing tools to more accurately evaluate the impacts of groundwater substitution transfers on streamflow. These tools may be implemented in the near future and may include a site-specific analysis that could be applied to each transfer proposal.*

Mitigation measure WS-1 states on page 3.1-21 that:

> *The exact percentage of the streamflow depletion factor will be assessed and determined on a regular basis by Reclamation and DWR, in consultation with buyers and sellers, based on the best technical information available at that time. The percentage will be determined based on hydrologic conditions, groundwater and surface water modeling, monitoring information, and past transfer data.*

From these statements it appears that: (1) the BoR, DWR and other Project Agencies have previously analyzed the amount of stream depletion caused by past groundwater substitution transfers, and (2) the default of 12% BoR-SDF may not be applied to groundwater substitution during the 10 years of transfers because transfer-specific studies will be needed. The Draft EIS/EIR doesn't provide information or cite references on the previous modeling and/or monitoring efforts to determine the correct stream depletion factor. It also doesn't provide specific information on the method(s) and review process to be used in implementing mitigation measure WS-1, or what additional assessments are needed to determine the "exact percentage" for the BoR-SDF. Mitigation measure WS-1 appears to require that the assessment, the calculation methodology, and determination of the correct BoR-SDF be done at a future time. The Draft EIS/EIR doesn't state whether other regulatory agencies and/or the public will have an opportunity in the future to review and comment on the methodology and determination of the "exact percentage" of the BoR-SDF for each groundwater substitution transfer seller. The Draft EIS/EIR also doesn't state whether other regulatory agencies and/or public comments will be considered by BoR and DWR in determining the BoR-SDF percentage.

The statement that real time stream depletion can't be directly measured contradicts other statements in the Draft EIS/EIR, requirements of mitigation measure GW-1, and the scientific literature. For example: Section 3.5 of the DTIPWTP states that one of the objectives of the monitoring plan is to:

> *Determine the extent of surface water-groundwater interaction in the areas where groundwater is pumped for the transfer.* (page 34)

This objective is in the project's monitoring program therefore it appears to indicate that some method is available for monitoring the surface water-groundwater interactions, not just the pre-pumping model simulations. The Fisheries (3.7) and Vegetation Wildlife (3.8) sections of the Draft EIS/EIR appear to state that flow reductions in surface waterways caused by groundwater substitution pumping will be monitored. Paragraphs similar to the ones given below state that monitoring wells are part of the mitigation measure for surface waters:

> *In addition, flow reductions as the result of groundwater declines would be observed at monitoring wells in the region and adverse effects on riparian vegetation would be mitigated by implementation of Mitigation Measure GW-1 (See Section 3.3, Groundwater Resources), because it requires monitoring of wells and implementing a mitigation plan if the seller's monitoring efforts indicate that the operation of the wells for groundwater substitution pumping are causing substantial adverse impacts. The mitigation plan would include curtailment of pumping until natural recharge corrects the environmental impact. Therefore, the impacts to fisheries resources would be less than significant in these streams.* (pages 3.7-26 and 3.7-56)
>
> *In addition, the Proposed Action has the potential to cause flow reductions of greater than ten percent on other small creeks where no data are available on existing streamflows to be able to determine this. The impacts of groundwater substitution on flows in small streams and associated water ways would be mitigated by implementation of Mitigation Measure GW-1 (see Section 3.3, Groundwater Resources) because it requires monitoring of wells and implementing a mitigation plan if the seller's monitoring efforts indicate that the operation of the wells for groundwater substitution pumping are causing substantial adverse impacts. The mitigation plan would include curtailment of pumping until natural recharge corrects the environmental impact. Implementation of these measures would reduce significant effects on vegetation and wildlife resources associated with streams to less than significant.* (pages 3.8-51, 3.8-58 and 3.8-68)

All of these statements seem to contradict the statement in mitigation measure WS-1 that stream depletion can't be measured in real time. Although the Draft EIS/EIR doesn't provide the technical method(s) for determining surface water flow using monitoring in groundwater wells, it's reliance on mitigation measure GW-1 to ensure that streamflows are adequate implies that a method is available. Because WS-1 and GW-1 both have one of the same objectives, to mitigation streamflow losses due to groundwater substitution pumping, the mitigation measure are linked. Thus, the real time monitoring of groundwater intended to mitigate streamflow losses under GW-1 might also facilitate real time monitoring of streamflow needed for WS-1. I'll provide in Part 2 of this letter some additional discussion and references to scientific literature on studies and methods for measuring stream seepage and stream depletion caused by groundwater pumping.

I recommend the Draft EIS/EIR be revised to clearly discuss the methods available for determining the value of the BoR-SDF for each groundwater substitution transfer well. I recommend the Draft EIS/EIR be revised to discuss the procedure for Project Agency review and approval, along with process for review and comment by other public agencies and the public. I recommend the Draft EIS/EIR be revised to discuss the methods and results of prior BoR-SDF determinations. I recommend the Draft EIS/EIR be revised to define the data needed to

determine the "exact percentage" of stream depletion from groundwater substitution pumping during the 10-year transfer project, the technical method(s) that will be used to calculate the amount of stream depletion and the BoR-SDF, and the method(s) for monitoring surface water flow losses and verifying the effectiveness of the BoR-SDF and mitigation measure WS-1.

c. Section 3.4.1 of the DTIPWTP discusses calculation of baseline groundwater pumping for groundwater substitution transfers. Baseline groundwater pumping and stream depletion reduction are part of the four-step process for determining the amount of transferable water (page 31). Water transfer sellers wanting to use groundwater substitution pumping are requested to submit information to:

> *Identify all wells that discharge to the contiguous surface water delivery system within which a well is proposed for use in the transfer program,* and
>
> *The amount of groundwater pumped monthly during 2013 for each well that discharges to the contiguous surface water delivery system.*

Section 3.4.2 discusses measuring groundwater pumping provided for groundwater substitution transfers and states that:

> *Sellers should provide pumping records from all wells that discharge to a contiguous surface water delivery system used in groundwater substitution transfers.* (page 32)

The requirement that the groundwater transfer pumping baseline and metering of transfer pumping be conditioned on the water being discharged to the *contiguous surface water delivery system* suggests that if the groundwater substitution pumping discharges to a non-contiguous surface water or directly to a field that the establishment of a pre-transfer pumping baseline and transfer metering aren't required. Is that the case? If it is the case, then how is the amount of transferable water determined whenever the groundwater substitution transfer pumping doesn't discharge to a *contiguous surface water deliver system*? If the pre-transfer baseline pumping is removed from the calculation, does that increase or decrease the amount of transferable water and how does that change the BoR-SDF requirement? Is metering required for groundwater substitution transfer wells that don't discharge to a *contiguous surface streams water delivery system*? If not, how will measurement of transferred water and the required amount of the BoR-SDF be verified? All of these factors are relevant because they are linked to mitigation measure WS-1 through the DTIPWTP four-step process to determine the amount of transferrable water. The amount of transferrable water incorporates the BoR-SDF to prevent injury and reduce groundwater substitution pumping stream depletion impacts to less than significant.

I recommend the Draft EIS/EIR be revised to provide a discussion of how the baseline for pre-transfer groundwater pumping will be determined and how metering of all groundwater substitution transfer pumping for wells will be done regardless of whether the well discharges to a contiguous surface water delivery system. I recommend the Draft EIS/EIR be revised to discuss how the BoR-SDF will be determined, monitored, and it's effectiveness verified for all groundwater substitution transfer wells regardless of whether the well discharges to a contiguous surface water delivery system.

Mitigation Measure GW-1

16. The Draft EIS/EIR has only two mitigation measures that apply to the groundwater substitution transfers, WS-1 and GW-1. GW-1 is the principle mitigation measure for the 10-year transfer project's Draft EIS/EIR and is discussed in Section 3.3.4.1. The requirements contained in the October 2013 joint DWR and BoR *Draft Technical Information for Preparing Water Transfer Proposals* (DTIPWTP) and its 2014 Addendum are included in GW-1 by reference. The monitoring and mitigation measures of GW-1 are generally statements of objectives and requirements for development in the future monitoring and mitigation plans that are approved by BoR and perhaps DWR. GW-1 doesn't appear to provide any future opportunity for review and comment by parties that may be impacted by the groundwater substitution transfers such as the non-participating well owners, the public, or other regulatory agencies. GW-1 has statements such as:

    > *The monitoring program will incorporate a sufficient number of monitoring wells to accurately characterize groundwater levels and response in the area before, during, and after transfer pumping takes place.* (page 3.3-88)
    >
    > *The monitoring program will include a plan to coordinate the collection and organization of monitoring data, and communication with the well operators and other decision makers.* (page 3.3-89)
    >
    > *Potential sellers will also be required to complete and implement a mitigation plan.* (page 3.3-89)
    >
    > *To ensure that mitigation plans will be feasible, effective, and tailored to local conditions, the plan must include the following elements:* (page 3.3-90 and 3.3-91)
    >
    > - *A procedure for the seller to receive reports of purported environmental or effects to non-transferring parties;*
    > - *A procedure for investigating any reported effect;*
    > - *Development of mitigation options, in cooperation with the affected parties, for legitimate significant effects*
    > - *Assurances that adequate financial resources are available to cover reasonably anticipated mitigation needs.*
    >
    > *Reclamation will verify that sellers adopt and implement these measures to minimize the potential for adverse effects related to groundwater extraction.* (page 3.3-91)

    GW-1 does have some specifics on requirements for the frequency of groundwater level monitoring, such as weekly monitoring during the transfer period (page 3.3-89). Requirements for the frequency of reporting are less specific. Summary tables to BoR during and after transfer-related groundwater pumping, and a summary report sometime after the post-project reporting period. The project reporting period extends through March of the year following the transfer (page 3.3-90). The requirement for only a single year of groundwater monitoring appears to be insufficient given the duration of the simulated pumping impacts (see Figure B-5 in Appendix B). Other reporting requirements such as groundwater elevation contour maps are given as "should be included" rather than "shall be included" (page 3.3-90).

    The BoR should already have monitoring and mitigation plans and evaluation reports based on the requirements of the DTIPWTP for past groundwater substitution transfers, which likely were undertaken by some of the same sellers as the proposed 10-year transfer project. The Draft EIS/EIR should provide these existing BoR approved monitoring programs and mitigation plans as examples of what level of technical specificity is required to meet the objectives of GW-1 that include: *(1) mitigate adverse environmental effects that occur; (2) minimize potential effects to other legal users of water; (3) provide a process for review and response to reported effects; and (4) assure that a local mitigation strategy is in place prior to the groundwater transfer* (page 3.3-91). In addition, examples of periodic reporting tables and final evaluation reports should be provided to demonstrate the effectiveness of the GW-1 process at preventing or mitigating impacts from the groundwater substitution transfer pumping. Other deficiencies in GW-1 have been discussed above in my comments nos. 1, 2, 3, 5, 6 and 15, and below in comment no. 18.

I recommend the Draft EIS/EIR be revised to include specifics on additional requirements that must be part of mitigation measure GW-1 including: (1) required distances from wells and surface water features, and aquifer zones for groundwater elevation monitoring; (2) the duration of the required post-transfer monitoring that accounts for the effects of the 10 years of pumping; (3) specifics requirements on scale and detail for maps, figures and tables needed to document groundwater substitution pumping impacts; and (4) specific threshold for changes in groundwater elevation, groundwater quality and subsidence that will be considered significant. I recommend the Draft EIR/EIS be revised to provide existing BoR approved monitoring and mitigation plans and reports for past groundwater substitution transfers as examples of the types of technical information necessary to ensure no injury with less than significant impacts and appropriate mitigations. I recommend the Draft EIS/EIR be revised to provide specifics on how the public will be able to participate in the BoR and DWR approval and revision process for the 10-year transfer project monitoring and mitigation plans. I also recommend the Draft EIS/EIR revise GW-1 to include the issues discussed elsewhere in my comments nos. 1, 2, 3, 5, 6, 15 and 18.

Water Quality

17. The Draft EIS/EIR discusses water quality in Section 3.2, but focuses on potential impacts to surface waters. Discussions of impacts from groundwater substitution transfer pumping on groundwater quality are given in Section 3.3 (pages 3.3-33 to 3.3-35). The Draft EIS/EIR discusses the potential for impacts to groundwater quality from migration of contaminants as a result of groundwater substitution pumping, but provides only a general description of the current condition of groundwater quality. Section 3.3 gives the following statements on water quality:

> *Groundwater Quality: Changes in groundwater levels and the potential change in groundwater flow directions could cause a change in groundwater quality through a number of mechanisms. One mechanism is the potential mobilization of areas of poorer quality water, drawn down from shallow zones, or drawn up into previously unaffected areas. Changes in groundwater gradients and flow directions could also cause (and speed) the lateral migration of poorer quality water.* (pages 3.3-59 and 3.3-60)
>
> *Degradation in groundwater quality such that it would exceed regulatory standards or would substantially impair reasonably anticipated beneficial uses of groundwater; or* (page 3.3-61)
>
> *Additional pumping is not expected to be in locations or at rates that would cause substantial long-term changes in groundwater levels that would cause changes to groundwater quality. Consequently, changes to groundwater quality due to increased pumping would be less than significant in the Redding Area Groundwater Basin.* (page 3.3-66)

> *Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Groundwater extraction under the Proposed Action would be limited to short-term withdrawals during the irrigation season. Consequently, effects from the migration of reduced groundwater quality would be less than significant. (*page 3.3-83*)*
>
> *Groundwater extracted could be of reduced quality relative to the surface water supply deliveries the seller districts normally receive; however, groundwater quality in the area is normally adequate for agricultural purposes. Distribution of groundwater for municipal supply is subject to groundwater quality monitoring and quality limits prior to distribution to customers. Therefore, potential impacts to the distribution of groundwater would be minimal and this impact would be less than significant.* (page 3.3-84)

The Draft EIS/EIR notes that several groundwater quality programs are active in the seller regions (pages 3.3-6 to 3.3-10). No maps are provided that show the baseline groundwater quality and known areas of poor or contaminated groundwater. Groundwater quality information on the Sacramento Valley area is available from existing reports by the USGS (1984, 2008b, 2010, and 2011) and Northern California Water Association (NCWA, 2014c). The Draft EIS/EIR doesn't compare the known groundwater quality problem areas with the SACFEM2013 simulated drawdowns to demonstrate that the proposed projects won't draw in or expand the areas of known poor water quality. The Draft EIS/EIR analysis doesn't appear to consider the impacts to the quality of water from private wells. Pumping done as part of the groundwater substitution transfer may cause water quality impacts from geochemical changes resulting from a lowering the water table below historic elevations, which exposes aquifer material to different oxidation/reduction potentials and can alter the mixing ratio of different quality aquifer zones being pumped. Changes in groundwater level can also alter the direction and/or rate of movement of contaminated groundwater plumes both horizontally and vertically, which may expose non-participating wells to contaminants they would not otherwise encounter.

As noted above in my general comment no. 7, the DWR well depth summary maps for the northern Sacramento Valley show that there are potentially thousands of private well owners in and adjacent to the proposed project areas of the groundwater substitution drawdown. Exhibit 2.1 has a composite map of DWR's northern Sacramento Valley well depth summary maps (DWR, 2014a) for the shallow aquifer zone, wells less than 150 feet deep and the areas of groundwater decline from 2004 to 2014 (DWR, 2014b). Exhibit 7.1 has a table that summarizes the range of the number of shallow wells by county that lie within the areas of groundwater decline from 2004 to 2014. In my general comment no. 5, I discussed the concept of capture zones for wells and the need for groundwater modeling using particle tracking to identify the areas where a well receives recharge. Particle tracking to define a well capture zone(s) can also be used to determine if known zones or areas of poor or contaminated water will migrate as a result of the groundwater substitution transfer pumping. Particle tracking can also identify private and municipal wells that lie within the capture zone of a groundwater substitution transfer well and might experience a reduction in water quality from the transfer pumping. Particle tracking can identify locations where mitigation monitoring of groundwater quality should be conducted to quantify changes in groundwater quality.

Even though there are already a number of shallow wells impacted by historic groundwater level declines, the Draft EIS/EIR reaches the conclusion that the groundwater substitution transfer pumping will not cause injury or a significant impact to groundwater quality. This conclusion is reached in part because the assumed beneficial use of groundwater substitution pumped water is agricultural, or urban, where the quality of water delivered is monitored by an urban water agency. Only these two beneficial uses are assumed even though Table 3.2-2 lists numerous other uses for waters in the seller service areas. The Draft EIS/EIR doesn't provide sufficient information on existing water quality conditions in the Sacramento Valley to allow for evaluation of potential geochemical changes that groundwater substitution pumping might cause. The Draft EIS/EIR sets a standard of significance in degradation of groundwater quality that requires contaminants exceed regulatory standards or impair reasonably anticipated beneficial uses (page 3.3-61). This standard of significance ignores the regulatory requirements of the Water Quality Control Basin Plans (Basin Plans) (http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/index.shtml). The Draft EIS/EIR only briefly discusses the role of the Basin Plans in maintaining water quality (page 3.2-7). In addition this water quality threshold of significance likely violates the State Water Resources Control Board Resolution No. 68-16, titled *Statement of Policy with Respect to Maintaining High Quality of Waters in California*, that states:

> *"Whenever the existing quality of water is better than the quality established in policies as of the date on which such policies became effective, such existing high quality will be maintained until it has been demonstrated to the state that any change will be consistent with the maximum benefit to the people of the state, will not unreasonably affect present and anticipated beneficial use of such water and will not result in water quality less than that prescribed in the policies."*
>
> *"The nondegradation policy of the State Board (Resolution No. 68-16) applies to surface and groundwaters that are currently better quality than the quality established in 'adopted policies.' In terms of water quality objectives, the basin plans are the source of adopted policies."*

I recommend the Draft EIS/EIR be revised to document the known condition of the groundwater quality in the Sacramento Valley and Redding Basin and include available maps. I recommend that this assessment evaluate the potential impacts from migration of known areas of poor groundwater quality that could be further impaired or spread as a result of the groundwater substitution transfer pumping. I recommend a groundwater quality mitigation measure be provided for evaluation the existing water quality in wells (assuming owner cooperation) within and adjacent to known areas of poor groundwater quality that lie within and adjacent to the simulated groundwater transfer drawdown areas, especially those that lie within the capture zone. I recommend the groundwater quality mitigation measure include: (1) procedures for sampling wells, (2) methods of water quality analysis, (3) a QA/QC program, (4) standards and threshold for water quality impairment consistent with public health requirements and Basin Plan beneficial uses and SWRCB Resolution No. 68-16, (5) provisions for independent oversight and review by regulatory agencies and affected well owners, and (6) specific reporting and notification requirements that keep the owners of non-participating wells, the public, and regulatory agencies informed. I recommend the groundwater quality mitigation measure include provisions for modification and/or treatment of non-participating wells should the quality of water delivered be significantly altered by groundwater substitution transfers. I recommend the groundwater quality mitigation measure be in effect during the 10-year period of transfer pumping and the following recovery period until groundwater flows return to the pre-project condition. I recommend the Draft EIS/EIR also

require a funding mechanism for implementing the groundwater quality mitigation measures for the entire 10-year duration of the groundwater substitution transfers and the recovery period. I recommend the costs of the groundwater quality mitigation monitoring be the responsibility of the project proponents, not the non-participating wells owners or the public. These costs should include reimbursement of any costs incurred by regulatory agency oversight and costs incurred by non-participating well owners.

Subsidence

18. The impacts of subsidence due to groundwater substitution transfer pumping are discussed in Section 3.3. Section 3.3.1.3.2 discusses groundwater-related land subsidence and notes that Global Positioning System (GPS) surveying is conducted by DWR every three years at 339 elevation survey monuments throughout the northern Sacramento Valley (page 3.3-28). In addition, eleven extensometers, as shown in Figure 3.3-11, monitor land subsidence. Figure 3.3-11 provides graphs of the subsidence for five of the eleven extensometers; no information is provided on the results on the GPS surveys. Mitigation measure GW-1 also incorporates by reference the October 2013 DTIPWRP and its 2014 Addendum. The DTIPWRP doesn't add any additional monitoring or mitigation requirements for subsidence, stating that areas that are susceptible to land subsidence may require land surface elevation surveys, and that the Project Agencies will work with the water transfer proponent to develop a mutually agreed upon subsidence monitoring program (pages 34 and 37). Apparently the Draft EIS/EIR expects that the mutually agreed upon subsidence monitoring programs will be a future mitigation measure. The Draft EIS/EIR doesn't discuss how other regulatory agencies or the public will participate in the reviewing and commenting on any future subsidence mitigation measure.

    The Draft EIS/EIR relies on local GMPs and county ordinances to prevent impacts from subsidence, but doesn't discuss any specific monitoring or mitigation measures for each proposed groundwater substitution transfer pumping area (page 3.3-7). The Draft EIS/EIR acknowledges that subsidence has occurred in the past in portions of the Sacramento Valley in Yolo County (page 3.3-29), and that the Redding groundwater basin has never been monitored (page 3.3-17). Yet only a qualitative assessment of potential project impacts was done by comparing SACFEM2013 simulated groundwater drawdowns with areas of existing subsidence and by comparing estimates of pre-consolidated heads/historic low heads (page 3.3-61).

    The Draft EIS/EIR relies on the mitigation measure GW-1 to prevent and remedy any significant impacts from subsidence. The requirements in mitigation measure GW-1 for subsidence impacts specify that the BoR will determine, apparently in the future and only when mutually agreed upon, the "strategic" monitoring locations throughout the transfer area where land surface elevations will be measured at the beginning and end of each transfer year (page 3.3-89). When the land surface elevation survey indicates an elevation decrease in an area, more subsidence monitoring will be required, which could include: (1) extensometer monitoring, (2) continuous GPS monitoring, or (3) extensive land-elevation benchmark surveys conducted by a licensed surveyor. More extensive monitoring will be required for areas of documented historic or higher susceptibility to land subsidence (page 3.3-89). The Draft EIS/EIR concludes that with these subsidence monitoring mitigation measures of GW-1, impacts will be reduced to less than significant (page 3.3-66).

    Exhibits 8.1a to 8.1c provides composite maps using as a base DWR's *Spring 2004 to 2014 Change in Groundwater Elevations* (DWR, 2014b) for the shallow (less than 200 feet bgs), intermediate (200 to 600 feet bgs) and the deep (greater than 600 feet bgs) aquifer zones in the northern Sacramento Valley. A map of the natural gas pipelines in the Sacramento Valley (Exhibit 8.6) has been scaled and combined with Exhibits 8.1a to 8.1c. Exhibit 8.2 depicts on DWR's (2014b) intermediate zone change in groundwater elevation map, the locations of extensometers and the GPS subsidence grid (from Figure 6 in DWR, 2008; Exhibit 8.4), and the known subsidence area southeast of Williams and into Yolo County (from Draft EIS/EIR Figure 3.3-11)).

The subsidence area in Yolo County isn't fully shown on the DWR's 2014 groundwater elevation change maps, but is shown in the composite maps (Exhibits 8.1a to 8.1c). These exhibits and Exhibit 8.2 show that the western line of extensometers lies along the eastern edge of the intermediate zone of greatest groundwater elevation change, and aligns with the central axis of the mapped changes in groundwater elevation in deeper aquifer zone. The extensometers don't appear to lie within the area of known subsidence southeast of Williams and into Yolo County (Figure 3.3-11). The GPS subsidence grid network does extend across eastern portion of the known subsidence area southeast of Williams and into Yolo County depicted in Figure 3.3-11 and the groundwater elevation change in the intermediate aquifer zone southwest of Orland (Exhibit 8.2).

Although there are several areas in the Sacramento Valley of known decrease in groundwater elevations, known areas of subsidence (Faunt, ed., 2009; Exhibit 8.3), and apparently a GPS network with repeated elevation measurements (Exhibit 8.4), the Draft EIS/EIR doesn't provide any specific information on the "strategic" locations where groundwater substitution pumping done under the 10-year transfer project will require additional subsidence monitoring. The historic subsidence data along with the GPS grid elevation data, historic groundwater elevation change data and the future areas of drawdown from the 10 years of groundwater substitution pumping shown in Figures 3.3-26 to 3.3-31 should be sufficient information to develop the initial "strategic" locations for monitoring potential subsidence. The Draft EIS/EIR should be able to provide the specific thresholds of subsidence that will trigger the need for additional extensometer monitoring, continuous GPS monitoring, or extensive land-elevation benchmark surveys by a licensed surveyor as required by GW-1. The Draft EIS/EIR should also specify in mitigation measure GW-1, the frequency and methods of collecting and reporting subsidence measurements, and discuss how the non-participating landowners and the public can obtain this information in a timely manner. In addition, the Draft EIS/EIR should provide a discussion of the thresholds that will trigger implementation of the reimbursement mitigation measure required by GW-1 for repair or modifications to infrastructure damaged by non-reversible subsidence, and the procedures for seeking monetary recovery from subsidence damage (page 3.3-90). The revised Draft EIS/EIR should review the information provided by Galloway and others (2008), and the Pipeline Research Council International (2009) regarding land subsidence hazards.

An objective of the mitigation measure GW-1 is to mitigate adverse environmental effects from groundwater substitution transfer pumping (page 3.3-88). As part of the preliminary assessment of potential environmental impacts from subsidence due to groundwater substitution pumping, a review and determination of the critical structures that might be impacts is recommended. There are a number of critical structures in the Sacramento Valley that may be susceptible to settlement and lateral movement. These include natural gas pipelines, gas transfer and storage facilities, gas wells, railroads, bridges, water and sewer pipelines, water wells, canals, levees, other industrial facilities. Exhibits 8.5 to 8.11 provide several maps of gas pipeline, and gas and oil related facilities obtained from the web sites of the CA Energy Commission (CEC) and the CA Department of Conservation's Division of Oil, Gas and Geothermal Resources (DOGGR). In addition, composite maps (Exhibits 8.1a to 8.1c) are provided that show the locations of the natural gas pipelines (Exhibit 8.6) with the DWR 2004 to 2014 change in groundwater elevation maps (DWR, 2014b). Additional maps of railroads, bridges, canals, levees, water and sewer pipelines and important industrial facilities should be sought and the location of those structures compared to the potential areas of subsidence from groundwater substitution transfer pumping. Specific "strategic" subsidence monitoring locations should be given in mitigation measure GW-1 based on analysis of the susceptible infrastructure locations and the potential subsidence areas. The local, state and federal agencies that regulate these critical structures and pipelines as well as the facility owners should be contacted for information on the limitations on the amount of movement and subsidence the infrastructures can withstand. The limitations on movement and subsidence should be incorporated into any triggers or thresholds for additional monitoring and implementing mitigations needed to reduce subsidence impacts to less than significant and cause no injury.

I recommend that: (1) the Draft EIS/EIR be revised to provide information on initial "strategic" locations and types of subsidence monitoring that are necessary based on the existing conditions and the proposed groundwater substitution pumping areas; (2) the Draft EIS/EIR and mitigation measure GW-1 be revised to provide specific thresholds of subsidence that will trigger the need for additional subsidence monitoring; (3) mitigation measure GW-1 be revised to include the frequency and methods of collecting and reporting subsidence measurements; (4) the Draft EIS/EIR discuss how the non-participating landowners and the public can obtain subsidence information in a timely manner; (5) the Draft EIS/EIR and GW-1 be revised to provide the thresholds that trigger implementation of the reimbursement mitigation measure required by GW-1 for repair or modifications to infrastructure damaged by non-reversible subsidence along with the procedures for seeking monetary recovery from subsidence damage; and (6) the Draft EIS/EIR be revised to provide a map and inventory of critical structures in the Sacramento Valley that may be susceptible to settlement and lateral movement. These structures should include natural gas pipelines, gas transfer and storage facilities, gas wells, power plants, railroads, bridges, water and sewer pipelines, water wells, canals, levees, other industrial facilities. I further recommend that the Draft EIS/EIR solicit advice from local, state and federal agencies, as well as the infrastructure owners on the amount of subsidence that these critical structures and pipelines can withstand, and provide copies of their responses and incorporate their requirements in mitigation measure GW-1 to ensure the stability and function of these facilities.

Geology and Seismicity

19. Environmental impacts from the project to geologic and soil resources are discussed in Section 3.4 of the Draft EIS/EIR. The Draft EIS/EIR assumes that because the projects don't *involve the construction or modification of infrastructure that could be adversely affected by seismic events, seismicity is not discussed in this section.* The Geology and Soils section therefore focused on *chemical processes, properties, and potential erodibility of soils due to cropland idling transfers.* Impacts of subsidence are discussed in Section 3.3 of the Draft EIS/EIR and above in my comment no. 18.

The Draft EIS/EIR reasoning that because the projects don't involve new construction or modification of existing structures that there are no potential seismic impacts from the activity undertaken during the transfers is incorrect. The project area has numerous existing structures that could be affected by the groundwater substitution transfer pumping, specifically settlement induced by subsidence. Although the seismicity in the Sacramento Valley is lower than many areas of California, it's not insignificant. There is a potential for the groundwater substitution transfer projects to increase the impacts of seismic shaking because of subsidence causing additional stress on existing structures. The discussion in Section 3.3 on potential subsidence from groundwater substitution pumping was only qualitative because the SACFEM2013 simulations didn't calculate an estimate of subsidence from the transfer projects (page 3.3-61). The subsidence assessment also didn't acknowledge or consider the numerous natural gas pipelines or other critical facilities and structures that occur the Sacramento Valley. Exhibits 8.5 to 8.11 provide a series of maps that show some of the major natural gas pipelines, oil refineries, terminal storage, and power plants in the Sacramento Valley. In addition, there are a number of railroads, bridges, canals, and water and sewer pipelines within the transfer project area. As I discussed in my comment no. 18 on subsidence impacts, some of these existing structures and pipelines are sited within or traverse areas of known subsidence, existing areas of large groundwater drawdown, and areas within the proposed groundwater substitution transfer pumping. There are a number of technical documents on seismic impacts to pipelines (O'Rouke and Norberg, 1992; O'Rouke and Liu, 1999, 2012) as well as a proceeding from a recent ASCE conference on pipelines (Miami, Florida, August 2012).

The characteristics of future seismic shaking in California can be assessed using the following web resources provided by the California Geological Survey (CGS) in conjunction with the U.S. Geological Survey and other academic and professional organizations:

California Fault Activity Map web site:

http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html

Probabilistic Seismic Hazard Mapping web site:

http://www.consrv.ca.gov/cgs/rghm/psha/pages/index.aspx

Probabilistic Seismic Ground Motion Interpolator web site:

http://www.quake.ca.gov/gmaps/PSHA/psha_interpolator.html

Earthquake Shaking Potential for California Map web site:

http://www.conservation.ca.gov/cgs/information/publications/ms/Documents/MS48_revised.pdf

In addition to the potential impacts to existing infrastructure from seismic shaking, the occurrence of faults within the Sacramento Valley may influence the movement of groundwater. The USGS-CVHM groundwater model (Faunt, ed., 2009) incorporated a number of horizontal flow groundwater barriers (Figure C1-A, pages 160, 203, and 204; Exhibits 9.1, 9.2, 9.3a and 9.3b) that appear to align with faults shown in a series of screen plots from the interactive web site 2010 Fault Activity Map for California (CGS, 2010) (Exhibits 9.4a to 9.4d, 9.5 and 9.6). The SACFEM2013 model documentation didn't indicate that faults were considered as potential flow barriers and the resulting simulation maps in Figures 3.3-26 to 3.3-31don't show any flow barriers.

I recommend that the Draft EIS/EIR be revised to: (1) assess the potential environmental impacts from seismic shaking on critical structures and pipelines in areas of potential subsidence caused by the groundwater substitution transfer pumping; (2) provide maps that identify and locate existing pipelines and critical structures such as storage facilities, railroads and bridges within the areas

affected by groundwater substitution pumping; (3) solicit and provide results of the advice from local, state and federal agencies, as well as the infrastructure owners, on the amount of subsidence that these critical structures and pipelines can withstand under in both static and seismic conditions; (4) provide a mitigation measure(s) that addresses the requirements for monitoring the subsidence in the area of these critical structures and pipelines; and (5) provide specific monitoring and reporting requirements for potential seismic impacts to critical structures that includes establishing any additional structures for monitoring and taking subsidence measurements, and conducting additional periodic surveys of ground elevation and displacement. I recommend the Draft EIS/EIR be revised to provide the thresholds that trigger implementation of the reimbursement mitigation measure required by GW-1 for repair or modifications to infrastructure that may be damaged by seismic movement in areas that have exceeded the thresholds for non-reversible subsidence, and provide procedures for seeking monetary recovery from subsidence damage. I also recommend the Draft EIS/EIR be revised to discuss the importance and impacts of the horizontal flow barriers and/or faults within the Sacramento Valley on the results of the drawdown and stream depletion simulations of SACFEM2013.

II. Additional Technical Information Relevant to the Assessment of Potential Environmental Impacts from the 10-Year Groundwater Substitution Transfers.

<u>Historic Changes in Groundwater Storage</u>

20. The Draft EIS/EIR provides SACFEM2013 simulations of groundwater substitution transfer pumping effects for WY 1970 to WY 2003. The discussion of the simulation didn't provide specifics on how the model simulated the current conditions of the Sacramento Valley groundwater system or the potential impacts from the 10-year groundwater substitution transfer project based on current conditions. A DWR groundwater contour map, Figure 3.3-4, shows the elevations in the spring of 2013 for wells screened at depths greater than 100 ft. bgs. and less than 400 ft. bgs. Figures 3.3-8 and 3.3-9 provide the locations and simulation hydrographs for selected monitoring wells in the Sacramento Valley. Appendix E provides additional monitoring well simulation hydrographs for selected wells at locations shown on Figures 3.3-26 to 3.3-31. As discusses above in comments no. 7, these hydrographs appear to show only simulated groundwater elevations. Actual measured groundwater elevations are needed to evaluate the accuracy of the simulations. The Draft EIS/EIR briefly discusses on page 3.3-12 the groundwater production, levels and storage for the Redding Basin, and on pages 3.3-21 to 3.3-27 there is a similar discussion for the Sacramento Valley. Faunt (ed., 2009) is cited for the conditions of the Sacramento Valley groundwater budget and Figure 3.3-10, taken from Faunt (ed., 2009; Figure B9; Exhibit 10.2a), shows the historic change in groundwater storage in the Central Valley as determined by the CVHM model simulations. Based in part on the information in Faunt (ed., 2009), the Draft EIS/EIR concludes that the Sacramento Valley basin's groundwater storage has been relatively constant over the long term, decreasing during dry years and increasing during wetter periods. However, the Draft EIR/EIS's discussion of the status of groundwater in the Sacramento Valley doesn't utilize all of the information on groundwater storage or water balance available in Faunt (ed., 2009), more recent simulation studies by Brush and others (2013a and 2013b), or the summary of groundwater conditions in recent reports by the Northern California Water Association (NCWA) (2014a and 2014b).

Faunt (ed., 2009) provides in Table B3 (Exhibit 10.1) selected average annual hydrologic budget values for WYs 1962-2003. In addition, Figures B10-A and B10-B of Faunt (ed., 2009) show bar graphs for the average annual groundwater budget for the Sacramento Valley and the Delta and Eastside Streams (Exhibits 10.2b and 10.2c). Table B3 gives the water balances for subregions in the Sacramento Valley (1 to 7) and the Eastside Streams (8). Table B3 gives values for the *net storage from specific yield and compressibility of water*; positive values indicate an increase in storage, while a negative value is a decrease. For Sacramento Valley, the sum of the annual average from 1962 to 2003 in net storage is given as -99,000 AFY and for the Eastside streams -26,000 AFY. Unfortunately, the components in Table B3 don't seem to be a complete groundwater water budget, so following the calculations of the average annual net change in groundwater storage isn't obvious. Figures 10A and 10B (Exhibits 10.2a and10.2b), however, do provide bar graphs of the groundwater water budgets with values for the entire Sacramento Valley and the Delta and Eastside Streams. If it's assumed that groundwater pumping shown as a negative value in Figures 10A and 10B represents an outflow from groundwater storage, then other negative values would also be considered outflows. Positive values are therefore assumed to be inflows to groundwater storage.

For the entire Sacramento Valley (subregions 1 to 7), Faunt (ed., 2009) shows the net change in annual groundwater storage as the sum of the negative outflows and positive inflow in Figure 10A at a negative 650,000 AFY (-0.65 million AFY) (2.88 – [0.29+0.03+1.66+1.37+0.18] = 2.88 – 3.53 = -0.65). The values in Figure 10B can be summed in a similar manner and yield a net change in storage of a positive 90,000 AFY for the Delta and Eastside Streams. Unfortunately, the bar graph in Figure 10B for the Eastside Streams (subregion 8) doesn't have numerical values. A visual comparison of the inflow and outflow bars suggests that for subregion 8 the outflows, mostly pumping, are at or slightly greater than the inflows.

The groundwater budget information by Faunt (ed., 2009) can be compared with two other more recent sources of Sacramento Valley information contained in four documents, Brush and others (2013a and 2013b) and NCWA (2014a and 2014b). Brush and others report on the recent version of the C2VSim groundwater model (version R374) and provide simulation results. The NCWA reports also used the C2VSim (R374) model, but provided additional analysis and results of the historic land development, water use and water balances in Sacramento Valley. Some of the information developed by Brush and others (2013a and 2013b), and Faunt (ed., 2009) on the condition of the Sacramento Valley groundwater system was previously discussed in my comments on the SACFEM2013 model simulations, nos. 8 to 14.

My comment no. 14 on groundwater flow between subregions is also relevant to this discussion of the historic changes in groundwater storage. Accounting for the transfer of groundwater between regions is critical for understanding the impacts of pumping in one region or area on the adjacent regions. The sources of water backfilling a groundwater depression don't all have to come from surface waters, ie., stream depletion, precipitation, deep percolation, and artificial recharge. Some of that "recharge" can come from adjacent aquifers by horizontal and vertical flow. When pumping creates a depression in the water table or piezometric surface, the depression steepens the gradient thereby increasing the rate of flow towards it; the depression can also change the direction of groundwater flow. Often the "recharge" to a pumping depression comes from adjacent groundwater storage that lies outside the zone of influence of the pumping. When the rates and volumes of recharge from surface waters are insufficient to rapidly backfill a pumping depression, the impact on groundwater storage and elevations in adjacent regions increases.

Brush and others (2013a) provide a breakdown of water budget by subregion, Tables 10 to 13 (Exhibits 6.3a to 6.3d), but only for the selected three decades (1922-1929, 1960-1969, and 2000-2009), and for the total modeled period from 1922 to 2009. They do provide values for the change in groundwater storage for all 21 of the Central Valley subregions and 5 hydrologic regions. Of particular importance to the discussion of the current condition of the groundwater basin are the results of the C2VSim simulations of the annual average change in groundwater storage for each of the three decades and from 1922 to 2009, Tables 10 to 13 (Exhibits 6.3a to 6.3d). For the Sacramento Valley (subregions 1 to 7), Table 10 lists the 1922-2009 change in storage as -165,417 AFY (I'm assuming the units of the table are acre-feet), and for the Eastern Streams (subregion 8) -135,304 AFY. For the most recent decade, 2000-2009, the average annual change in groundwater storage has increased in both the Sacramento Valley and the Eastern Streams to -303,425 AFY and -140,715 AFY, respectively (Table 13). Although the tables in Brush and others don't list the groundwater flow between subbasins, Figures 81A to 81C (2013a) and Figure 39 (2013b) (Exhibits 6.1a to 6.1c and 6.2) provide this information for the selected decades and for the total simulation period. As discussed above in my comment no. 14, the change in interbasin groundwater flow can be significant particularly when recharge in a region is deficient. The Draft EIS/EIR should specifically discuss and account for any changes in the rate and direction of interbasin groundwater flow. Interbasin groundwater flow may become a hidden long-term impact that increases the time needed for recovery of groundwater levels from groundwater substitution transfer pumping, and can extend the impact from groundwater substitution transfer pumping to areas outside of the groundwater substitution transfer seller's boundary.

Two recent reports on the condition of groundwater in the Sacramento Valley are provided by the Northern California Water Association (NCWA, 2014a and 2014b). Tables 3-6, 3-7, and 3-8 in the NCWA technical supplement report (2014b; Exhibits 10.5a to 10.5c) provide water balance information for the Sacramento Valley for the same three decades as Brush and others (2013a). The NCWA tables separate the water balance elements into three types, land uses (Table 3-6), streams and rivers (Table 3-7), and groundwater (Table 3-8). The values of the change in groundwater storage given in Table 3-8 are similar to those given by Brush and others (2013a). The NCWA technical supplement report (2014b) also provides additional information on the 1922 to 2009 water balance through the use of graphs and bar charts. Figures 3-22 and 3-24 (Exhibits 10.6c and 10.6d) provide graphs of simulated estimates of annual groundwater pumping in the Sacramento Valley and the annual stream accretion. Positive stream accretion occurs when groundwater discharges to surface water, negative when groundwater is recharged. Other graphs include simulated deep percolation, Figures 3-26 and 3-27 (Exhibits 10.6e and 10.6f), annual diversions, Figures 3-19 and 3-20 (Exhibits 10.6a and 10.6b), and relative percentages of surface water to groundwater supplies, Figure 3-29 (10.6g).

The NCWA technical supplement report (2014b) notes in Sections 3.8 and 3.8.4 that negative changes in groundwater storage

> *... suggest that the groundwater basin is under stress and experiencing overdraft in some locations. Review of the Sacramento Valley water balance, as characterized based on C2VSim R374 and summarized in Tables 3-6 through 3-8 reveals substantial changes in water balance parameters over time that affect overall groundwater conditions. … Over time, it appears that losses from surface streams have increased as a result of declining groundwater levels. The declining levels result from increased demand for groundwater as a source of supply without corresponding increases in groundwater recharge.* (page 41)

> *A contributing factor to the decrease in accretions to rivers and streams over the last 90 years is that deep percolation of surface water supplies (and other forms of recharge) has not increased in a manner that offsets increased groundwater pumping.* (page 48)

The simulated groundwater pumping graph in NCWA Figure 3-22 and stream accretion graph in NCWA Figure 3-24 were combined into one graph by scaling and adjusting their axes (Exhibits 10.7). The vertical scales of these two graphs were adjusted so that a zero value of stream accretion aligned with 1.5 million acre-feet (MAF) of annual groundwater pumping. This alignment was done to reflect the fact that in the early 1920s, groundwater pumping was approximately 0.5 MAF per year (MAFY) while stream accretion was approximately 1.0 MAFY. As shown in the combined graph, stream accretion generally decreases at approximately the same rate as groundwater pumping increases. Thus, at a point of no appreciable groundwater pumping, pre-1920s, the total long-term average annual stream accretion was likely 1.5 MAF, based on the C2VSim simulations.

Drawn on top of the stream depletion and groundwater pumping graphs are several visually fit, straight trend lines. These lines, which run from 1940 to the mid-1970s and the late 1980s to mid-1990s, are mirror images reflected around the horizontal 0 accretion axis. Information provided at the bottom of the composite graph was taken from NCWA Tables 3-7 and 3-8 (Exhibits 10.5b and 10.5c). The slope of the trend line from 1940 to the mid-1970s is approximately (+-)27,000 AFY, and (+-)85,000 AFY in the late 1980s to the mid-1990s; a 3-fold increase in slope. After the mid-1990s the slope of groundwater pumping flattens to be similar to that of the 1940s–mid-1970s, while the stream depletion line became almost flat, ie., no change in rate of accretion. The reason for the stream depletion rate being flat is unknown, but there are several factors that could contribute to a fixed rate of stream accretion.

First, after depleting 1.5 MAFY from the Sacramento Valley streams, the surface waters may not be able to provide much more, at least no increase to match the pumping. Second, this may also be a consequence of the model design because the number of streams simulated was limited. Third, the model's grid may not extend out far enough to encompass all of the streams that contribute to groundwater recharge. More information on the areas of where streams gain and lose in the Sacramento Valley is needed to determine if there are any sections of stream, gaining or losing, that might still have the ability to interact at a variable rate in the future, ie., during and after the 10-year groundwater substitution transfer project.

A third graph is drawn on the composite accretion-pumping graph in Exhibit 10.7 that shows the C2VSim simulated cumulative change in groundwater storage for the Sacramento Valley from 1922 to 2009. This graph was taken from Figure 35 of Brush and others, 2013b (Exhibit 10.4). A straight trend line with a negative slope of approximately -163,417 AFY is drawn on top of the third graph, which is the value for average annual change in storage from 1922 to 2009 given in Table 10 of Brush and others (2013a; Exhibit 6.3a) for the seven subregions of the Sacramento Valley. The selected graph of the cumulative change in groundwater storage is one of three available.

The graph of cumulative change in groundwater storage for the Sacramento Valley in Figure 35 differs from the graph in Figure 83 in Brush and others (2013a; Exhibit 10.3) and in Figure B9 of Faunt (ed., 2009; Exhibit 10.2a). Both of Figure 83 and Figure B9 show a gain in groundwater storage with their Sacramento Valley graphs lying generally above the horizontal line of zero change in storage. The cumulative change in groundwater storage graph from Figure 35 (Exhibit 10.4) was selected because:

- its slope is a close match for the average annual change in storage from 1922 to 2009 of -163,417 AFY given in Table 10,
- the values for change in groundwater storage in the three selected decades are all negative (Table 3-8, NCWA, 2014b), which the other two graphs don't clearly indicate,
- the calculation of average annual change in groundwater storage from 1962 to 2003 shown in Table B3 and Figures B10-A and B10-B of Faunt (ed., 2009) are negative, which conflicts with Figures B9 and 83, and
- change in DWR groundwater elevation maps from spring 2004 to spring 2014 (Exhibit 3.1, 3.2 and 3.3) suggest that there are significant regions of the Sacramento Valley that have lost groundwater storage, which suggests that the current condition is one of a loss in storage rather than a gain.

Additional review and analysis of the changes in groundwater storage in the Sacramento Valley is needed. Any additional review of changes in groundwater storage in the Sacramento Valley should consider the recent changes in groundwater elevations such as those shown in DWR (2014b) for WYs 2004 to 2014, and Figures 2-4 and 2-5 of NCWA, 2014b (Exhibit 10.8 and 10.9), as well as other studies such as the support documents for the regional IRWMPs.

I recommend the Draft EIS/EIR be revised to provide a more comprehensive assessment of the historic change in groundwater storage in the Sacramento Valley groundwater basin, and other seller sources areas within the proposed 10-year groundwater substitution transfer project. I also recommend that the Draft EIS/EIR be revised to include an assessment of the impacts of groundwater flow among subregions due to the proposed 10-year groundwater substitution transfer project.

The Concept of the Stream Depletion Factor, SDF

21. The Draft EIS/EIR proposes that a stream depletion factor, BoR-SDF, be applied to groundwater substitution transfers as mitigation for flow losses due to groundwater pumping. The Draft EIS/EIR implies that the BoR-SDF will be a fixed percentage of the transferred groundwater substitution water. The main text of the Draft EIS/EIR doesn't clearly specify the BoR-SDF percentage, but appended documents state that the default is 12%, *unless available monitoring data analyzed by Project Agencies supports the need for the development of a transfer proposal site-specific SDF* (page 33 in the DTIPWTP). Elsewhere in the Draft EIS/EIR, the average annual surface water–groundwater interaction losses are estimated at approximately 15,800 AF and in multiple dry years losses of 71,200 AFY are anticipated (page 3.1-18). The Draft EIS/EIR proposes mitigation measure WS-1, which utilizes the BoR-SDF with the transfers to account for the losses from stream depletions, and thereby reduces the water supply impacts to less than significant (page 3.1-18). As I discussed above in my comment no. 9, the maximum annual groundwater substitution pumping is 290,495 AF as calculated from Table 2-5. The estimated annual average surface water–groundwater interaction loss of 15,800 AF is 5.4 % of the maximum allowable annual groundwater substitution transfer, while a loss of 71,200 AF is 24.5%.

    The use of a fixed percentage of transfer water to mitigate increased stream flow losses from the groundwater substitution pumping may not result in the reduction of stream flow impacts to less than significant. I've discussed above in my comment no. 15 several of the issues about the design of mitigation measure WS-1. The following are additional comments on WS-1 specific to the fixed percentage BoR-SDF and how it differs from the concept of stream depletion commonly used in scientific literature.

Jenkins (1968a and b; Barlow and Leake, 2012) defined the "stream depletion factor" (herein called the Jenkins-SDF) as the product of the square of the distance between a well and a surface water body (a^2) multiplied by the storage coefficient (S or Sy) divided by the transmissivity (T) (Jenkins-SDF = distance^2 x storage coefficient/transmissivity = a^2 x S/T) (see Table 1 and page 14 in Barlow and Leake, 2012). The units of the Jenkins-SDF are in time, ie., days, years, etc. The Jenkins-SDF also occurs in Theis' well function, *W(u)* (see pages 136 and 150 in Domenico and Schwartz, 1990). Domenico and Schwartz (1990) showed that the Jenkins-SDF can be expressed as a dimensionless Fourier number, which occurs in all unsteady groundwater flow problems. The Jenkins-SDF has several other important characteristics that are not part of the BoR-SDF, which likely influence the actual rate and volume of surface water lost due to groundwater substitution transfer pumping.

1. The value of stream depletion varies with the duration of pumping and unlike the BoR-SDF isn't a fixed value. For an ideal aquifer (homogeneous, isotropic and infinite), two ideal curves normalized to the Jenkins-SDF value can be created that show stream depletion as a percentage of the total pumping rate or total pumped volume against the normalized logarithm of pumping time (see Figure 1 from Miller and Durnford, 2005; Exhibit 11.1). In Figure 1, equation no. 1 shows the instantaneous rate of stream depletion as a percentage of the maximum pumping rate versus the logarithm of normalized time, and equation no. 2 shows the volume of depletion as a percentage of the total volume pumped versus the logarithm of normalized time. Jenkins somewhat arbitrarily defined his SDF as the pumping duration equal to the calculated stream depletion factor (a^2 x S/T). Jenkins noted that for the ideal aquifer at the time of the SDF, the cumulative volume of water depleted from the stream equals 28% of the total volume pumped (Jenkins, 1968a; Wallace and Durnford, 2005 and 2007). As shown in Figure 1 in Exhibit 11.1, when the actual pumping duration is normalized to the Jenkins-SDF, the ideal volume curve always goes through 28% when the pumping time equals the Jenkins-SDF (time/SDF = 1; Jenkins, 1968a).
2. An important factor in the Jenkins-SDF is that stream depletion varies with the square of the distance between the well and the stream, whereas, the depletion rate varies only linearly with changes in S or T. The ratio of T/S is also called the hydraulic diffusivity, D, which has units of length^2/time (see Table 1 and Box A in Barlow and Leake, 2012). The rate that hydraulic stress propagates through an aquifer is a function of the diffusivity. Greater values of D result in more rapid propagation of hydraulic stresses. Barlow and Leake (2012) note that the ratio T/S (or T/Sy) controls the timing of stream depletion and not each value individually. Streamflow depletion can occurs more rapidly in confined aquifers than in unconfined aquifers because S is much smaller than Sy, resulting in a larger D value.
3. For a given duration of pumping, the percentage of instantaneous depletion is greater than the percentage of volume depleted. For the ideal aquifer at a pumping duration equal to the Jenkins-SDF value, the instantaneous depletion is 48% of the maximum pumping rate, while the cumulative volume of depletion is 28% of the total pumped volume (Figure 1, Exhibit 11.1). For a non-ideal aquifer where numerical simulations are needed to estimate stream depletion, eg., the SACFEM2013 simulations, the time when the cumulative volume of stream depletion is at 28% of the total volume pumped can be used as an "effective" Jenkins-SDF to allow for evaluation and comparison of potential impacts from pumping.
4. Stream depletion continues to occur after pumping ceases. Jenkins (1968a, b) referred to this as residual depletion. Depending on the duration of pumping and the value of the Jenkins-SDF, stream depletion can be greater after pumping ceases (see

pages 42 to 45 in Barlow and Leake, 2012). Barlow and Leake (2012 on page 43) give the following five key points regarding stream depletion after cessation of pumping:

   a. *Maximum depletion can occur after pumping stops, particularly for aquifers with low diffusivity or for large distances between pumping locations and the stream.*
   b. *Over the time interval from when pumping starts until the water table recovers to original pre-pumping levels, the volume of depletion will equal the volume pumped.*
   c. *Higher aquifer diffusivity and smaller distances between the pumping location and the stream increase the maximum rate of depletion that occurs through time, but decrease the time interval until water levels are fully recovered after pumping stops.*
   d. *Lower aquifer diffusivity and larger distances between the pumping location and the stream decrease the maximum rate of depletion that occurs through time, but increase the time interval until water levels are fully recovered after pumping stops.*
   e. *Low-permeability streambed sediments, such as those illustrated in figure 11, can extend the period of time during which depletion occurs after pumping stops.*
   f. *In many cases, the time from cessation of pumping until full recovery can be longer than the time that the well was pumped.*

5. As noted above in key point no. 4b, the volume of stream depletion will eventually equal the total pumped volume. The time required for full aquifer recovery from pumping depends on the value of the Jenkins-SDF, availability of water to capture, the rate and duration of recharge above what normally occurs, and other factors like the streambed sediment permeability and aquifer layering. Figure 1 in Exhibit 11.1 also shows that for an ideal aquifer the time needed to reach 95% depletion is approximately 127 times the Jenkins-SDF value. This is consistent with the estimates made by Wallace and others (1990) in Table 3 (Exhibit 11.2) on the time it takes to reach 95% depletion, which they consider a point where a new dynamic equilibrium is established. Although the 127-times-SDF multiplier assumes continuous pumping, the fact is the time for full recovery by residual depletion without pumping shouldn't be any sooner than it takes to obtain 95% stream depletion with pumping. In other words, rate and volume of loss from a stream can't be any higher without pumping than with pumping, all other parameters being equal. This means that without some additional source of recharge above what normally occurs, including natural wet and dry cycles, the total time required to achieve full recovery from the 10 years of groundwater substitution transfer pumping will be much longer than the 5 years cited in the Draft EIS/EIR (pages 3.3-80). For additional discussion of the stream depletion under natural variations in recharge and discharge see Maddock and Vionnet (1998).

Another factor that isn't clearly acknowledged in the Draft EIS/EIR is the difference between the instantaneous depletion rate and cumulative volumetric depletion rate. The Draft EIS/EIR appears to focus on cumulative volumetric depletion in mitigation measure WS-1. However, the instantaneous stream depletion rate is probably more important when evaluating impacts to fisheries and stream habitat. The instantaneous rate of flow, instantaneous depth of flow and the corresponding instantaneous wetted perimeter of flow at any point in a stream are the best measures of habitat value to the fish and other water dependent species. The cumulative volume of stream depletion relative to the total pumped volume, on the other hand, can't be easily translated stream to instantaneous flow, water depth or wetted perimeter at a point in a stream because discharges having different hydrographs can result in the same total volume of flow. For example, if I estimate that the stream depletion during a 3- to 6-month period of groundwater substitution pumping will be a maximum of 1 cubic-foot-per-second, I can evaluate the significance of this change to the stream's habitat value using the stream's historic hydrograph and fluvial geomorphology. However, if I estimate that over the same period of pumping the stream will lose, at the end of pumping, a total 12 percent of the total volume pumped, I can't determine what changes will occur in the habitat function of the stream at a specific time and place. Perhaps, if I assume that the cumulative volume of stream depletion increases linearly with time, going from zero at time zero, to 12% at the end of pumping, then I could also assume that the instantaneous rate of stream depletion would also change linearly from 0% at the start to 24% of the pumping rate at the end of pumping. Remember that in this case the area under the instantaneous depletion curve is triangular, and therefore the maximum instantaneous depletion rate would be twice the total cumulative depletion rate. In reality, the ratio of instantaneous to volumetric depletion for the ideal Jenkins-SDF curves vary with pumping duration; the ratio is approximately 1.7:1 for time/SDF = 1 (Figure 1, Exhibit 11.1). Figure 1 also shows for the ideal curve that when the instantaneous depletion (eq. 1) is 24%, the volumetric depletion is 10% (eq. 2), a ratio of 2.4:1, and when eq. 1 is at 83%, eq. 2 is at 70%, a ratio of 1.19:1.

Mitigation measure WS-1 appears to be based on the cumulative volume of water pumped for each period of groundwater substitution transfers, not the instantaneous rate of stream depletion caused by the pumping. Mitigation measure WS-1 uses of a fixed value for compensating stream losses, which is inconsistent with the hydraulics of stream depletion. Because stream depletion actually increases with pumping time, mitigation measure WS-1 needs to specify the maximum duration of pumping allowed, ensuring that the depletion rate stays below the WS-1 value, ie., 12%. This maximum duration of pumping should be established based on impacts to stream habitat from instantaneous changes in stream flow, not the cumulative change in volume. The maximum duration of allowable pumping would change with the distance between the well and stream and with the diffusivity around each well because these control the rate of stream depletion. The well acceptance criteria in Table B-1 of Appendix B in the DTIPWTP suggests that some calculation has been made to establish the specified setback distances, but no methodology or calculation is given in the Draft EIS/EIR. The Draft EIS/EIR should document how the maximum allowable stream depletion rate, instantaneous and volumetric, and the associated maximum duration of pumping will be calculated for each well in the groundwater substitution transfer project.

Although the Draft EIS/EIR doesn't fully evaluate the potential stream depletion that may occur with the proposed 10-year groundwater substitution transfer project, another report prepared by CH2MHill (2010) and submitted to DWR provides additional analysis on the simulated impacts from the 2009 groundwater substitution transfers. The simulations of the 2009 transfer impacts were done using the SACFEM model, presumably an earlier version of the SACFEM2013 model. Figures 4, 5 and 6 in the CH2MHill 2010 report provide simulation graphs of stream depletion for three groundwater substitution transfer periods, 1976, 1987 and 1994 (Exhibits 11.3a to 11.3c). Graphs (a) to (c) in each figure appear somewhat like Figures B-5 and B-6 in Appendix B of the Draft EIS/EIR in that they show a depletion peak shortly after pumping starts, with a gradual decay following the cessation of pumping. Graphs (d) of Figures 4, 5 and 6 are not provided in the Draft EIS/EIR, but provide important additional information. These (d) graphs show the cumulative depletion for each of the three scenarios and are essentially the volumetric depletion curve of eq. 2 in Miller and Durnford's Figure 1 (Exhibit 11.1). These cumulative volume depletion curves are important because they show the time needed to fully recover from the three groundwater substitution transfer pumping events. For example, Figure 4(d) shows that recovery from the pumping event in 1976 is only approximately 60% after 25 years; much longer than the 5 years for 55% to 75% recovery stated in the Draft EIS/EIR (pages 3.3-70). For comparison, Figure 4(d) of CH2Mhill (2010) is plotted on Miller and Durnford's Figure 1 in Exhibit 11.1 by normalizing the values plotted in 4(d) by an effective Jenkins-SDF value of 2.4 years.

Notice that for the simulated Figure 4(d) Jenkins-SDF curve, depletion initially occurs sooner than with an ideal aquifer, but then depletion slows. At 127 times the SDF, approximately 300 years, the depletion is at approximately 80%.

A point can be identified on each graph (d) where the volume of stream depletion is equal to 28%, the Jenkins-SDF point, and the time since pumping started measured. For example, in Figure 4(d) approximately at approximately 2.4 years after the beginning of pumping the volume of depletion reaches 28%. For Figure 5(d) the time to 28% is similar, estimated at 2.3 years. The time interval to 28% volumetric depletion in Figure 6(d) is significantly greater at an estimated 7.5 years. The results presented in both Figures 4 and 5 are from simulation of stream depletion during dry or critically dry years followed by normal or dry years, while the simulation scenario of Figure 6 is for a critical year followed by wet years. All of the cumulative (d) graphs are filtered for the Delta conditions. This may be the reason it takes longer for stream depletion to reach 28% during a wet period than dry period when one might expect the opposite because of the increased stream flow would provides more water for recharge.

The point of this discussion is that the simulated stream depletions from the SACFEM2013 modeling can also be presented as cumulative depletion response curves that are normalized by the effective Jenkin-SDF time. The stream depletion can then be estimated for any rate or duration of pumping at an individual well when the stream depletion response curves given as percentages of both the maximum pumping rate and total volume pumped are normalized to the effective Jenkins-SDF (without the Delta conditions filter). Losses for different distances between the well and surface water feature can be roughly estimated without the need to run another simulation by adjusting the Jenkins-SDF curves by the ratio of the square of the different distances. Cumulative depletion for different pumping rates during and following the 10-year groundwater substitution transfer project can be estimated by the principle of superposition (Wallace and other, 1990; Barlow and Leake, 2012). As I discussed in my comment no. 15b, additional discussion is needed in the Draft EIS/EIR on how the amount of stream depletion for WS-1 is calculated. This discussion should include normalized stream depletion response curves for each groundwater substitution transfer well so that impacts from pumping can be estimated for different pumping durations and rates.

Barlow and Leake (2012) provide an extensive discussion of the factors controlling stream depletion including several misconceptions (pages 39 to 45). Review of their discussion of stream depletion misconceptions is recommended as part of any revision of the Draft EIS/EIR. Barlow and Leake identified the following misconceptions regarding stream depletion (page 39):

- *Misconception 1. Total development of groundwater resources from an aquifer system is "safe" or "sustainable" at rates up to the average rate of recharge.*
- *Misconception 2. Depletion is dependent on the rate and direction of water movement in the aquifer.*
- *Misconception 3. Depletion stops when pumping ceases.*
- *Misconception 4. Pumping groundwater exclusively below a confining layer will eliminate the possibility of depletion of surface water connected to the overlying groundwater system.*

I recommend that the Draft EIS/EIR be revised to document stream depletion response curves for each groundwater substitution transfer well. These response curves should be normalized to the effective Jenkins-SDF value, given as a percentage of the pumping rate and total pumped volume, along with the

distance between the well and the modeled surface water feature. Multiple stream depletion response curves should be provided, if necessary. I recommend that the Draft EIS/EIR be revised to review how the BoR-SDF value accounts for the variability in rate and volume of stream depletion. I recommend that the Draft EIS/EIR be revised to document how the maximum allowable instantaneous and volumetric stream depletion rates, and the associated maximum duration of pumping will be calculated for each well in the groundwater substitution transfer project to ensure that the BoR-SDR provides adequate flow mitigation. I recommend that the Draft EIS/EIR be revised to discuss how WS-1 addresses the common stream depletion misconceptions noted by Barlow and Leake (2012).

Measurement of Stream Seepage in Real Time

22. Barlow and Leake (2012) state that methods for determining the effects of pumping on stream flow follow two general approaches: (1) collection and analysis of field data, and (2) analytical and numerical modeling (page 50). The Draft EIS/EIR states in the OTIPWTP that stream depletion can't be measured in real time (page 33) and instead relies on simulations of groundwater pumping to determine impacts to surface waters. As discussed in **my comment no. 15b**, the Draft EIS/EIR also states that monitoring of surface water-groundwater interaction is part of mitigation measures WS-1 and GW-1. The statement that stream depletion measurements, ie., stream seepage rates, surface water depths, and surface flows, can't be done in "real time" conflicts with scientific literature. Measurements of stream flow and water depth are fundamental to stream surveys. Although measurement of the seepage rate from or into a stream is done less often and is generally more difficult than other direct surface water measurements, procedures for making these measurements are well documented (Barlow and Leake, 2012; Rosenberry and LaBaugh, 2008; Zamora, 2008; Stonestrom and Constantz, ed., 2003; Constantz, 2008; Kalbus and others, 2006). Linking field measurements to changes in stream flow and seepage to adjacent groundwater pumping is made more difficult because of the lag between the start of pumping and stream response, damping of the pumping response with increases in distance between the well and measured surface water body, and the variation in seepage rate with the increases in pumping time or pumping cycles. Measurements of surface water and groundwater flow are also difficult because of inherent measurement errors that are sometimes greater than the change in flow being sought. Barlow and Leake (2012) discuss the measurement of stream depletion and conclude that:

> *Two general approaches are used to monitor streamflow depletion: (1) short-term field tests lasting several hours to several months to determine local-scale effects of pumping from a specific well or well field on streams that are in relative close proximity to the location of withdrawal and (2) statistical analyses of hydrologic and climatic data collected over a period of many years to test correlations between long-term changes in streamflow conditions with basinwide development of groundwater resources. Direct measurement of streamflow depletion is made difficult by the limitations of streamflow-measurement techniques to accurately detect a pumping-induced change in streamflow, the ability to differentiate a pumping-induced change in streamflow from other stresses that cause streamflow fluctuations, and by the diffusive effects of a groundwater system that delay the arrival and reduce the peak effect of a particular pumping stress.* (Page 77)

The Draft EIS/EIR provides the following statements in the DTIPWTP regarding groundwater substitution transfers, which are therefore part of mitigation measure GW-1:

- … *must account for* … the *extent to which transfer-related groundwater pumping decreases* *streamflow (resulting from surface water-groundwater interaction), and the timing of those decreases in available surface water supply.* (page 25);

- *Project Agencies are developing tools to more accurately evaluate the impacts of groundwater substitution transfers on streamflow. These tools may be implemented in the near future and may include a site-specific analysis that could be applied to each transfer proposal.* (page 33);
- *Water transfer proponents transferring water via groundwater substitution transfers must establish a monitoring program capable of identifying any adverse transfer related effects before they become significant.* (page 34);

The objectives of the DTIPWTP groundwater substitution transfer-monitoring program include:

- *Determine the extent of surface water-groundwater interaction in the areas where groundwater is pumped for the transfer;*
- *Determine the direct effects of transfer pumping on the groundwater basin, observable until March of the year following the transfer;*
- *Assess the magnitude and potential significance of any effects on other legal users of water, instream beneficial uses, the environment, and the economy.* (page 34)

All of these statements and monitoring objectives imply that measurement of impacts to surface water from groundwater substitution transfer pumping is possible. While measurement of stream depletion is complex and problematic, it is possible. The conflicting statements in the Draft EIS/EIR that "real time" measurements can't be done while apparently including a requirement for field monitoring of the effects of stream depletion in mitigation measures WS-1 and GW-1 need further explanation.

I recommend that the Draft EIS/EIR be revised to evaluate and discuss the methods, techniques and procedures available for monitoring and measuring the rate, volume and impacts of stream depletion due to groundwater substitution transfer pumping. The revised Draft EIS/EIR should provide specific mitigation measures, procedures and methods for monitoring groundwater substitution transfer pumping impacts on surface water features, including the frequency of monitoring and reporting.

Other Available Data to Consider in the Establishing Baseline Conditions

23. The Draft EIS/EIR for the 10-year long-term water transfer project should provide a review of the existing technical documents that describe historic environmental, surface water and groundwater conditions in the Sacramento Valley. The information in these technical documents is critical for establish an accurate and complete environmental baseline and for evaluating the potential impacts from future water transfers. Exhibit 12.1 provides an annotated bibliography provided by researchers with AquAlliance (Nora and Jim) of some of the available technical reports on groundwater resources in the Sacramento Valley. In addition to creating a complete bibliography of relevant technical reports, the Draft EIS/EIR should provide an index map showing the areas or locations covered by each report should be developed. For an example of an index map, see the 1:250000 scale regional geologic map sheets produced by the California Geological Survey.

    Other information is likely available from local government agencies that would document the current condition of the groundwater basin both quantity and quality. For example, Exhibit 12.2 has a list provide by B. Smith, a researcher with AquAlliance, of recently well permits issued since January 1, 2009 for wells that have gone dry in Shasta County. A GIS should be used to plot the locations of the wells that have gone dry. The locations of these dry wells should then be compared to the current groundwater levels, past groundwater substitution transfer pumping areas, and the proposed 10-year long-term project pumping areas. This type of spatial analysis would help to establish an accurate baseline on groundwater elevations and impacts on existing wells, and provide the foundation for assessing the potential impacts from the 10-year long-term groundwater substitution transfer pumping. Other relevant information on baseline conditions in the 10-year Transfer Project area can be found in the Integrated Regional Water Management Plans for the Northern Sacramento Valley Basin, the American River Basin, Yuba County, and Yolo County, see my comment no. 6.

I recommend the Draft EIS/EIR be revised to provide an annotated bibliography and index map(s) of all documents that are relevant to proposed 10-year long-term water transfer project and describe or provide data on the historic and environmental, surface water and groundwater baseline conditions in the Sacramento Valley. I also recommend the Draft EIS/EIR be revised to provide information from local and regional agencies on the conditions of wells within their jurisdictions covering at least the last 10 years. This local information should include, if available, replacement well permits issued for dry wells, complaints or treatment systems installed because of poor water quality, and damage to infrastructure from subsidence or settlement. I recommend this information be mapped and compared to areas of past groundwater substitution transfer pumping, areas of known groundwater level depression, and the pumping area for the proposed 10-year project.

Reference Cited

ASCE (American Society of Civil Engineers), 2012, Pipelines 2012: Innovations in Design, Construction, Operations, and Maintenance, Doing More with Less Title Information, Proceeding edited by Robert J. Card, P.E., M.ASCE; and Michael K. Kenny, M.ASCE, Pipelines Conference 2012, Miami Beach, Florida August 19-22, 2012 (http://content.asce.org/conferences/pipelines2012/)

Barlow, P.M., and Leake, S.A., 2012, Streamflow depletion by wells—Understanding and managing the effects of groundwater pumping on streamflow: U.S. Geological Survey Circular 1376, pp. 84 (*http://pubs.usgs.gov/circ/1376/*)

Galloway, D.L, Bawden, G.W., Leake, S.A. and Honegger, D.G., 2008, Land subsidence hazards, *in* Baum, R.L., Galloway, D.L., and Harp, E.L., Landslide and land subsidence hazards to pipelines: U.S. Geological Survey Open-File Report 2008-1164, p. 192 (http://pubs.usgs.gov/of/2008/1164/)

Brush, C.F., Dogrul, E.C., and Kadir, T.N., 2013a, DWR Technical Memorandum: Development and Calibration the California Central Valley Groundwater- Surface Water Simulation Model (C2VSim), Version 3.02-CG, This report describes version R374 of the C2VSim-CG model, released in June 2013, pp. 193 (http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/download/C2VSim_Model_Report_Final.pdf)

Brush, C.F., Dogrul, E.C., and Kadir, T.N., 2013b, DWR Technical Memorandum: User's Manual for the California Central Valley Groundwater-Surface Water Simulation Model (C2VSim), Version 3.02-CG, This report describes version R374 of the C2VSim-CG model, released in June 2013, pp. 134) (http://baydeltaoffice.water.ca.gov/modeling/hydrology/C2VSim/download/C2VSim_User s_Manual_Final.pdf)

California Energy Commission, November 2014, Energy Maps of California web site, (http://www.energy.ca.gov/maps/)

CH2MHill, 2010, Technical Memorandum - Groundwater Substitution Transfer Impact Analysis, Sacramento Valley, To: Abdul Khan/California Department of Water Resources and Bob Niblack/California Department of Water Resources, From: Peter Lawson/CH2M HILL, Redding, California, March 29, 2010, Project No. 376301.08.01, pp. 21

Constantz, J., 2008, Heat as a tracer to determine streambed water exchanges, Water Resources Research, v. 44, W00D10, pp. 20

Driscoll, F.G., 1986, Groundwater and Wells, Second Edition, Johnson Division, St. Paul, Minnesota, pp. 1089

Department of Conservation, California Geological Survey, 2010, Fault activity map of California: California Geological Survey Geologic Data Map No. 6, map scale 1:750,000, compilation and interpretation by Jennings, C.W., and Bryant, W.A., (http://www.quake.ca.gov/gmaps/FAM/faultactivitymap.html)

Department of Conservation, Division of Oil, Gas and Geothermal Resources, 2000, Energy Map of California, Third Edition, scale 1:1,000,000, (ftp://ftp.consrv.ca.gov/pub/oil/maps/Map_S-2.pdf)

Department of Water Resources, 2008, Land Subsidence: What is it and why is it an important aspect of groundwater management?, by Fulton I, A., in cooperation with the California Department of Water Resources, Northern Region, Groundwater Section 2, pp. 4 (http://www.water.ca.gov/groundwater/docs/WhatIsLandSubsidence.pdf)

Department of Water Resources, 2014a, Maps of Domestic Well Depth Summary with Depth to Groundwater Contours for Wells Screened at Depths Less Than 150 Feet, for Butte County, Colusa County, Glenn County, Tehama County, and Redding Basin, Northern Regional Office, January 2014 (http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Well%20Depth%20Summary%20Maps)

Department of Water Resources, 2014b, Northern Sacramento Valley Change in Groundwater Elevation Maps; Shallow Aquifer Zone, (Well depths less than 200 ft bgs), Spring 2013 to Spring 2014, Plate 1S-A; Intermediate Aquifer Zone, (Well depths generally greater than 200 ft and less than 600 ft deep bgs), Spring 2013 to Spring 2014, Plate 1I-B; Deep Aquifer Zone, (Well depths greater than 600 ft bgs) Spring 2013 to Spring 2014, Plate 1D-B, (http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm)

Domenico, P.A., and Schwartz, F.K., 1990, Physical and Chemical Hydrogeology, John Wiley and Sons, pp. 824

Faunt, C.C., ed., 2009, Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, pp. 225 (http://pubs.usgs.gov/pp/1766/)

Frind, E.O., Muhammad, D.S., and Molson, J.W., 2002, Delineation of Three-Dimensional Well Capture Zone for Complex Multi-Aquifer Systems, Groundwater, v.40, no. 6, pgs. 586-598

Franke, O.L., Reilly, T.E., Pollock, D.W., and LaBaugh, J.W., 1998, Estimating Areas Contributing Recharge to Wells, Lessons from Previous Studies, USGS Circular 1174, pp. 14 (http://water.usgs.gov/ogw/pubs/Circ1174/)

Jenkins, C.T., 1968a, Computation of rate and volume of stream depletion by wells: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. D1, pp. 17 (http://pubs.usgs.gov/twri/twri4d1/)

Jenkins, C.T., 1968b, Techniques for computing rate and volume of stream depletion by wells: Ground Water, v. 6, no. 2, p. 37–46

Kalbus, E., Reinstorf, F. and Schirmer, M., 2006, Measuring methods for groundwater – surface water interactions: a review, Hydrology and Earth System Sciences, v. 10, pgs. 873–887 (www.hydrol-earth-syst-sci.net/10/873/2006/)

Maddock, T., III, and Vionnet, L.B., 1998, Groundwater capture processes under a seasonal variation in natural recharge and discharge, Hydrogeology Journal, v. 6, pgs. 24-32

Miller, C.D., Durnford, D., 2005, Modified use of the "SDF" semi-analytical stream depletion model in bounded alluvial aquifers, in *Hydrology Days 2005*, Colorado State University, Fort Collins, CO, pgs. 146 -159 (http://hydrologydays.colostate.edu/Papers_2005/Miller_paper.pdf)

Miller, C.D., Durnford, D., Halstead, M.R., Altenhofen, J., and Flory, V., 2007, Stream depletion in alluvial valleys using the *SDF* semianalytical model, Ground Water, v. 45, no. 4, p. 506–514

Northern California Water Association, 2014a, Sacramento Valley Groundwater Assessment, Active Management – Call to Action, prepared by Davids Engineering, Macaulay Water Resources, and West Yost Associates, June 2014, pp. 20 (http://www.norcalwater.org/res/docs/NCWA-GW-2014-web.pdf)

Northern California Water Association, 2014b, Sacramento Valley Groundwater Assessment, Active Management – Call to Action, Technical Supplement, prepared by Davids Engineering, Macaulay Water Resources, and West Yost Associates, June 2014, pp. 91 (http://www.norcalwater.org/res/docs/NCWA_supp-web.pdf)

Northern California Water Association, 2014c, Sacramento Valley Water Quality Coalition Groundwater Quality Assessment Report, Final Draft, June 2014, prepared by CH2MHill, pp. 168 (http://www.norcalwater.org/res/docs/NCWA_GWQ_Assessment_7-18-2014_FinalDRAFT.pdf)

O'Rourke, M.J., and Norberg, C., 1992, Longitudinal Permanent Ground Deformation Effects on Buried Continuous Pipelines, National Center for Earthquake Engineering Research, State University of New York at Buffalo, pgs. 181 (http://mceer.buffalo.edu/publications/catalog/reports/Longitudinal-Permanent-Ground-Deformation-Effects-on-Buried-Continuous-Pipelines-NCEER-92-0014.html)

O'Rourke, M.J., and Liu, X., 1999, Response of Buried Pipelines Subject to Earthquake Effects, Monograph Series No. 3, Multidisciplinary Center for Earthquake Engineering Research, MCEER, Research Foundation of the State University of New York and the Multidisciplinary Center for Earthquake Engineering Research, pp. 249 (http://mceer.buffalo.edu/publications/catalog/reports/Response-of-Buried-Pipelines-Subject-to-Earthquake-Effects-MCEER-99-MN03.html)

O'Rourke, M.J., and Liu, X., 2012, Seismic Design of Buried and Offshore Pipelines, Monograph MCEER-12-MN04, Multidisciplinary Center for Earthquake Engineering Research, MCEER, Research Foundation of the State University of New York and the Multidisciplinary Center for Earthquake Engineering Research, pp. 380 (http://mceer.buffalo.edu/pdf/report/12-MN04.pdf)

Pipeline Research Council International, Inc., 2009, Guidelines for Constructing Natural Gas and Liquid Hydrocarbon Pipelines Through Areas Prone to Landslide and Subsidence Hazards, Final Report, prepared by: C-CORE D.G. Honegger Consulting SSD, Inc., January 2009, pp. 203 (http://ntl.bts.gov/lib/46000/46300/46316/FilGet.pdf)

Rosenberry, D.O., and LaBaugh, J.W., eds., 2008, Field techniques for estimating water fluxes between surface water and ground water: U.S. Geological Survey Techniques and Methods 4–D2, pp. 128 (http://pubs.usgs.gov/tm/04d02/)

Stonestrom, D.A., and Constantz, J., 2003, Heat as a tool for studying the movement of ground water near streams: U.S. Geological Survey Circular 1260, pp. 96 (http://pubs.usgs.gov/circ/2003/circ1260/)

U.S. Environmental Protection Agency, 2008, A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems, Project Officer David S. Burden, EPA/600/R-08/003, January 2008, pp. 165 (http://www.epa.gov/ada/)

U.S. Geological Survey, 1984, Hull, L.C., Geochemistry of Ground Water in the Sacramento Valley, California, U.S. Professional Paper 1401-B, pp. 36 (http://pubs.usgs.gov/pp/1401b/report.pdf)

U.S. Geological Survey, 2008, Dawson, B.J., Bennett, G.L., V, and Belitz, Kenneth, 2008, Ground-Water Quality Data in the Southern Sacramento Valley, California, 2005—Results from the California GAMA Program: U.S. Geological Survey Data Series 285, pp. 93 (http://pubs.usgs.gov/ds/285/ds285.pdf)

U.S. Geological Survey, 2010, Thiros, S.A., 2010, Section 13, Conceptual understanding and groundwater quality of the basin-fill aquifer in the Central Valley, California; *in* Thiros, S.A., Bexfield, L.M., Anning, D.W., and Huntington, J.M., eds., 2010, Conceptual understanding and groundwater quality of selected basin-fill aquifers in the Southwestern United States: U.S. Geological Survey Professional Paper 1781, pgs. 267–287 (http://pubs.usgs.gov/pp/1781/pdf/pp1781.pdf)

U.S. Geological Survey, 2011, Bennett, G.L., V, Fram, M.S., and Belitz, Kenneth, 2011, Status of groundwater quality in the Southern, Middle, and Northern Sacramento Valley study units, 2005–08—California GAMA Priority Basin Project: U.S. Geological Survey Scientific Investigations Report 2011–5002, pp. 120 (http://pubs.usgs.gov/sir/2011/5002/pdf/sir20115002.pdf)

Wallace, R.B., Yakup, D., and Annable, M.D., 1990, Stream depletion by cyclic pumping of wells, Water Resources Research, v. 26, no. 6, pgs. 1263–1270 (http://www.hydra.iwr.msu.edu/iwr/cv/proposals/publications/documents/1990/Stream%20Depletion%20by%20Cyclic%20Pumping%20of%20Wells%20Vol%2026%20No%206%20June%201990.pdf)

Zamora, C., 2008, Estimating Water Fluxes Across the Sediment–Water Interface in the Lower Merced River, California: U.S. Geological Survey Scientific Investigations Report 2007–5216, pp. 47 p. (Available at http://pubs.usgs.gov/sir/2007/5216/)

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1.2 – Figure 29 from Barlow and Leake, 2012
2.1 – Composite map of domestic wells, < 150 ft. bgs depth summary maps for northern Sacramento Valley (DWR, 2014a) and traced shallow zone, well depths < 200 ft. bgs., 2004 to 2014 changes in groundwater elevation (DWR, 2014b)
3.1 – Composite plot of DWR's spring 2004 to spring 2014 groundwater elevation change maps for shallow aquifer zone, well depths less than 200 feet bgs, and Draft EIS/EIR SACFEM2013-1990 hydrologic conditions simulations shown in Figures 3.3-29, aquifer depth approximately 35 feet
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4.8 a to f – Figures 34A to C (a, b, c), 35A to C (d, e, f), 37A to C (g, h, i), 38A and B(j, k), 39A and B (l, m), page 92 (n) from Brush and others, 2013a, and page 154 (o) from Faunt, ed., 2009
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8.1a to c – Shallow (a), intermediate (b) and deep (c) composite maps of spring 2004 to spring 2014 groundwater elevation changes in northern Sacramento Valley (DWR, 2014b) with California natural gas pipelines map by California Energy Commission (Exhibit 8.6)
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11.2 – Table 3 from Wallace and others, 1990
11.3a to c – Figures 4 (a), 5 (b) and 6 (c) from CH2MHill, 2010
12.1 – Annotated bibliography of reports relevant to groundwater resource assessment in the Sacramento Valley provided by Nora and Jim, researchers with AquAlliance, 11 pages
12.2 – List of permits to replace dry wells in Shasta County provided by B. Smith, researcher with AquAlliance, 2 pages

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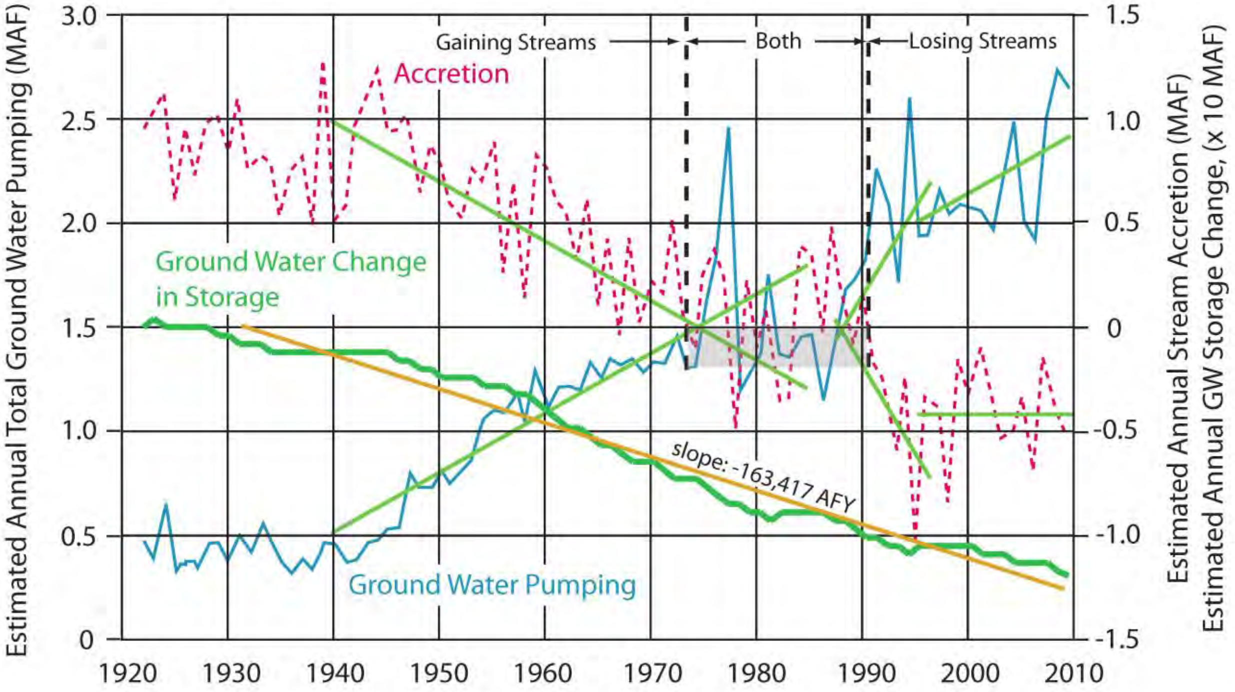
DEFENDING NORTHERN CALIFORNIA WATERS

Exhibit 10.7

Comparison of Ground Water Pumping and Accretion
Sacramento Valley
1920's to 2009



Changes in Accretion, Ground Water Pumping and Ground Water Storage

1. 1920's: ~+953 TAFY accretion with ~+451 TAFY gw pumping = ~ 1,400 TAFY loss in gw storage
2. Late 1960's to Early 1970's: first zero accretion occurs with ~1,300 to ~1,500 TAFY gw pumping
3. 1920' to 2009: ~ +953 TAFY accretion to ~ - 445 TAFY accretion = ~ 1,400 TAFY difference
4. Slope of Accretion 1940 to mid-1970's ~ -27,000 AFY; late 1980's to mid-1990's ~ - 85,000 AFY; ratio ~ 3X
5. 1940 to mid-1970s' and late 1980's to mid 1990's slopes of ground water pumping increases are mirror images of slopes of accretion losses
6. Mid -1990's to 2010 groundwater pumping slope is similar to 1940 to mid-1970's, but accretion slope is flat.
7. Ground water change in storage ~ 12 to 14 MAF 1922 to 2009 (Figure 35, C2VSim User's Manual v. 3.02-CG, v. R374, June 2013, and Table 10 C2VSim Final Report 3.02-CG, v. R374, June 2013)

Kit Custis, certified Geologist and Hydrogeologist for AquAlliance, 2014

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

July 29, 2014

BDCP Comments
Ryan Wulff, NMFS
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814
Via Email to: BDCP.Comments@noaa.gov

Subject: Comments on the Draft BDCP and Draft BDCP EIS/EIR

Dear Mr. Wulff:

AquAlliance represents groundwater dependent communities, farms, and ecosystems in the northern Sacramento Valley and foothills and submits the following comments and questions regarding the Draft Bay Delta Conservation Plan ("Draft Plan") and the Draft BDCP EIS/EIR ("EIS/EIR") ("Project"). The Draft Plan has been developed as a habitat conservation plan ("HCP") pursuant to the federal Endangered Species Act and a natural community conservation plan ("NCCP") pursuant to the California Natural Community Conservation Planning Act for the Sacramento–San Joaquin River Delta. The California Department of Water Resources ("DWR"), the US Bureau of Reclamation ("Bureau") ("Agencies") and many of their contractors[1] are the proponents of the Draft Plan. DWR acts as the lead agency for the purposes of the California Environmental Quality Act ("CEQA") and the Bureau, the U.S. Fish and Wildlife Service, and the U.S. National Marine Fisheries Service serve as the lead agencies for the National Environmental Policy Act ("NEPA").

AquAlliance supports the possibilities found in HCP and NCCP planning processes, but this effort has at its heart a perverse incentive: to drain as much water as possible from the Sacramento River Watershed and the Delta to continue some of the most destructive forms of desert agriculture, urban sprawl, and industrial extraction. The EIS/EIR attempts to disclose impacts as required by CEQA and NEPA, but simultaneously obfuscates many of the direct and indirect impacts. AquAlliance seeks to bring to light some of these hidden impacts and to highlight the absurdity of referring to the Twin Tunnels project, which creates the infrastructure to drain the Sacramento River Watershed and the Delta of essential fresh water, as "Conservation Measure 1."

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[1] " The BDCP proponents include the following state and federal water contractors under either the SWP or CVP: Alameda County Flood Control and Water Conservation District, Zone 7; Kern County Water Agency; Metropolitan Water District of Southern California; San Luis & Delta-Mendota Water Authority; Santa Clara Valley Water District; and Westlands Water District. Additional water contractors may become BDCP proponents in the future through the BDCP process." (EIR/EIS p. 1-1)

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We incorporate by reference the comments submitted by our coalition of C-WIN, CSPA, and AquAlliance and the two comment letters submitted by the Environmental Water Caucus. We also submit the Project modeling analysis prepared for AquAlliance by Professor Kyran Mish. AquAlliance's previous comments on the Bureau's Environmental Assessments for the 2010/2011 Water Transfer Program, the 2013 Water Transfer Program, the 2014 Water Transfer Program, and scoping comments on the Bureau and San Luis Delta Mendota Water Authority's Ten-Year Water Transfer Plan are attached, as well. These four comment letters all pertain to water transfer programs that illustrate the history of Sacramento Valley water transfers to south of the Delta, contain valuable background and impact information for the area of origin, and present AquAlliance's opposition to the water transfers that will expand under BDCP.

Hydrology

1. **The EIS/EIR fails to adequately disclose the planned increase in water transfers from the Sacramento River Watershed to south of the Delta.**

If the Twin Tunnels (the facilities identified in "Conservation Measure 1") are built as planned with the capacity to take 15,000 cubic feet per second ("cfs") from the Sacramento River, they will have the capacity to drain almost two-thirds of the Sacramento River's average annual flow of 23,490 cfs at Freeport[2] (north of the planned Twin Tunnels). As proposed, the Twin Tunnels will also increase water transfers when the infrastructure for the Project has capacity. This will occur during dry years when State Water Project ("SWP") contractor allocations drop to 50 percent of Table A amounts or below or when Central Valley Project ("CVP") agricultural allocations are 40 percent or below, or when both projects' allocations are at or below these levels (EIS/EIR Chapter 5). With this Project, North to South water transfers will be in demand and feasible.

For an understanding of water transfers, it would be valuable to know how much is currently exported from the Delta. The EIS/EIR even fails at this task by explaining the current export regime from the Delta thusly, "Some water flowing through the Delta is exported by the SWP/CVP to areas outside the Delta (see Chapter 5, *Water Supply*)…" (p. 7-1) How is the reader to know that "some water" is an immense number on the order of 5-7 million acre-feet ("MAF")? It would be immensely helpful to the reader of a 40,000+ page document to have a better understanding of the magnitude of water being discussed with it presented openly and clearly at every opportunity, such as page one of Chapter seven.

The EIS/EIR also fails to reveal that the current Project is part of many more programs, plans and projects to develop groundwater in the Sacramento Valley, to develop a "conjunctive" system for the region, and to place water districts in a position to integrate the groundwater into the state water supply. These are plans that the Bureau, together with DWR, water districts, and others have been pursuing and developing for many years.

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[2] USGS 2009. http://wdr.water.usgs.gov/wy2009/pdfs/11447650.2009.pdf

An environmental impact statement should consider "[c]onnected actions." 40 C.F.R. §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3). The Bureau's participation in planning, attempting to execute, and frequently executing the programs, plans and projects has circumvented the requirements of NEPA. DWR's failure to conduct project level CEQA review for water transfers and comprehensive environmental review for the *Sacramento Valley Water Management Agreement* has segmented a known, programmatic project for decades, which means that the Bureau is also failing to comply with state law as the CVPIA mandates. A list of connected actions and similar actions is found in the Cumulative Impacts section below.

2. **The EIS/EIR fails to adequately disclose the existing geology that is the foundation of the Sacramento River's hydrology and the Sacramento Valley's groundwater basins.**

Page 7-1 fails to note a significant geographic feature in the Sacramento River hydrologic region: the Cascade Range. The Cascade Range is the genesis of the Sacramento River and some of its most significant tributaries: the Pit and the McCloud Rivers. This serious omission continues throughout Chapter 7. The enormous influence of the Cascade Mountain Range on not only the Sacramento River, but also the geology, soils, and hydrology of the Sacramento Valley's ground water basin is completely missing. The California Department of Conservation describes the Range thusly: "The Cascade Range, a chain of volcanic cones, extends through Washington and Oregon into California. It is dominated by Mt. Shasta, a glacier-mantled volcanic cone, rising 14,162 feet above sea level. The southern termination is Lassen Peak, which last erupted in the early 1900s. The Cascade Range is transected by deep canyons of the Pit River. The river flows through the range between these two major volcanic cones, after winding across interior Modoc Plateau on its way to the Sacramento River."[3] The Sacramento River Watershed Program provides another simple, adequate description of its namesake: "The Sacramento River is the largest river and watershed system in California (by discharge, it is the second largest U.S. river draining into the Pacific, after the Columbia River). This 27,000–square mile basin drains the eastern slopes of the Coast Range, Mount Shasta, the western slopes of the southernmost region of the Cascades, and the northern portion of the Sierra Nevada. The Sacramento River carries 31% of the state's total surface water runoff."[4]

Without describing the structural attributes of the Sacramento Valley groundwater basin that supports the rivers, streams, communities, and orchards of the region, the EIS/EIR states that, "The Sacramento Valley *groundwater basin* is extremely productive and provides much of the water supply for California's agricultural and urban water needs," (page 7-2). [emphasis added] The EIS/EIR fails to disclose to what extent it is productive, what limitations exist to its

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[3] California Department of Conservation, California Geological Survey, 2002. *California Geomorphic Provences*. [sic]

[4] http://www.sacriver.org/aboutwatershed/roadmap/sacramento-river-basin

productivity, or how it provides so much water for the State when one considers that groundwater is usually used at a local level. These grandiose claims that lack supporting material lead AquAlliance to ask the following questions:

- Have the agencies conflated a watershed with a groundwater basin?
- Is this a Freudian slip that discloses the intent of the agencies to incorporate the Sacramento Valley groundwater basin into the State's water supply as presented in numerous plans and programs over two decades (see list in Cumulative Impacts)?
- If the lead agencies truly believe that the Sacramento Valley groundwater basin has been and is this important to California's agricultural and urban water needs, why has the EIS/EIR failed to identify it in Figures 7-3, *Groundwater Subbasins Underlying the Central Valley*, and 7-4, *Groundwater Model Domains in the Central Valley,* while both figures name the San Joaquin and Tulare basins?

The repeated absence of some of the most basic geologic, geographic and hydrologic information in the EIS/EIR on which the entire Project is dependent causes the reader to wonder what else has been ignored or purposely omitted in the document.

3. The EIS/EIR fails to disclose the over appropriation of water rights in the Sacramento River Watershed

The public is presented with inadequate baseline data with which to consider the consequences of the Project. One such area is the comparison of the average unimpaired flow of the Sacramento River Watershed stacked against the claims that have been made for water. The average annual unimpaired flow in the Sacramento River basin is 21.6 MAF, but the consumptive use claims are an extraordinary 120.6 MAF![5]

4. The EIS/EIR fails to disclose the existing conditions of the Sacramento Valley groundwater.

There is an absence of accurate and detailed information that describes the Sacramento Valley groundwater conditions. The EIS/EIR instead states, "A portion of this applied water, and the remaining 13.9 MAF of runoff, is potentially available to recharge the basin and replenish groundwater storage depleted by groundwater pumping. Therefore, except during drought, the Sacramento Valley groundwater basin is "full," and groundwater levels recover to pre-irrigation season levels each spring. Historical groundwater level hydrographs suggest that even after extended droughts, groundwater levels in this basin recovered to pre-drought levels within 1 or 2 years following the return of normal rainfall quantities." (p. 7-13)

The conclusory statements fail to provide decision-makers and the public with important factual data. For example, a summary of conditions in the Durham area of Butte County find that while water levels may recover after dry to drought periods with intense use, wells aren't returning to previous levels, but moving steadily in a downward trajectory.[6] Additionally, even the Yuba River area, often touted by state and federal agencies as a successful conjunctive use program,

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[5] California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance 2012. *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay-Delta Estuary*.
[6] Buck, Christina 2014. *Groundwater Conditions in Butte County*.

takes 3-4 years to recover from groundwater substitution in the south sub-basin[7] although the Yuba County Water Agency analysis fails to determine how much river water is sacrificed to achieve the multi-year recharge rate.

More examples that contradict long-term predictions of "full" and "recovered" groundwater basins are found in the most current DWR maps.[8] Presented below are tables that illustrate maximum and average groundwater elevation decreases for Butte, Colusa, Glenn, and Tehama counties at three aquifer levels in the Sacramento Valley between the Fall of 2004 and 2013.
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County Fall '04 - '13	**Deep Wells (Max decrease gwe)**	**Deep Wells (Avg. decrease gwe)**
Butte	-11.4	-8.8
Colusa	-31.2	-20.4
Glenn	-60.7	-37.7
Tehama	-19.5	-6.6

County Fall '04 - '13	**Intermediate Wells (Max decrease gwe)**	**Intermediate Wells (Avg. decrease gwe)**
Butte	-21.8	-6.5
Colusa	-39.1	-16.0
Glenn	-40.2	-14.5
Tehama	-20.1	-7.9

County Fall '04 - '13	**Shallow Wells (Max decrease gwe)**	**Shallow Wells (Avg. decrease gwe)**
Butte	-13.3	-3.2
Colusa	-20.9	-3.8
Glenn	-44.4	-8.1
Tehama	-15.7	-6.6

Below are the results from DWR's spring monitoring for Sacramento Valley groundwater basin from 2004 to 2014.

County Spring '04 - '14	**Deep Wells (Max decrease gwe)**	**Deep Wells (Avg. decrease gwe)**
Butte	-20.8	-14.6
Colusa	-26.9	-12.6
Glenn	-49.4	-29.2
Tehama	-6.1	-5.3

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[7] 2012. *The Yuba Accord, GW Substitutions and the Yuba Basin*. Presentation to the Accord Technical Committee.

[8] http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm

County Spring '04 - '14	Intermediate Wells (Max decrease gwe)	Intermediate Wells (Avg. decrease gwe)
Butte	-25.6	-12.8
Colusa	-49.9	-15.4
Glenn	-54.5	-21.7
Tehama	-16.2	-7.9

County Spring '04 - '14	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-23.8	-7.6
Colusa	-25.3	-12.9
Glenn	-46.5	-12.6
Tehama	-38.6	-10.8

The DWR data clearly present a different picture of the condition of the Sacramento Valley groundwater basin over time than what is provided in the EIS/EIR. This must be corrected and considered in the NEPA and CEQA process.

5. **The EIS/EIR fails to disclose direct and indirect groundwater impacts to the Sacramento Valley that would result from expanded cross-Delta water transfers**

Internal BCDP communication from the Department of the Interior indicates that the purchase of approximately 1.3 MAF of water is being planned as a means to make up for flows that would be removed from the Sacramento River by the BDCP tunnels.[9] As provided above, it is possible that the Twin Tunnels may extract almost two-thirds of the average annual flow from the Sacramento River, which is what creates the need for the 1.3 MAF. The source of the additional water that is integral to the Project is not disclosed or analyzed in the EIS/EIR. If Sacramento Valley groundwater is the intended target, this must be disclosed and analyzed in a re-circulated Draft EIS/EIR.

6. **The EIS/EIR vastly understates the extent of groundwater depletion in the San Joaquin Valley.**

In regards to the San Joaquin groundwater basin, the DEIS/DEIR states that, "Long-term groundwater production throughout this basin has lowered groundwater levels beyond what natural recharge can replenish." (p. 7-4) It is no surprise that the relentless extraction of groundwater in the San Joaquin Valley has halted natural recharge, but this mild under-statement of fact masks the tremendous devastation that has occurred there. "Mining" would provide a more accurate depiction of what has transpired over 80+ years instead of "production." The USGS exposes this form of groundwater exploitation in the San Joaquin and Santa Clara Valleys (1999) in Circular 1182 entitled Part I, "Mining Ground Water." Current research by Michelle Sneed expands on the impacts from groundwater mining in the San Joaquin by disclosing the extent of historic and current subsidence levels.[10]

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[9] Belin, Lety Summary of Assurances Email, dated 2/25/13.

[10] Sneed, Michelle et al. 2013. *Land Subsidence along the Delta-Mendota Canal in the Northern Part of the San Joaquin Valley, California*. http://pubs.usgs.gov/sir/2013/5142/

Without explanation or apology, the EIS/EIR omits this current analysis, mentions “overall subsidence” in the Mendota area of 28 feet (without a citation or timeframe), and then recounts older research: “Most San Joaquin Valley subsidence is thought to have been caused primarily by deep aquifer system pumping during the 1950s and 1960s, but is considered to have largely abated since 1974 because of the development of more reliable agricultural surface water supplies from the Delta-Mendota Canal and Friant-Kern Canal (U.S. Geological Survey 1999).” The absence of current scientific research in the EIS/EIR regarding groundwater mining and subsidence leaves the document exceedingly deficient under CEQA and NEPA and the agencies exposed to charges of ineptitude.

Economics of the Draft Plan

The University of the Pacific Eberhardt School of Business concluded in 2012:

> This report updates an initial benefit-cost analysis of the water conveyance tunnels at the center of the Bay Delta Conservation Plan (BDCP). Primarily using the results of the BDCP’s own economic benefit and cost studies, we find a benefit-cost ratios ranging from 0.3 to 0.5, meaning that there are between $1.90 and $3.36 of costs for every $1 in economic benefits. To put this in perspective, this benefit-cost ratio is 80% lower than those estimated for the State’s high-speed rail project.
>
> When these very low benefit-cost ratios are considered alongside the inconsistent and incomplete financial plans, it is clear that the Delta water conveyance tunnels proposed in the draft BDCP are not justified on an economic or financial basis.

How has the Project responded and adjusted to such a stinging rebuke by such a reputable source or has it been shunted aside as an illegitimate critique that is contrary to the outcome sought by the agencies?

Modeling

1. **The EIS/EIR hinges on models and modeling that are seriously deficient.**

The agencies had opportunities to advance both water and environmental planning once again through the Bay Delta Conservation Plan. Like a journeyman in any trade, the tools one has and the skills in using them are what distinguish a journeyman from an apprentice or an imposter. DWR and the Bureau have had ample feedback on the Draft Plan to know, as a journeyman should, that their toolbox is wanting and their use of the tools they selected is inadequate. Among all the areas where this proves to be the case (see referenced June 11, 2014 EWC comments), nowhere is it more glaring than in the model and modeling that are the foundation for the entire Project.

Kyran Mish, Ph.D., provides a succinct review of the Project model and modeling and finds serious deficiencies and concludes:

> The technical risks associated with this ambitious project, and the immense budget required for its construction and operation, clearly mandate that the best-

> available scientific principles be deployed and documented in all project artifacts, including the Draft EIS/EIR. It is technically indefensible that these principles (including all fundamental physical assumptions) are not readily available in the tens of thousands of pages of the Draft EIS/EIR, and the omission of the particulars of the science used to estimate these environmental effects precludes both accurate prediction of the environmental effects of this project, as well as independent technical verification of the claims made in the plan. Since independent verification is a fundamental hallmark of scientific investigation, the current version of the BDCP Draft EIS/EIR fails even this most basic test of science.

He continues his review with concerns regarding seismic risks, liquefaction, and the model, CalSim II:

- "The plan promises that seismic risks will be addressed during the design and construction phases of the project, but also explicitly admits that no substantial efforts toward accurate identification of seismic risks yet exist within the plan's scope. Thus the costs of mitigating these risks is unknown from the outset, and any estimate of project cost must thus be considered to be a substantial underestimate of actual project lifespan costs."
- "One of the worst cases of poor risk assessment in seismic sections of the report is the discussion of possible liquefaction effects. After a good introductory discussion of the natural phenomenon of liquefaction, the Draft EIS/EIR provides little in the way of realistic mitigation plans to handle the very-real risk that liquefaction could destroy the project once it is built (or even damage components of the system during construction)."
- "In the interest of simplicity, only a few key concerns about the suitability of the current version of CalSim will be presented here, but these should be sufficient to indicate that CalSim II does not yet warrant sufficient trust to justify its use for analysis of the alternatives that lie at the heart the water-transfer plan."

AquAlliance includes Dr. Mish's entire analysis of the Project model and modeling with our comments.

Cumulative Impacts

The Ninth Circuit has made clear that NEPA mandates "a useful analysis of the cumulative impacts of past, present and future projects." *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). Indeed, "[d]etail is required in describing the cumulative effects of a proposed action with other proposed actions." *Id.* The very cursory cumulative effects discussion contained in the EIS/EIR regarding groundwater plainly fails to meet this standard.

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

As discussed above, the Project is dependent on the hydrology of the Delta watershed to implement the Draft Plan. The EIS/EIR blatantly fails to consider other past, present and reasonably foreseeable future actions in the Delta watersheds by deferring analysis to a future day. To illustrate the omissions in the EIS/EIR, AquAlliance submits a partial list of Sacramento River Watershed programs, plans, and projects in which the agencies have participated or funded, that, at a minimum, should have been presented in the EIS/EIR for cumulative impact discussion, and better yet, analyzed to comply with CEQA and NEPA:

- The *Sacramento Valley Water Management Agreement* was signed in 2002 and the need for a programmatic EIS/EIR was clear to both the Bureau and DWR. The process was initiated, but never completed.[11] Indeed, even the short-term phase of the Sacramento Valley Water Management Program is the subject of an ongoing scoping process for a Programmatic EIS that has not yet been completed (*id.*)
- The *Sacramento Valley Integrated Regional Water Management Plan* (2006).
- The *Sacramento Valley Water Management Plan.* (2007)
- The Stony Creek Fan Partnership Orland Project Regulating Reservoir Feasibility Investigation.
- The Glenn Colusa Irrigation District ("GCID") *Stony Creek Fan Aquifer Performance Testing Plan* to install seven production wells in 2009 that extracted 26,530 AF of groundwater as an experiment.
- GCID's Lower Tuscan Conjunctive Water Management Program (Bureau provided funding).
- GCID's water transfers in 2008 and in 2010, 2013, and 2014.
- The Drought Water Bank for 2009.
- The Bureau of Reclamation's 2010/2011 Water Transfer Program of 395,910 af of CVP and non-CVP water with 154,237 AF of groundwater substitution (EA/FONSI p. 2-4 and 3-107).
- The Bureau's planned 2012 water transfers of 76,000 af of CVP water all through ground water substitution.
- The Bureau's 2013 Water Transfer Program
- The Bureau and San Luis Delta Mendota's 2014 Water Transfer Program.
- The Bureau of Reclamation's 600,000 AF, North-to-South Water Transfer Program. EIS/EIR pending since scoping in January 2011.

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[11] *The Bureau actually began its own Programmatic EIS to facilitate water transfers from the Sacramento Valley, and the interconnected actions that are integrally related to it, but never completed that EIS and has impermissibly broken out segments of the overall Program for piecemeal review for water transfers for GCID's 2008 Forbearance Transfer, the 2009 Drought Water Bank, 2010/2011,2012, 2013, and 2014.. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "includ[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" Id. At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").*

The Bureau Has Failed to Consider the Cumulative Impact of Other Groundwater Development and Surface Water Diversions Affecting the Sacramento Valley

In addition to the improper segmentation evident in the draft EIS/EIR, the assessment of environmental impacts is further deficient because the Bureau has failed to consider the cumulative impacts of the planned groundwater extraction when taken in conjunction with other projects proposed for the development of groundwater and surface water. The General Plans of the counties and cities in the Sacramento Valley must be considered as well as the agricultural crop and land use changes that have taken and are taking place. Lastly, we must emphasize again that existing conditions in the Sacramento River Watershed, that is so crucial to California's population, economy, and environment, and therefore the Project, must be more accurately understood and described, so that impacts may be more accurately assessed from the Project.

Conclusion

The Draft EIS/EIR is seriously deficient as noted here, in the coalition comments of C-WIN, CSPA, and AquAlliance, the CSPA comments, and the EWC comments. AquAlliance requests that you incorporate these comments into a new and re-circulated Draft EIS/EIR.

Sincerely,

B. Vlamis

Barbara Vlamis
AquAlliance's Executive Director

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

CALIFORNIA SPORTFISHING PROTECTION ALLIANCE
CSPA
Since 1983

ATA
AQUA TERRA AERIS
LAW GROUP

December 1, 2014

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Subject: Comments on the *Draft Environmental Impact Statement/Environmental Impact Report Long Term North-to-South 2015-2024 Water Transfer Program*

Dear Mr. Hubbard and Ms. Mizuno:

AquAlliance, California Sportfishing Protection Alliance ("CSPA"), and Aqua Terra Aeris submit the following comments and questions for the Bureau of Reclamation ("Bureau") and the San Luis Delta Mendota Water Authority's ("SLDMWA") ("Lead Agencies") *Draft Environmental Impact Statement* ("EIS") and *Environmental Impact Report* ("EIR") ("EIS/EIR"), for the 2015-2024 *Long Term North-to-South Water Transfer Program* ("Project" or "*2015-2024 Water Transfer Program*").

AquAlliance exists to sustain and defend northern California waters. We have participated in past water transfer processes, commented on past transfer documents, and sued the Bureau twice in the last five years. In doing so we seek to protect the Sacramento River's watershed in order to sustain family farms and communities, enhance Delta water quality, protect creeks and rivers, native flora and fauna, vernal pools and recreational opportunities, and to participate in planning locally and regionally for the watershed's long-term future. The *2015-2024 Water Transfer Program* is seriously deficient and should be withdrawn. If the Bureau and DWR are determined to purse water transfers from the Sacramento Valley, AquAlliance requests that the agencies regroup and prepare an adequate programmatic EIS/EIR.

This letter relies significantly on, references, and incorporates by reference as though fully stated herein, for which we expressly request that a response to each comment contained therein be provided, the following comments submitted on behalf of AquAlliance:

- Custis, Kit H., 2014. Comments and recommendations on U.S. Bureau of Reclamation and San Luis & Delta-Mendota Water Authority Draft Long-Term Water Transfer DRAFT EIS/EIR, Prepared for AquAlliance. ("Custis," Exhibit A)
- ECONorthwest, 2014. Critique of Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report Public Draft, Prepared for AquAlliance. ("EcoNorthwest," Exhibit B)
- Mish, Kyran D., 2014. Comments for AquAlliance on Long-Term Water Transfers Draft EIR/EIS. ("Mish," Exhibit C)
- Cannon, Tom, Comments on Long Term Transfers EIR/EIS, Review of Effects on Special Status Fish. Prepared for California Sportfishing Protection Association. ("Cannon," Exhibit D)

In addition, we renew the following comments previously submitted, attached hereto, as fully bearing upon the presently proposed project and request:

- *2009 Drought Water Bank* ("DWB"). (Exhibit F)
- *2010-2011 Water Transfer Program*. (Exhibit G)
- *2013 Water Transfer Program*. (Exhibit G)
- *2014 Water Transfer Program*. (Exhibit G)
- C-WIN, CSPA, AquAlliance Comments and Attachments for the Bay Delta Conservation Plan's EIS/EIR. (Exhibit H)
- AquAlliance's comments on the Bay Delta Conservation Plan's EIS/EIR. (Exhibit H)
- CSPA's comments on the Bay Delta Conservation Plan's EIS/EIR. (Exhibit H)

I. The EIS/EIR Contains an Inadequate Project Description.

A "finite project description is indispensable to an informative, legally adequate EIR." *County of Inyo v. City of Los Angeles* (1977) 71 Cal.App.3d 185, 192. CEQA defines a "project" to include "the whole of an action" that may result in adverse environmental change. CEQA Guidelines § 15378. A project may not be split into component parts each subject to separate environmental review. *See*, *e.g.*, *Orinda Ass'n v. Board of* Supervisors (1986) 182 Cal.App.3d 1145, 1171; *Riverwatch v. County of San Diego* (1999) 76 Cal.App.4th 1428. Without a complete and accurate description of the project and all of its components, an accurate environmental analysis is not possible. *See*, *e.g.*, *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818, 829; *Sierra Club v. City of Orange* (2008) 163 Cal.App.4th 523, 533; *City of Santee v. County of San Diego* (1989)214 Cal.App.3d 1438, 1450; *Blue Mountains Biodiversity Project v. United States Forest Service*, 161 F.3d 1208, 1215 (9th Cir. 2008).

As discussed, below, and in the expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance, the EIS/EIR fails to comport with these standards.

a. The Project / Proposed Action Alternative Description Lacks Detail Necessary for Full Environmental Analysis.

i. Actual transfer buyers, sellers, modes, amounts, criteria, market demands, availability, and timing, are undisclosed.

The Proposed Action Alternative is poorly specified and needs additional clarity before decision-makers and the public can understand its human and environmental consequences. The Lead Agencies tacitly admit that they have no idea how many acre-feet of water may be made available, by what mechanism the water may be made available (fallowing, groundwater substitution, or crop changes), or to what ultimate use (public health, urban, agricultural) the water may be put.

Glenn Colusa Irrigation District is listed as the largest potential seller, but its General Manager, Thad Bettner, asserted publicly on October 7, 2014 that the district hadn't committed to the 91,000 AF found in Table ES-2 (Potential Sellers). GCID subsequently sent the Bureau a letter that states that GCID plans to pursue its own Groundwater Supplemental Supply Program and that, "It is important for Reclamation to understand that GCID has not approved the operation of any District facilities attributed to the LTWTP Action/Project that is presented in the draft EIR/EIS." [1] The letters continues stating that, "It is important to underscore that GCID would prioritize pumping during dry and critically dry water years for use in the Groundwater Supplemental Supply Program, and thus wells used under that program would not otherwise be available for the USBR's LTWTP." First, these public and written comments contradict the EIS/EIR on page 3.8-37 where it states that, "The availability of supplies in the seller service area was determined based on data provided by the potential sellers." Second, the largest potential seller in the *2015-2024 Water Transfer Program* is seemingly unable or unwilling to participate in the groundwater substitution component during dry and critically dry years. In addition, GCID has stated that "it will not participate in a groundwater substitution transfer, and for land idling reduce the acreage from 20,000 acres to no more than 10,000 acres." [2] Similarly, the Sacramento Suburban Water District received $2 million from the Governor's Water Action Plan to move groundwater to member agencies that have been "[h]eavily dependent on Folsom reservoir," according to John Woodling of the Sacramento Regional Water Authority. [3] Woodling continues that, "During these dry times, the groundwater basin really is our insurance

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[1] GCID October 14, 2014.

[2] GCID November 6, 2014 Board Meeting Item #6.

[3] Ortiz, Edward 2014. *Region's water districts split $14 million for drought relief*. Sacramento Bee November 7, 2014.

policy," (*Id*). Knowing that smart water managers are very aware of this fact, why would Sacramento Suburban Water District turn around and propose to sell 30,000 AF of water to the out-of-region buyers through groundwater substitution transfers during the Project's "[d]ry and critically dry years"? In short, the EIS/EIR has no way of knowing what transfers may occur, and when.

It is also not possible to determine with confidence just how much water is requested by potential urban and agricultural buyers and how firm the requests are. What are SLDMWA's specific requests for agricultural or urban uses of Project water? What are the SLDMWA's present agricultural water demands for the 850,000 acres that it serves? Left to guess at the possible requests for water, we look at the 2009 DWB where there were between 400,000 and 500,000 AF of presumably urban buyer requests alone (which had priority over agricultural purchases, according to the 2009 DWB priorities) and a cumulative total of less than 400,000 AF from willing sellers. It is highly possible, based on the example during the 2009 DWB, that many buyers are not likely to have their needs addressed by the *2015-2024 Water Transfer Program*. How would this affect the project objectives and purpose? How would this affect variable circumstances for other proposed transfers?

The EIS/EIR also fails to address the ability and willingness of potential buyers to pay for Project water given the supplies that may be available. Complaints from agricultural water districts were registered in the comments on the Draft Environmental Water Account EIS/EIR and reported in the Final EIS/EIR in January 2004 indicating that they could not compete on price with urban areas buying water from the EWA. Given the absence of priority criteria, will agricultural water buyers identified in Table ES-1 have the ability to buy water when competing with urban districts? Moreover, since buyers are not disclosed in the EIS/EIR for non-CVP river water, these further effects on water market conditions and competition between agricultural and urban sectors is impossible to evaluate. Who are the buyers that may request non-CVP river water, and what are their maximum requests? That DWR is not the CEQA lead agency further complicates the evaluation of competition for water in the EIS/EIR.

Nor does the *2015-2024 Water Transfer Program* prevent rice growers (or other farmers) from "double-dipping," but actually encourages it. Districts and their growers have opted to turn back their surface supplies from the CVP and the State Water Project and substitute groundwater to cultivate their rice crop—thereby receiving premiums on both their CVP contract surface water as well as their rice crop each fall when it goes to market. There appear to be no caps on water sale prices to prevent windfall profits to sellers of Sacramento Valley water — especially for crops with high market prices, such as rice.

The EIS/EIR is inadequate because it fails to identify and analyze the market context for crops as well as water that would ultimately influence the size and scope of the *2015-2024 Water*

Transfer Program.[4] The Project's sellers and buyers are highly sensitive to the influences of prices—prices for water as well as crops such as rice, orchard and vineyard commodities, and other field crops. It is plausible that crop idling would occur more in field crops, while groundwater substitution would be more likely for orchard and vineyard crops. However, high prices for rice—the Sacramento Valley's largest field crop— undermines this logic and leads to substantial groundwater substitution. These potential issues and impacts should be recognized in the EIS/EIR because crop prices are key factors in choices potential water sellers would weigh in deciding whether to idle crops, substitute groundwater, or decline to participate in the Project altogether.

To enable a more complete and discrete project description, the EIS/EIR should propose criteria other than price alone to manage allocation of state water resources. The EIS/EIR should consider some priority criteria as was included in the 2009 Drought Water Bank EA/FONSI (p. 3-88). Do both authorizing agencies, the Bureau and DWR, lack criteria to prioritize water transfers? Are transfers approved on a first-come first-serve basis, as generated by market conditions alone? What is the legal or policy basis to act without providing priority criteria? A lack of criteria fails to encourage regions to develop their own water supplies more efficiently and cost-effectively without damage to resources of other regions. If criteria will be applied, these need to be disclosed and analyzed in the EIS/EIR.

Additional uncertainty caused by the incomplete project description includes:

- How many of the proposed transfers would be one year in duration, multi-year, or permanent. How will the duration of any agreement be determined? The duration of a transfer agreement will have dramatic effects on the water market as well as the environmental impact analysis.
- The EIS/EIR purports to be a 10 year project, but is there an actual sunset date, since it continues serially in multiple years? Could any transfer be approved in the next 10 years that would extend beyond 2024?
- The proposed program provides no way to know what ultimate use transferred water will be put to; nor does the EIS/EIR provide any way to know what activities may occur on idled cropland. The EIS/EIR assumptions on these points are inherently incomplete and fail to support any discrete environmental analysis.

In sum, the proposed program provides no way to know which transfers may or may not occur, individually or cumulatively. The lack of a stable and finite project description undermines the entire EIS/EIR. As discussed further, below, description of the environmental setting, evaluation of potentially significant impacts, and formulation of mitigation measures, among other issues, all are rendered unduly imprecise, deferred, and incomplete, subject to the theoretical transfers taking shape at some, unknown, future time.

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[4] EcoNorthwest (Exhibit B).

ii. Historic transfer data is excluded.

Absent from the DEIS/EIR are any of the required monitoring reports from previous transfer projects. *See*, *e.g.*, *Citizens for East Shore Parks v. State Lands Commission* (2010) 48 Cal.App.4th 549; *Communities for a Better Environment v. South Coast Air Quality Mgmt. Dist.* (2010) 48 Cal.App.4th 310. Without the required monitoring reports, the public is left in the dark regarding this new proposal to sell up to 600,000 AF annually over a 10 year period. No information is provided regarding the impacts to downstream users, wells near production wells, the Sacramento River and its tributaries, refuges, water quality, special status species and the San Francisco Bay Delta Estuary from past CVP transfers or cumulatively including non-CVP water transfers in the area of origin. For example, groundwater substitution transfers and transfers that result in reduced flows in combination with below normal water years are known to have to have the potential for significant impacts on water quality, fish, wildlife and the flows in the Sacramento River and its tributaries. Providing all such documentation of the terms, conditions, effects, and outcomes of prior transfers is integral to understanding the proposed Project.

b. The Proposed Project is in Fact a Proposed Program.

The lack of any stable, discrete, project description, at best, renders the proposed project a "program," rather than any specific project itself. "[A] *program* EIR is distinct from a *project* EIR, which is prepared for a specific project and must examine in detail site-specific considerations." *Center for Sierra Nevada Conservation v. County of El Dorado* (2012) 202 Cal.App.4th 1156, 1184. As discussed further, below, this EIS/EIR does not and cannot complete site-specific and project-specific analysis of unknown transfers at unknown times. Buyers and sellers have "expressed interest," but no specific transfers or combination of transfers are proposed, and we don't know which may be proposed or ultimately approved.

Put differently, the EIS/EIR project description is not simply inadequate: the EIS/EIR fails to propose or approve any project at all. Instead, the EIS/EIR should be recharacterized and revised as a program EIS/EIR. Indeed, agency documents have referred to this program, as such, for years. (E.g., Federal Register /Vol. 75, No. 248 /Tuesday, December 28, 2010 /Notices *Long-Term North to South Water Transfer Program, Sacramento County, CA*; Final EA/FONSI for 2010-2011 Water Transfer Program.[5]) And other external sources also support the proposition that this EIS/EIR does not and cannot review and approve specific transfers:

> "Each transfer is unique and must be evaluated individually to determine the quantity and timing of real water made available." (BDCP DEIR at 1E-2.)
>
> "Although this document seeks to identify in the best and most complete way possible the information needed for transfer approval, to both expedite that approval and to

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[5] http://www.usbr.gov/newsroom/newsrelease/detail.cfm?RecordID=31781

> reduce participant uncertainty, each transfer is unique and must be considered on its individual factual merits, using all the information that is available at the time of transfer approval and execution of the conveyance or letter of agreement with the respective Project Agency in accordance with the applicable legal requirements. This document does not pre-determine those needs or those facts and does not foreclose the requirement and consideration of additional information." (Draft Technical Information for Preparing Water Transfer Proposals ("DTIPWTP") 2014.)

Indeed, the Bureau and DWR have known for over a decade that programmatic environmental review was and is necessary for water transfers from the Sacramento Valley. The following examples highlight the Bureau and DWR's deficiencies in complying with NEPA and CEQA.

a. The Sacramento Valley Water Management Agreement was signed in 2002, and the need for a programmatic EIS/EIR was clear at that time it was initiated but never completed.
b. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken.
c. Sacramento Valley Integrated Regional Water Management Plan (2006).
d. The Sacramento Valley Water Management Plan (2007).
e. The CVPIA mandates the Bureau contribute to the State of California's *long-term* efforts to protect the San Francisco Bay/Sacramento-San Joaquin Delta Estuary, among other things. (EIS/EIR 1-10.)

Accordingly, the EIS/EIR should be revised to state that it does not and cannot constitute sufficient environmental review of any particular, as-of-yet-unknown, water transfer proposal; and instead be revised, restructured, and recirculated to provide programmatic policies, criteria, and first-tier environmental review.

c. <u>The EIS/EIR Improperly Segments Environmental Review of the Whole of this Program.</u>

As discussed throughout these comments, the proposed Project does not exist in a vacuum, but rather is another transfer program in a series of many that have been termed either "temporary," "short term," "emergency," or "one-time" water transfers, and is cumulative to numerous broad programs or plans to develop regional groundwater resources and a conjunctive use system. The *2015-2024 Water Transfer Program* is also only one of several proposed and existing projects that affect the regional aquifers.

For example, the proposed Project is, in fact, just one project piece required to implement the Sacramento Valley Water Management Agreement ("SVWMA"). The Bureau has publically stated the need to prepare programmatic environmental review for the SVWMA for over a decade, and the present EIS/EIR covers a significant portion of the program agreed to under the SVWMA. In 2003, the Bureau published an NOI/NOP for a "Short-term Sacramento Valley Water Management Program EIS/EIR." (68 Federal Register 46218 (Aug 5, 2003).) As summarized on the Bureau's current website:

> The Short-term phase of the SVWM Program resolves water quality and water rights issues arising from the need to meet the flow-related water quality objectives of the 1995 Bay-Delta Water Quality Control Plan and the State Water Resources Control Board's Phase 8 Water Rights Hearing process, and would promote better water management in the Sacramento Valley and develop additional water supplies through a cooperative water management partnership. Program participants include Reclamation, DWR, Northern California Water Association, San Luis & Delta-Mendota Water Authority, some Sacramento Valley water users, and Central Valley Project and State Water Project contractors. SVWM Program actions would be locally-proposed projects and actions that include the development of groundwater to substitute for surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells, reservoir re-operation, system improvements such as canal lining, tailwater recovery, and improved operations, or surface and groundwater planning studies. These short-term projects and actions would be implemented for a period of 10 years in areas of Shasta, Butte, Sutter, Glenn, Tehama, Colusa, Sacramento, Placer, and Yolo counties.[6]

The resounding parallels between the SVWMA NOI/NOP and the presently proposed project are not merely coincidence: they are a piece of the same program. In fact, the SVWMA continues to require the Bureau and SLDMWA to facilitate water transfers through crop idling or groundwater substitution:

> *Management Tools for this Agreement.* A key to accomplishing the goals of this Agreement will be the identification and implementation of a "palette" of voluntary water management measures (including cost and yield data) that could be implemented to develop increased water supply, reliability, and operational flexibility. Some of the measures that may be included in the palette are:
> . . .
> (v) Transfers and exchanges among Upstream Water Users and with the CVP and SWP water contractors, either for water from specific reservoirs, or by substituting groundwater for surface water . . . [7]

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[6] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788

[7] http://www.norcalwater.org/wp-content/uploads/2010/12/sac_valley_water_mgmt_agrmt_new.pdf

It is abundantly clear that the Bureau and SLDMWA are proposing a program through the present draft EIS/EIR to implement this management tool, as required by the SVWMA. But neither CEQA nor NEPA permit this approach of segmenting and piecemealing review of the whole of a project down to its component parts. The water transfers proposed for this project will directly advance SVWMA implementation, and the Bureau and DWR must complete environmental review of the whole of the program, as first proposed in 2003 but since abandoned. For example, the draft EIS/EIR does not reveal that the current Project is part of a much larger set of plans to develop groundwater in the region, to develop a “conjunctive” system for the region, and to integrate northern California’s groundwater into the state’s water supply.

In this vein the U.S. Department of Interior, 2006. Grant Assistance Agreement, *Stony Creek Fan Conjunctive Water Management Program and Regional Integration of the lower Tuscan Groundwater formation* laid bare the intentions of the Bureau and its largest Sacramento Valley water district partner, Glenn Colusa Irrigation District, to take over the Tuscan groundwater basin to further the implementation of the SVWMA, stating:

> GCID shall define three hypothetical water delivery systems from the State Water Project (Oroville), the Central Valley Project (Shasta) and the Orland Project reservoirs sufficient to provide full and reliable surface water delivery to parties now pumping from the Lower Tuscan Formation. The purpose of this activity is to describe and compare the performance of three alternative ways of furnishing a substitute surface water supply to the current Lower Tuscan Formation groundwater users to eliminate the risks to them of more aggressive pumping from the Formation and to optimize conjunctive management of the Sacramento Valley water resources.

d. <u>The Project Description Contains an Inadequate Statement of Objectives, Purpose, and Need.</u>

The lack of a stable project description/prosed alternative, as discussed, above, further obfuscates the need for the Project. Further, without programmatic criteria to prioritize certain transfers, the public is not provided with even a basic understanding of the need for the Project. The importance of this section in a NEPA document can’t be overstated. “It establishes why the agency is proposing to spend large amounts of taxpayers' money while at the same time causing significant environmental impacts… As importantly, the project purpose and need drives the process for alternatives consideration, in-depth analysis, and ultimate selection. The Council on Environmental Quality (CEQ) regulations require that the EIS address the "no-action" alternative and "rigorously explore and objectively evaluate all reasonable alternatives." Furthermore, a well-justified purpose and need is vital to meeting the requirements of Section 4(f) (49 U.S.C. 303) and the Executive Orders on Wetlands (E.O. 11990) and Floodplains (E.O. 11988) and the Section 404(b)(1) Guidelines. Without a well-defined, well-established and well-justified purpose and need, it will be difficult to determine which alternatives are reasonable, prudent and practicable, and it may be impossible to dismiss the no-build alternative" [8]

With the importance of a Purpose and Need statement revealed above, the Project's version for purposes of NEPA states that, "The purpose of the Proposed Action is to facilitate and approve voluntary water transfers from willing sellers upstream of the Delta to water users south of the Delta and in the San Francisco Bay Area. Water users have the need for immediately implementable and flexible supplemental water supplies to alleviate shortages," (p. 1-2). Noticeably missing from this section of the EIS/EIR is a statement about the <u>Bureau's</u> purpose and need, not the buyers' purpose and need. The omission of *any* need on the Bureau's part for this Project highlights the conflicts in the Bureau's mission, deficiencies in planning for both the short and long term, and the inadequacy of the EIS/EIR that should provide the public with the basis for the development of the range of reasonable alternatives and the identification and eventual selection of a preferred alternative. The *Reclamation's NEPA Handbook* (2012) stresses that, "The need for an accurate (and adequate) purpose and need statement early in the NEPA process cannot be overstated. This statement gives direction to the entire process and ensures alternatives are designed to address project goals." (p.11-1)

For purposes of CEQA, the Project Objectives (p. 1-2) go on to state that,

> SLDMWA has developed the following objectives for long-term water transfers through 2024:
>
> - Develop supplemental water supply for member agencies during times of CVP shortages to meet existing demands.
> - Meet the need of member agencies for a water supply that is immediately implementable and flexible and can respond to changes in hydrologic conditions and CVP allocations.
>
> Because shortages are expected due to hydrologic conditions, climatic variability, and regulatory requirements, transfers are needed to meet water demands.

But merely asserting that there are "demands" from their member lacks context, specificity, and rigor. It also fails to mention the need of the non-member buying agencies involved in the Project.

Some context for the policy failures that lead to the stated need for the Project must be presented. First, the hydrologic conditions described on pages ES-1, 1-1, and 1-2 almost always

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[8] Federal Transportation and Highway Administration, 1990. *NEPA and Transportation Decisionmaking: The Importance of Purpose and Need in Environmental Documents.* http://www.environment.fhwa.dot.gov/projdev/tdmneed.asp

apply to the entire state, including the region where sellers are sought, not just the areas served by SLDMWA and non-member buyers as presented here. Second, SLDMWA has chronic water shortages due to its contractors' junior position in water rights, risks taken by growers to plant permanent crops, and serious long-term overdraft in its service area. Where is this divulged? Third, SLDMWA or its member agencies have sought to buy and actually procured water in many past water years to make up for poor planning and risky business decisions, which violates CEQA's prohibition against segmenting a project to evade proper environmental review.[9] The habitual nature of the transfers is acknowledged on pages ES-1 and 1-1 stating, "In the past decades, water entities have been implementing water transfers to supplement available water supplies to serve existing demands, and such transfers have become a common tool in water resource planning." (See Table 1 for an attempt at documenting transfers since actual numbers are not disclosed in the EIS/EIR).

The Bureau and DWR's facilitation of so-called "temporary" annual transfers in 12 of the last 14 years is illustrated in Table 1 (2014 transfer totals have not been tallied to date).

Table 1. The table is based on one from Western Canal Water District's Negative Declaration for a 2010 water transfer.

Past Water Transfers from the Sacramento Valley Through the Delta in TAF Annually*													
Water Year Type **	Dry	Dry	AN	BN	BN	Wet	Dry	Critical	Dry	BN	Wet	BN	Dry
Program	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**[10]	**2009**	**2010**	**2011**	**2012**	**2013**
DWR Drought Water Bank/Dry Year Programs	138	22	11	0.5	0	0	0	0	74	0	0	0	0
Enviro Water Acct	80	145	70	120	5	0	147	60	60	60	0	60	60
Others (CVP, SWP, Yuba, inter alia)	160	5	125	0	0	0	0	173	140	243	0	190	210
Totals	**378**	**172**	**206**	**120.5**	**5**	**0**	**147**	**233**	**274*****	**303**	**0**	**250**	**270**

*Table reflects gross AF purchased prior to 20% Delta carriage loss (i.e., actual amounts pumped at Delta are 20% less)
** Based on DWR's measured unimpaired runoff (in million acre-feet)
Abbreviations: AN - Above normal year type and BN - Below normal year type (http://cdec.water.ca.gov/cgi-progs/iodir/wsihist)
*** The *2015-2024 Water Transfer Program's* EIS/EIR contradicts the 274,000 AF total for 2009 on EIS/EIR page 1-16 that states that the CVP portion alone during 2009 was 390,000 AF.

The Project has become an extension of the so-called "temporary" annual transfers based on the demands of junior water rights holders who expect to receive little contract water during dry years. The low priority of their junior water service contracts within the Central Valley Project leaves their imported surface supplies in question year-to-year. It is the normal and appropriate function of California's system of water rights law that makes it so. Yet the efforts

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[9] Laurel Heights Improvement Association v. Regents of the University of California, 1988, 47 Cal.3d 376
[10] The Environmental Water Account ended in 2007 (Bay Delta Conservation Plan Draft EIS/EIR 2013). The figures that continue in this row are based on a long-term contract with the Yuba County Water Agency to sell water.-

of the Bureau and DWR to oversee, approve, and facilitate water sales from the Sacramento, Feather, and Yuba rivers with fallowing and groundwater substation are only intended to benefit the few western San Joaquin Valley farmers whose contractual surface water rights have always been less reliable than most—and whose lands are the most problematic for irrigation. These growers have chosen to harden demand by planting permanent crops, a very questionable business decision, but the Bureau fails to explain why this “tail” in water rights is wagging the dog.

e. The Project Description does Not Include all Project Components.

i. Carriage water.

The EIS/EIR’s description of and reliance on “carriage water” is completely uncertain, undefined, and provides no meaningful information to the public. The EIS/EIR states that “Outflows would generally increase during the transfer period because carriage water would become additional Delta outflow.” (EIS/EIR 3.2-39.) The EIS/EIR also asserts that, “ Carriage water (a portion of the transfer that is not diverted in the Delta and becomes Delta outflow) will be used to maintain water quality in the Delta.” (EIS/EIR 2-29.) Elsewhere the EIS/EIR references 20% carriage losses for CCWD and SLDMWA in the EIS/EIR (3.2-39, 3.2-57-58, and B-6), while prior documents have used higher estimates:

> Historically, approximately 20-30% of the water transferred through the Delta would be necessary to enable the maintenance of water quality standards, which are based largely upon the total amount of water moving through the Bay-Delta system. This water, which is not available for delivery to Buyers, is known as “carriage water.” Given historically dry conditions prevailing in 2014, DWR estimates that carriage losses could be higher.

(Biggs West Gridley 2014 Water Transfer Neg Dec, p. 4)(Exhibit I). A Bureau spreadsheet that documents the final transfer numbers for 2013 clearly demonstrates that the 30% figure was used for carriage losses. [11] The spreadsheet further reveals that there are additional water deductions that were made prior to delivery in 2013 for DWR Conveyance Loss (2%) and Warren Act Conveyance Loss (3%). When all the water deductions are tallied for stream depletion, carriage losses, and the two conveyance losses, the actual water available for delivery when groundwater substitution is used is 53%. This is not presented in the EIS/EIR, which allows the Lead Agencies to overestimate the amount of water that is delivered through the Delta to Buyers and therefore the economic benefits of the *2015-2024 Water Transfer Program*. What is lacking is any meaningful discussion of the need for, role, availability, and effect of carriage water and conveyance losses in any transfer in the EIS/EIR. Without such information it is not possible to determine the water quality and supply effects of the program.

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[11] Bureau of Reclamation, 2013-12-17 2013 Total Pumpage (FINAL) nlw.xlsx (Exhibit J)

ii. Monitoring and production wells.

The identity and locations of all wells that will be used to monitor groundwater substitution transfer pumping impacts are unknown. The EIS/EIR must include proposed transfer well locations that are sufficiently accurate to allow for determination of distances between the wells and areas of potential impact. These are integral project features that must be disclosed in detail prior to any meaningful effects analysis.

In 2009, GCID installed four production wells to extract 26,530 AF of groundwater as part of its *Stony Creek Fan Aquifer Performance Testing Plan*. Other districts have also installed production wells, most with public funds, that have been used for past transfers such as Anderson/Cottonwood Irrigation District, Butte Water District, and RD-108. To the extent those wells and any others would be used in this project, they must be considered to be part of the whole of the action, and disclosed and analyzed herein.

i. "Other" transfers.

The EIS/EIR states that, "Other transfers not included in this EIS/EIR could occur during the same time period, subject to their own environmental review (as necessary)." (EIS/EIR 1-2.) In other words, not only is the EIS/EIR unclear precisely about which transfers are likely to occur and are analyzed in this EIR/EIR, it also leaves open-ended the prospect of some transfers not being covered by the EIS/EIR. This apparent piecemealing of transfer projects short-circuits comprehensive environmental review.

f. The Project Description Fails to Include Sufficient Locations, Maps, and Boundaries.

The project description must show the location of the project, its component parts, and the affected environmental features. CEQA Guidelines § 15124(a).

Maps are needed of each seller service area at a scale that allows for reasonably accurate measurement of distances between the groundwater substitution transfer wells and surface water features, other non-participating wells, proposed monitoring wells, fisheries, vegetation and wildlife areas, critical surface structures, and regional economic features. Maps with rates and times of stream depletion by longitudinal channel section are needed to allow for an adequate review of the Draft EIR/EIS conclusion of less than significant and reasonable impacts with no injury. These maps are also needed to evaluate the specific locations for monitoring potential impacts. Thus, detailed maps that show the locations of the monitoring wells and the areas of potential impact along with the rates and seasons of anticipated stream depletion are needed for each seller service area. These maps are also needed to allow for evaluation of the cumulative effects whenever pumping by multiple sellers can impact the same resource. The only maps provided by the Draft EIS/EIR that show the location of the groundwater substitution transfer wells, and the rivers and streams potentially impacted are the simulated drawdown Figures 3.3-26 to 3.3-31, which are at a scale of approximately 1 inch to 18 miles. The lack of maps with sufficient detail to see the relationship between the wells and the surface water features prevents adequate review of the Draft EIS/EIR analysis to determine groundwater and surface water impacts.

Furthermore, figure 3.1-1, mapping the project area, is impossible to read and determine where each seller and buyer service area actually lies. Nor does the figure itself actually include many geographic points of reference used throughout the EIS/EIR. The EIS/EIR, for example, states that "Pelger MCW is located on the east side of the Sacramento River near Robbins (Figure 3.1-1.)" (EIS/EIR at 3.1-7.) But Robbins is not on the map, and the Pelger MCW is virtually impossible to locate on Figure 3.1-1. Similarly, the EIS/EIR states that the Sacramento River is impaired from Keswick dam to the Delta, but the EIS/EIR contains no description or map showing where Keswick dam is located, or any map enabling an understanding of the geographic scope of this water quality impairment. This problem repeats for literally dozens of existing environmental features described in the EIS/EIR. And, this problem is compounded by the unstable nature of the project description itself, leaving the EIS/EIR to string together multiple combinations of place names where transfers may or may not be imported or exported, and leaving the reader to continually search out secondary information to attempt to follow the EIS/EIR's terse and convoluted descriptions. A clear explanation, with visual aids, of the affected environment, including all local creeks and streams, and transfer water routes, is necessary to enable any member of the general public to grasp the potential types and locations of environmental impacts caused by the proposed program.

II. <u>The EIS/EIR State Lead Agency Should be DWR, Not SLDMWA.</u>

SLDMWA is not the proper Lead Agency for the Project. California Environmental Quality Act ("CEQA") Guidelines sections 15367 and 15051 require that the California Department of Water Resources ("DWR"), as the operator of the California Aqueduct and who has responsibility to protect the public health and safety and the financial security of bondholders with respect to the aqueduct, is the more appropriate lead agency. In *PCL v DWR*, the court found that DWR's attempt to delegate lead agency authority impermissibly insulated the department from "public awareness and possible reaction to the individual members' environmental and economic values."[12]

Pursuant to CEQA, ""lead agency" means the public agency which has the principal responsibility for carrying out or approving a project which may have a significant effect upon the environment." (Public Res. Code § 21067.) As such, the lead agency must have authority to require imposition of alternatives and mitigation measures to reduce or avoid significant project effects, and must have the authority to disapprove of the project altogether. Here, the DWR clearly fits this description. As the EIS/EIR states, "[t]hese transfers require approval from Reclamation and/or Department of Water Resources (DWR)." (EIS/EIR 1-2.) Additionally, the

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[12] *Planning and Conservation League et al. v Department of Water Resources* (2000) 83 Cal.App.4th 892, 907, citing Kleist v. City of Glendale (1976) 56 Cal. App. 3d 770, 779.

EIS/EIR reveals the obvious and long-standing relationship between the Bureau and DWR in facilitating surface water transfers. The Bureau and DWR have collaborated on each DTIWT publication, which provides specific environmental considerations for transfer proposals; are said to have "sponsored drought-related programs" together; have created the joint EIS/EIR for the Environmental Water Account ("EWA"); and "cooperatively implemented the 2009 Drought Water Bank."

SLDMWA should not serve as the lead agency. The *2015-2024 Water Transfer Program* has the potential to impact the long-term water supplies, environment, and economies in many California counties far removed from the SLDMWA geographic boundaries. With SLDMWA designated as the lead agency, and no potential sellers or source counties designated as responsible agencies, the process is unreasonably biased toward the narrow functional interests of SLDMWA and its member agencies. According to the EIS/EIR, the SLDMWA's role is to "[h]elp negotiate transfers in years when the member agencies could experience shortages." (EIS/EIR 1-1.) Helping to negotiate a transfer is a wholly different role than that of a lead agency with approval authority over a project. All of SLDMWA's purposes and powers are centered on providing benefit to member organizations,[13] and do not implement the Sustainable Groundwater Management Act.[14] Not only would SLDMWA be advocating on behalf of its members in this process, but nothing provided in the EIS/EIR suggests that it has authority to require mitigation measures or alternatives to reduce or avoid significant project impacts, for example, to groundwater resources in the seller service area, as such limitations would clearly be contrary to the specific interests of the SLDMWA members.

Importantly, DWR not only has jurisdiction over the SLDMWA transfers in ways that SLDMWA does not, but also DWR has review and approval authority over potential transfers outside of the SLDMWA altogether, including, for example, the East Bay Municipal Utilities District, as well as "[o]ther transfers not included in this EIS/EIR [that] could occur during the same time period, subject to their own environmental review (as necessary)." (EIS/EIR 1-2.) Environmental review of transfers should be unified and comprehensive, and cumulative across both geography and over time in a way that DWR and not SLDMWA can provide.

III. <u>The EIS/EIR Fails to Completely and Accurately Describe the Affected Environmental Setting and Baseline Conditions.</u>

A complete and accurate description of the existing and affected environmental setting is critical for an adequate evaluation of impacts to it. *See e.g. San Joaquin Raptor/Wildlife Rescue Ctr. v. County of Stanislaus* (1994) 27 Cal.App.4th 713; *Galante Vineyards v. Monterey Peninsula Water Mgmt. Dist.* (1997) 60 Cal.App.4th 1109, 1122; *County of Amador v. El Dorado County*

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[13] SLDMWA JPA, para. 6, pp. 4-7.
[14] StAmant 2014. Letter to Bureau of Reclamation and SLDMWA re the 2015-2024 Water Transfer Program.

Water Agency (1999) 76 Cal.App.4th 931, 955; *Cadiz Land Co. v. Rail Cycle* (2000) 83 Cal.App.4th 74, 94.

As discussed, below, and in the expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance, the EIS/EIR fails to comport with these standards.

a. The EIS/EIR Fails to Describe Existing Physical Conditions.

i. Groundwater Supply

The EIS/EIR fails to provide a comprehensive assessment of the historic change in groundwater storage in the Sacramento Valley groundwater basin, and other seller sources areas within the proposed 10-year groundwater substitution transfer project. Historic change and current groundwater contour maps are critical to establishing an environmental baseline for the groundwater substitution transfers. The EIS/EIR uses SACFEM2013 simulations of groundwater substitution transfer pumping effects for WY 1970 to WY 2003, but the discussion of the simulation didn't provide specifics on how the model simulated the current conditions of the Sacramento Valley groundwater system or the potential impacts from the 10-year groundwater substitution transfer project based on current conditions. Again, The EIS/EIR relies on only modeling to consider impacts from the Project when it should disclose the results from actual monitoring and reporting for water transfer conducted in 12 of the last 14 years.

The EIS/EIR concludes that the Sacramento Valley basin's groundwater storage has been relatively constant over the long term, decreasing during dry years and increasing during wetter periods, but the EIR/EIS ignores more recent information and study (e.g. Brush 2013a and 2013b, NCWA, 2014a and 2014b). According to the BDCP EIS/EIR:

> Some locales show the early signs of persistent drawdown, including the northern Sacramento County area, areas near Chico, and on the far west side of the Sacramento Valley in Glenn County where water demands are met primarily, and in some locales exclusively, by groundwater. These could be early signs that the limits of sustainable groundwater use have been reached in these areas."

(BDCP EIS/EIR at 7-13.) The Draft EIS/EIR provides only one groundwater elevation map of the Sacramento Valley groundwater basin, Figure 3.3-4, which shows contours only from selected wells that omit many depths and areas. The Draft EIS/EIR doesn't provide maps showing groundwater elevations, or depth to groundwater, for groundwater substitution transfer seller areas in Sutter, Yolo, Yuba, and Sacramento counties. The DWR provides on a web site a number of additional groundwater level and depth to groundwater maps that the EIS/EIR should use to help complete its description of the affected environment.[15]

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[15] http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Well%20Depth%20Summary%20Maps

Presented below are tables that illustrate maximum and average groundwater elevation decreases for Butte, Colusa, Glenn, and Tehama counties at three aquifer levels in the Sacramento Valley between the fall of 2004 and 2013. (Id).

County Fall ’04 - ’13	Deep Wells (Max decrease gwe)	Deep Wells (Avg. decrease gwe)
Butte	-11.4	-8.8
Colusa	-31.2	-20.4
Glenn	-60.7	-37.7
Tehama	-19.5	-6.6

County Fall ’04 - ’13	Intermediate Wells (Max decrease gwe)	Intermediate Wells (Avg. decrease gwe)
Butte	-21.8	-6.5
Colusa	-39.1	-16.0
Glenn	-40.2	-14.5
Tehama	-20.1	-7.9

County Fall ’04 - ’13	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-13.3	-3.2
Colusa	-20.9	-3.8
Glenn	-44.4	-8.1
Tehama	-15.7	-6.6

Below are the results from DWR’s spring monitoring for Sacramento Valley groundwater basin from 2004 to 2014.

County Spring ’04 - ’14	Deep Wells (Max decrease gwe)	Deep Wells (Avg. decrease gwe)
Butte	-20.8	-14.6
Colusa	-26.9	-12.6
Glenn	-49.4	-29.2
Tehama	-6.1	-5.3

County Spring ’04 - ’14	Intermediate Wells (Max decrease gwe)	Intermediate Wells (Avg. decrease gwe)
Butte	-25.6	-12.8
Colusa	-49.9	-15.4
Glenn	-54.5	-21.7
Tehama	-16.2	-7.9

County Spring '04 - '14	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-23.8	-7.6
Colusa	-25.3	-12.9
Glenn	-46.5	-12.6
Tehama	-38.6	-10.8

The DWR data clearly present a different picture of the condition of the Sacramento Valley groundwater basin over time than what is provided in the EIS/EIR. This must be corrected and considered in the NEPA and CEQA process.

The EIS/EIR omits other critical information needed to understand the project's impacts to area groundwater, including but not limited to:

- the distances between the transfer well(s) and surface water features;
- the number of non-participating wells in the vicinity of the transfer wells that may be impacted by the pumping; and,
- the distance between the transfer wells and non-participant wells that may be impacted by the transfer pumping, including domestic, public water supply and agricultural wells.

The EIS/EIR assumes that, "The groundwater modeling results indicate that shallow groundwater is typically deeper than 15 feet in most locations under existing conditions, and often substantially deeper." (3.8-32.) However, existing hydrologic condition documents clearly show Depth to Groundwater levels in shallow portions of the aquifer system that are <15' from the surface.

- The Chart titled **Depth to Water by Sub-Inventory Unit (SIU)** on **2014_10_Summary_Table.PDF** page 2/2 shows the Average Depth to Water (feet) in March through October 2014. 7 of 16 Sub-Inventory Units ("SIUs") in Butte County show average groundwater levels <15' from the surface at some time of the year. [16]
- November 2014 Adobe spreadsheets show numerous monitoring wells with water levels closer than 10' to the surface. The wells are located in Butte County SIUs designated under the county Basin Management Objective ("BMO") program. While some of the SIUs are corresponding to an Irrigation District primarily served by surface water, the Butte Sink, Cherokee, North Yuba, Angel Slough, Llano Seco and M&T SIUs have naturally occurring water levels <10'. All 3 pages show ground surface to water surface (feet). [17]

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[16] https://www.buttecounty.net/wrcdocs/Programs/Monitoring/GWLevels/2014/2014_10_Summary_Table.pdf
https://www.buttecounty.net/wrcdocs/Programs/Monitoring/GWLevels/2014/2014_10_Data_Summary_Update.pdf (Exhibit K)

[17] 2014 Monthly Groundwater Depth to Water- CASGEM:
https://www.buttecounty.net/wrcdocs/Programs/Monitoring/GWLevels/2014/2014_10_Data_Summary_Update.pdf (Exhibit K)

- The January 2014 *BUTTE COUNTY DOMESTIC WELL DEPTH* **SUMMARY** shows the 10' Depth to Groundwater Contour lines in the lower portion of the map. [18]
- The January 2014 *COLUSA COUNTY DOMESTIC WELL DEPTH SUMMARY* shows the 10' Depth to Groundwater Contour lines in large portions of the county. [19]
- The January 2014 *GLENN COUNTY DOMESTIC WELL DEPTH SUMMARY* shows the 10' Depth to Groundwater Contour lines in the lower portion of the map. [20]

Dan Wendell of The Nature Conservancy, a panelist at a workshop held by the California Natural Resources Agency, the California Department of Food and Agriculture, and California EPA on March 24, 2014, presented a similar picture as the county summaries above, but also raised the alarm about the existing, significant streamflow losses from groundwater pumping and, even more significantly, how long it takes for those losses to appear:

> "The Sacramento Valley still has water levels that are fairly shallow," he said. "There are numerous perennial streams and healthy ecosystems, and the basin is largely within a reasonable definition of sustainable groundwater yield. However, since the 1940s, groundwater discharge to streams in this area has decreased by about 600,000 acre-feet per year due to groundwater pumping, and it's going to decrease an additional 600,000 acre-feet in coming years under 2009 status quo conditions due to the time it takes effects of groundwater pumping to reach streams. It takes years to decades, our work is showing."[21]

What areas in the Sellers' region were used to reach the EIS/EIR conclusion that "[i]ndicate that shallow groundwater is typically deeper than 15 feet"? What prevented the analysis from disclosing the many miles of riparian habitat in the Sacramento Valley that indicate that riparian forest vegetation remains healthy with groundwater levels shallower than 15 feet? As we presented above, there are many areas in the Sellers' region that have groundwater higher than 15 feet below ground surface.

In addition, the EIS/EIR fails to provide recharge data for the aquifers. Professor Karin Hoover, Assistant Professor of hydrology, hydrogeology, and surficial processes from CSU Chico, found

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[18] Butte County shallow Groundwater Contours: www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/WellDepthSummaryMaps/Domestic_BUTTE.pdf (Exhibit L)

[19] Colusa County shallow Groundwater Contours: www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/WellDepthSummaryMaps/Domestic_COLUSA.pdf (Exhibit M)

[20] Glenn County shallow Groundwater Contours: www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/WellDepthSummaryMaps/Domestic_GLENN.pdf (Exhibit N)

[21] http://mavensnotebook.com/2014/04/28/groundwater-management-workshop-part-1-sustainable-groundwater-management-panel/ (Exhibit O)

in 2008 that, "Although regional measured groundwater levels are purported to 'recover' during the winter months (Technical Memorandum 3), data from Spangler (2002) indicate that recovery levels are somewhat less than levels of drawdown, suggesting that, in general, water levels are declining." According to Dudley, "Test results indicate that the 'age' of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the Lower Tuscan Formation along the eastern margin of the valley have the 'youngest' water and the deeper wells in the western and southern portions of the valley have the 'oldest' water," adding that "the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas." (2005). "This implies that there is currently no active recharge to the Lower Tuscan aquifer system (M.D. Sullivan, personal communication, 2004)," explains Dr. Hoover. "If this is the case, then water in the Lower Tuscan system may constitute fossil water with no known modern recharge mechanism, and, once it is extracted, it is gone as a resource," (Hoover 2008).[22]

ii. Groundwater Quality

The Draft EIS/EIR discusses the potential for impacts to groundwater quality by migration of contaminants as a result of groundwater substitution pumping, but provides only a general description of the current condition of groundwater quality. No maps are provided that show the baseline groundwater quality and known areas of poor or contaminated groundwater, or from all areas where groundwater pumping may occur. Groundwater quality information on the Sacramento Valley area is available from existing reports by the USGS (1984, 2008b, 2010, and 2011) and Northern California Water Association (NCWA, 2014c). Determination of groundwater quality prior to pumping is critical to avoiding significant adverse impacts, both to adjacent groundwater users impacted by migrating contaminants, as well as surface water potentially impaired by contaminated runoff from irrigated agriculture or other uses.

There are numerous hazardous waste plumes in Butte County, which could easily migrate with the potential increased groundwater pumping proposed for the Project. The State Department of Toxics Control and the Regional Water Resources Control Boards have a great deal of information readily available for all counties involved with the proposed Project. Fluctuating domestic wells can lead to serious contamination from heavy metals and non-aqueous fluids. Because the Bureau fails to disclose basic standards for the mitigation and monitoring requirements, it is unknown if hazardous plumes in the areas of origin will be monitored or not.

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[22] Spangler, Deborah L. 2002. *The Characterization of the Butte Basin Aquifer System, Butte County, California*. Thesis submitted to California State University, Chico; Dudley, Toccoy et al. 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update*; Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

Please note the attached map from the State Water Resources Control Board (2008) that highlights areas vulnerable to groundwater contamination throughout the state. A significant portion of both the areas of origin and the receiving areas are highlighted. When the potential for serious health and safety impacts exists, NEPA and CEQA require that this must be disclosed and analyzed.

iii. Surface Water Flows

The EIS/EIR asserts that, under the no action/no project alternative, "Surface water supplies would not change relative to existing conditions. Water users would continue to experience shortages under certain hydrologic conditions, requiring them to use supplemental water supplies." (3.1-15.) It would be most helpful if the lead agencies would explain the geographic scope of this statement since the shortages could be experienced throughout the areas of origin, transmission, and delivery – as well as the entire State of California. The section continues with, "Under the No Action/No Project Alternative, some agricultural and urban water users may face potential shortages under dry and critical hydrologic conditions." Again, to what geographic areas is the EIS/EIR referring? The final sentence in the section reads, "Impacts to surface water supplies would be the same as the existing conditions." Without further elaboration or a reference that would further explain what exactly are the "existing conditions, mentioned" this is merely a conclusory assertion without the benefit of factual data. For example, existing conditions vary wildly in California weather patterns and agency allocations can as well. For example, in 2014 CVP Settlement Contractors were threatened with an unprecedented 40 percent allocation, which later became 75 percent when they cooperated with water transfers. Failing to disclose the wide range of natural and agency decisions that comprise the No Action/No Project alternative must be corrected and re-circulated in another draft EIS/EIR.

The EIS/EIR states that "[b]ecause of the interaction of surface flows and groundwater flows in riparian systems, including associated wetlands, enables faster recharge of groundwater, these systems are less likely to be impacted by groundwater drawdown as a result of the action alternatives;" therefore, "[t]hese systems are less likely to be impacted by groundwater drawdown as a result of the action alternatives." (EIS/EIR 3.8-32.) This flawed assumption has been readily discredited by USGS:

> There is more of an interaction between the water in lakes and rivers and groundwater than most people think. Some, and often a great deal, of the water flowing in rivers comes from seepage of groundwater into the streambed. Groundwater contributes to streams in most physiographic and climatic settings… Groundwater pumping can alter how water moves between an aquifer and a stream, lake, or wetland by either intercepting groundwater flow that discharges into the surface-water body under natural conditions, or by

> increasing the rate of water movement from the surface-water body into an aquifer. A related effect of groundwater pumping is the lowering of groundwater levels below the depth that streamside or wetland vegetation needs to survive. The overall effect is a loss of riparian vegetation and wildlife habitat. [23]

Lastly, the EIR/EIS presents the rivers and streams analyzed for impacts from the Proposed Action alternative with numerous omissions and conclusory remarks that are not supported. (3.8-49 – 3.8-51.) Examples include:

- *Table 3.8.3 Screening Evaluation Results for Smaller Streams in the Sacramento River Watershed for Detailed Vegetation and Wildlife Impact Analysis for the Proposed Action* fails to designate the counties of origin except for Deer and Mill creeks. Even readers familiar with the region need this basic information.
- Creeks with groundwater/surface water connections, but omitted from Tehama and Butte counties in Table 3.8.3 include, but are not limited to: Clear, Cottonwood, Battle, Singer, Pine, Zimmershed, Rock, Mud, and Big Chico.
- The modeling that is used to omit streams from analysis and to select and analyze other streams is completely inadequate to the task. Page D-3 has information about model resolution. It is normal to have five to ten nodes to resolve a feature of interest, but the nodal spacing is listed as ranging from 125 to 1000 meters, with stream node spacing around 500 meters (EIS/EIR p. D-3). This implies that spatial features smaller than about 2 kilometers cannot be resolved with this model. With the physical response of interest below the threshold of resolution even under the best of circumstances, then you have 100% margin of error, because the model cannot "see" that response.[24]

iv. Surface Water Quality

The baseline water quality data presented in the EIS/EIR is insufficient to accomplish any meaningful understanding of existing water quality levels throughout the project area. The EIS/EIR fails to show where each affected water body is, or disclose its existing beneficial uses, or numeric water quality objectives. Data that are presented is scattered, inconsistent, incomplete, often severely out of date, and often misleading. Further, the EIS/EIR fails to explain exactly where much of the presented water quality data comes from – indeed, failing to explain exactly where the affected environment is at all.

Many waterways are left out of this section entirely. The biological and vegetation effects of the program are discussed elsewhere in the EIS/EIR, and show that most would be impacted by the proposed program, but these waterways are not discussed in the EIS/EIR water quality section. Diminished flows can affect water quality in a variety of way, for example, causing

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[23] The USGS Water Science School. http://ga.water.usgs.gov/edu/gwdepletion.html

[24] Mish, p. 8. (Exhibit C)

higher temperatures, lower dissolved oxygen, or high sediment contamination or turbidity. Therefore, these affected waterways should be described and analyzed in the EIS/EIR water quality chapter.

In addition, the EIS/EIR only names the California Aqueduct, the Delta-Mendota Canal, and the San Luis Reservoir as affected waters within the buyer areas. Later, the EIS/EIR admits that increased irrigation in the buyers' areas may adversely impact stream water quality, but none of these rivers, streams, creeks, or any other potentially affected waterway of any kind, are described in the buyer project areas. (EIS/EIR 3.2-26.)

The EIS/EIR also fails to meaningfully describe the existing water quality in the affected environment. The EIS/EIR repeatedly misleads the public and decision-makers regarding the baseline conditions of waters within the project area by labeling them as "generally high quality." For example, the EIS/EIR states that "certain segments of the Sacramento River contain several constituents of concern, including Chlordane, dichlorodiphenyltrichloroethane, Dieldrin, mercury, polychlorinated biphenyls (PCBs), and unknown toxicity (see Table 3.2-1); however, the water quality in the Sacramento River is generally of high quality." What is the basis for this non-sequitur used here, and repeated throughout the existing environmental descriptions in the EIS/EIR? How do constituents of concern and unknown toxicity translate to generally high quality?

The remaining baseline information presented in the EIS/EIR contains significant gaps that preclude a meaningful understanding of the existing environmental conditions. In order to attempt to characterize the water quality in the affected environmental area, the EIS/EIR lists out beneficial uses, 303(d) impairments, and a variety of water quality monitoring data. The EIS/EIR presents almost no reference to existing numeric water quality objectives, and evaluation of potential breaches of those standards is therefore impossible.

Table 3.2-1 lists 303(d) impairments within the area of analysis. The table states the approximate mileage or acreage of the portion of each water body that is impaired, but fails to inform the public exactly where these stretches are located. For example, table 3.2-1 states that, within the Delta, approximately 43,614 acres are impaired for unknown toxicity, 20,819 acres are impaired for electrical conductivity, and 8,398 acres are impaired for PCBs; but without knowing which acres within the Delta this table describes, it is impossible to know whether transfer water will affect those particular areas. This problem repeats for all impairments listed in table 3.2-1.

The baseline environmental condition of the Delta is poorly described. The EIS/EIR states that:

> [e]xisting water quality constituents of concern in the Delta can be categorized broadly as metals, pesticides, nutrient enrichment and associated eutrophication, constituents associated with suspended sediments and turbidity, salinity, bromide, and organic

> carbon. Salinity is a water quality constituent that is of specific concern and is described below.

(EIS/EIR at 3.2-21.) The EIS/EIR provides no further information about "metals, pesticides, nutrient enrichment and associated eutrophication, constituents associated with suspended sediments and turbidity." These contaminants are each the focus of intensive regulation and controversy, and could cause significant adverse impacts if contaminated surface waters are transferred, but no meaningful baseline data of existing conditions is provided to facilitate an evaluation of the effects of the incremental changes caused by the proposed program.

The EIS/EIR provides scattered and essentially useless monitoring data to attempt to describe the existing water quality conditions in the program area. First, the EIS/EIR is unclear exactly what year or years it uses to constitute the baseline environmental conditions. Then, Tables 3.2-4 through 3.2-20 provide data from 1980 through 2014. Some tables average data, some use median data, some present isolated data, and none provide a comparison to existing numeric water quality objectives. Of all of the existing environmental baseline data provided, only table 3.2-15 provides any data regarding contamination caused by metals in the water column, and only for Lake Natoma from April to September of 2008. As a result, any contamination relating to any metals in any transfer water is essentially ignored by the EIS/EIR. Moreover, the scattershot data provided in the EIS/EIR does not provide the public with any information about the actual water quality of transfer water that may be used in any future project.

Table 3.2-21 presents mean data from "selected" monitoring stations throughout the Delta. The EIS/EIR states that "[s]ampling period varies, depending on location and constituent, but generally is between 2006-2012." (EIS/EIR 3.2-22.) EIS/EIR readers simply have no way to know what these data actually represent. Columns are labeled "mean TDS," "mean electrical conductivity," and "mean chloride, dissolved." Are these data averaged for the approximate period of 2006-2012? Were any data excluded? The EIS/EIR lists these monitoring stations, but doesn't explain where each is actually located, which should be mapped for ease of reference. Nor does the EIS/EIR state what the applicable water quality objective is at each monitoring point for each parameter; nor how often these water quality objectives were breached.

Figure 3.2-2 presents the monthly median chloride concentrations at selected monitoring sites, and misleadingly states that these median concentrations do not exceed the secondary MCL for chloride of 250 mg/L; but that comparison is irrelevant as the Bay-Delta Plan sets water quality objectives for chloride at 250 mg/day, not monthly mean.

Figures 3.2-3 through 3.2-5 show average electrical conductivity at selected monitoring stations, but the EIS/EIR fails to state the relevant water quality standard against which to compare these data, and fails to report the frequency and magnitude of exceedances, which are numerous and great. When do exceedances occur, and how can the proposed program avoid transferring water from or into waterways with elevated EC?

The EIS/EIR fails to provide any discussion or analysis of how SWRCB Decision 1641 would be implemented. The EIS/EIR states that Decision 1641 "requires Response Plans for water quality and water levels to protect diverters in the south Delta that may affect the opportunity to export transfers." (EIS/EIR at 2-32.) Later, the EIS/EIR adds that Decision 1641 "require[s] that the Central Valley Project (CVP) and State Water Project (SWP) be operated to protect water quality, and that DWR and/or Reclamation ensure that the flow dependent water quality objectives are met in the Delta (SWRCB 2000)." (EIS/EIR 3.2-10.) Nowhere does the EIS/EIR actually identify what these requirements entail, nor analyze when they would or would not be met by any portion of the proposed program. D-1641 is among the most critical of water quality regulations controlling the proposed program, and the EIS/EIR must provide significantly more analysis of how it would propose to comply with these State Water Board standards. As discussed, below, compliance with D-1641 standards is far from certain.

Similarly, the EIS/EIR notes that "DWR has developed acceptance criteria to govern the water quality of non-Project water that may be conveyed through the California Aqueduct. These criteria dictate that a pump-in entity of any non-project water program must demonstrate that the water is of consistent, predictable, and acceptable quality prior to pumping the local groundwater into the SWP." (EIS/EIR at 3.2-10.) Again, however, the EIS/EIR fails to explain what these criteria require, and fails to provide any discussion of whether, when, or how these criteria could be met for each transfer contemplated by the program. This lack of information and analysis is insufficient to support informed public and agency environmental decision-making.

IV. The EIS/EIR Fails to Evaluate Inconsistency with Applicable Laws, Plans, and Policies.

a. State Water Policies.

The EIS/EIR should fully disclose the consolidated places of use for DWR and the Bureau, and what criteria might be applied for greater flexibility claimed for the consolidated place of use necessary for any given year's water transfer program, and what project alternatives could avoid this shift. Could the transfers be facilitated through transfer provisions of the Central Valley Project Improvement Act? Would the consolidation be a permanent or temporary request, and would the consolidation be limited to the duration of just the *2015-2024 Water Transfer Program*? How would the consolidated places of use permit amendments to the SWP and CVP permits relate to their joint point of diversion? Would simply having the joint point of diversion in place under D-1641 suffice for the purpose of the Project?

The EIS/EIR should better describe existing water right claims of sellers, buyers, the Bureau, and DWR. In response to inquiries from the Governor's Delta Vision Task Force, the SWRCB acknowledged that while average runoff in the Delta watershed between 1921 and 2003 was 29 million acre-feet annually, the 6,300 active water right permits issued by the SWRCB is approximately 245 million acre-feet [25] (pp. 2-3). In other words, **water rights on paper are 8.4 times greater than the real water in California's Central Valley rivers and streams diverted to supply those rights on an average annual basis.** And the SWRCB acknowledges that this 'water bubble' does not even take account of the higher priority rights to divert held by pre-1914 appropriators and riparian water right holders (*Id*. p. 1). More current research reveals that the average annual unimpaired flow in the Sacramento River basin is 21.6 MAF, but the consumptive use claims are an extraordinary 120.6 MAF – 5.6 times more claims than there is available water. [26] Informing the public about water rights claims would necessarily show that buyers and the Agencies clearly possess junior water rights as compared with those of many willing sellers. Full disclosure of these disparate water right claims and their priority is needed to help explain the actions and motivations of buyers and sellers in the *2015-2024 Water Transfer Program*. Otherwise the public and decision makers have insufficient information on which to support and make informed choices.

To establish a proper legal context for these water rights, the EIS/EIR should also describe more extensively the applicable California Water Code sections about the treatment of water rights involved in water transfers.

Like federal financial regulators failing to regulate the shadow financial sector, subprime mortgages, Ponzi schemes, and toxic assets of our recent economic history, the state of California has been derelict in its management of scarce water resources. As we mentioned above we are supplementing these comments on this matter of wasteful use and diversion of water by incorporating by reference and attaching the 2011 complaint to the State Water Resources Control Board of the California Water Impact Network the California Sportfishing Protection Alliance, and AquAlliance on public trust, waste and unreasonable use and method of diversion as additional evidence of a systemic failure of governance by the State Water Resources Control Board, the Department of Water Resources and the U.S. Bureau of Reclamation, filed with the Board on April 21, 2011. (Exhibit Q)

b. Public Trust Doctrine.

The State of California has the duty to protect the people's common heritage in streams, lakes, marshlands, and tidelands through the Public Trust Doctrine.[27] The Sacramento, Feather, and Yuba rivers and the Delta are common pool resources. DWR acknowledges this legal reality in

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[25] SWRCB, 2008. Water Rights Within the Bay Delta Watershed (Exhibit P.)

[26] California Water Impact Network, AquAlliance, and California Sportfishing Protection Alliance 2012. *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay-Delta Estuary*. (Exhibit Q)

[27] *National Audubon Society v. Superior Court* (1983) 33 Cal 3d, 419, 441.

its publication, *Water Transfer Approval: Assuring Responsible Transfers*.[28] The application of the Public Trust Doctrine requires an analysis of the public trust values of competing alternatives, as was directed by the State Water Board in the Mono Lake Case. Its applicability to alternatives for the water transfers planned from the Sacramento, Feather, and Yuba rivers and through the Delta, where species recovery, ecosystem restoration, recreation and navigation are pitted against damage from water exports, is exactly the kind of situation suited to a Public Trust analysis, which should be required by the 2015-2024 Water Transfer Program. The act of appropriating water—whether for a new use or for a new method of diversion or of use— is an acquisition of a property right from the waters of the state, an act that is therefore subject to regulation under the state's public trust responsibilities. Groundwater pumping with adverse effects to public trust surface waters must also be considered.

c. Local General Plans and Ordinances.

The Draft EIS/EIR discusses only two county ordinances, the Colusa Ordinance No. 615 and Yolo Export Ordinance No. 1617, one agreement, the Water Forum Agreement in Sacramento County, and one conjunctive use program, the American River Basin Regional Conjunctive Use Program. Except for the brief discussion of the two ordinances, one agreement, and one conjunctive use program listed above, the Draft EIS/EIR doesn't describe the requirements of local GMPs, ordinances, and agreements listed in Tables 3.3-1 (page 3.3-8) and Table 3-1 (page 27). Thus, the actual groundwater substitution transfer project permit requirements, restrictions, conditions, or exemptions required for each seller service area by the Bureau, DWR, and one or more County GMP or groundwater ordinance will apparently be determined at a future date.

Additional information is needed on what the local regulations require for exporting groundwater out of each seller's groundwater basin. The Draft EIS/EIR needs to discuss how the local regulations ensure that the project complies with Water Code Sections 1220, 1745.10, 1810. 10750, 10753.7, 10920-10936, and 12924 (for more detailed discussion of these Water Codes see Draft EIS/EIR Section 3.3.1.2.2). Although the Draft EIS/EIR doesn't document, compare or evaluate the requirements of all local agencies that have authority over groundwater substitution transfers in each seller service area, the Draft EIS/EIR concludes that the environmental impacts from groundwater substitution transfer pumping by each of the sellers will either be less than significant and cause no injury, or be mitigated to less than significant through mitigation measures WS-1, and GW-1 with its reliance on compliance with local regulations.

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[28] California Department of Water Resources, *Water Transfer Approval: Assuring Responsible Transfers*, July 2012, page 3. Accessible online 16 February 2014 at http://www.water.ca.gov/watertransfers/docs/responsible_water_transfers_2012.pdf. In addition, the Delta Protection Act of 1959 also acknowledges this reality, California Water Code Sections 12200-12205. (Exhibit R)

As noted above, this conclusions is derived from information absent from the EIS/EIR and, even if there was information considered by the Lead Agencies, without any apparent analysis. Butte, Glenn, and Shasta counties represent counties with Sellers and all of them have the potential to be heavily impacted by activities in or adjacent to their jurisdictions. AquAlliance has examined their ordinances and found them insufficient to protect other users and the environment (Exhibits U, V, X). Sincere efforts at monitoring for groundwater levels and subsidence become meaningless if the monitoring infrastructure is scant and enforcement absent. The Butte County Department of Water and Resource Conservation also explains that local plans are simply not up to the task of managing a regional resource:

> Each of the four counties that overlie the Lower Tuscan aquifer system has their own and separate regulatory structure relating to groundwater management. Tehama County, Colusa, and Butte Counties each have their own version of an export ordinance to protect the citizens from transfer-related third party impacts. Glenn County does not have an export ordinance because it relies on Basin Management Objectives (BMOs) to manage the groundwater resource, and subsequently to protect third parties from transfer related impacts. Recently, Butte County also adopted a BMO type of groundwater management ordinance. Butte County, Tehama County and several irrigation districts in each of the four counties have adopted AB3030 groundwater management plans. All of these groundwater management activities were initiated prior to recognizing that a regional aquifer system exists that extends over more than one county and that certain activities in one county could adversely impact another. Clearly the current ordinances, AB3030 plans, and local BMO activities, which were intended for localized groundwater management, are not well suited for management of a regional groundwater resource like that theorized of the Lower Tuscan aquifer system.[29]

There is a possibility that a seller's groundwater substitution area of impact will occur in multiple local jurisdictions, which should results in project requirements coming from multiple local as well as state and federal agencies. The Draft EIS/EIR doesn't discuss the obstacles from cross jurisdictional impacts that are immense because groundwater basins cross county lines thereby eliminating authority. (*Id*) One obvious example is found with productions wells placed in Glenn County in the lower end of the Tuscan Aquifer Basin that may affect the up-gradient part of the aquifer in Butte and Tehama counties.

If the Project proceeds, each seller's project analysis should identify what future analyses, ordinances, project conditions, exemptions, monitoring and mitigation measures are required to ensure that each of the seller's project meets or exceed the goals of the Draft EIS/EIR.

V. **The EIS/EIR Fails to Adequately Analyze Numerous Environmental Effects.**

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[29] Butte County Department of Water and Resource Conservation, *Needs Assessment Tuscan Aquifer Monitoring, Recharge, and Data Management Project*,.2007. (Exhibit S)

The EIS/EIR fails to include numerous required elements to support a meaningful analysis of the project's significant adverse impacts. First, the deficiencies in the incomplete and undefined project description, and incomplete description of existing environmental conditions, render any true impact analysis, or hard look at the project effects, impossible. *See*, *e.g.*, *Santiago County Water Dist. v. County of Orange* (1981) 118 Cal.App.3d 818; *San Joaquin Raptor Rescue Ctr. v. County of Merced* (2007) 149 Cal.App.4th 645. Even the analysis provided, however, employs unsupported and inapplicable standards of significance. (CEQA Guidelines § 15064(b); *see*, *e.g.*, *Oakland Heritage Alliance v. City of Oakland* (2011) 195 Cal.App.4th 884, 896; *Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal.App.4th 1099, 1111). The EIS/EIR fails to completely analyze the project's significant adverse impacts, and fails to support its conclusions with substantial evidence, failing to characterize the project effects in the proper context and intensity. (*Id.*; 40 C.F.R. § 1508.27(a); *City of Maywood v. Los Angeles Unified School Dist.* (2012) 208 Cal.App.4th 362, 391; *Laurel Heights Improvement Association v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376, 393; *Madera Oversight Coalition, Inc. v. County of Madera* (2011) 199 Cal.App.4th 48, 102 ("whether an EIR is sufficient as an informational document is a question of law subject to independent review by the courts.")

As discussed, below, and in the expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance, the EIS/EIR fails to comport with these standards.

a. Surface Water Flows.

The EIS/EIR fails to adequately analyze changes to all surface water flows as a result of the proposed project. While the EIS/EIR presents some level of streamflow drawdown analysis in its vegetation and biological resources section, that analysis is not taken into consideration with respect to affects to other water supply rights. This raises the specter of injury to senior water rights holders, and the EIS/EIR fails to provide sufficient information regarding where such rights are held and in what amounts, and where proposed transfers may interfere.

Streamflow depletion in the EIS/EIR is evaluated through modeling, but a closer look at the models employed shows significant omissions. First, because the rate of stream depletion is scaled to pumping rate and because the model documentation doesn't indicate the pumping locations, rates, volumes, times or durations that produced the pumped volumes shown in Figure 3.3-25, or the stream depletions shown in Figures B-5 and B-6 in Appendix B, it appears that the SACFEM2013 modeling did not simulate the maximum rate of stream depletion for the proposed 10-year project. Second, the available Delta export capacity was determined from CalSim II model results using only conditions through WY 2003, which fails to account for current conditions, climate change conditions, and future conditions. (EIS/EIR 3.7-18.) The adequacy of CalSIM II has also been called into question. [30]

In addition, the Bay-Delta Conservation Plan establishes flow limits for the Delta that the EIS/EIR fails to consider. Instead, the EIS/EIR states that the proposed projects could decrease outflows by 0.3 percent in winter and spring, and provides a bare conclusion that this impact is less than significant. (EIS/EIR 3.2-39.) Just this year the Bureau of Reclamation and DWR requested a Temporary Urgency Change from the SWRCB, a modification to Delta flow objectives that were not being met, and D-1641 standards, in order to attempt to manage species protection.[31]

The EIS/EIR attempts to consider changes in available supplies for project participants, but fails to review what other water rights holders may be affected by diminished flows. This is especially important given the EIS/EIR's conclusion that transfers would be most needed in times of critical shortage.

The EIS/EIR also fails to disclose changes in flows as a result of tailwater and ag drainage, which could lead to significant streamflow impacts.

b. Water Quality.

i. The EIS/EIR improperly excludes substantial amounts of water from any meaningful impact evaluation.

The EIS/EIR fails to provide any evidence to support its proposition that "if the change in flow is less than ten cubic feet per second (cfs), it is assumed that there would be no water quality impacts as this is within the error margins of the model." (EIS/EIR 3.2-27.) First, the margin of error of the model has no bearing on actual water quality. Second, NPDES permits regularly regulate flows of less than 10 cfs. According to USGS, 10 cfs equals 6.46 million gallons per day (MGD). The EIS/EIR's assumption that a change in reservoir elevation of less than 1,000 acre feet could not possibly have significant impacts to water quality is similarly baseless. (EIS/EIR 3.2-27.) This amounts to approximately 325,800 gallons of water, more than enough to result in a noticeable difference in water quality. The Federal Clean Water Act is a strict liability statute providing no de minimis exceptions. By way of comparison, the City of Galt Wastewater Treatment Plant maintains flows at 4.5 MGD (NPDES Permit No. CA0081434), the City of Colusa Wastewater Treatment Plant maintains flows of approximately 0.7 MGD (NPDES Permit No. CA0078999), and each of these facilities has been assessed penalties for effluent exceedances by the Regional Water Board in recent years. The EIS/EIR's conclusion that flows equivalent to entire municipal wastewater treatment plants have no ability to compromise water quality standards is simply wrong.

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[30] Close, A., et al, 2003. A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California (Exhibit T)

[31] Letter from Mark W. Cowin to Tom Howard, April 9, 2014 (Exhibit U)

Similarly, the EIS/EIR provides the bare conclusion that:

> CVP and SWP reservoirs within the Seller Service Area would experience only small changes in storage, which would not be of sufficient magnitude and frequency to result in substantive changes to water quality. Any small changes to water quality would not adversely affect designated beneficial uses, violate existing water quality standards, or substantially degrade water quality. Consequently, potential effects on reservoir water quality would be less than significant.

(EIS/EIR 3.2-31.) The EIS/EIR simply provides no evidence or analysis in making this conclusion.

Lastly, the EIS/EIR provides no actual analysis of potential impacts to San Luis Reservoir as a result of lowering water levels in response to transfers. The EIS/EIR admits that "storage under the Proposed Action would be less than the No Action/No Project Alternative for all months of the year," and asserts that water levels would be lowered between 3%-6% as a result of the Project. (EIS/EIR 3.2-41.) The EIS/EIR then presents the bare conclusion that "These small changes in storage are not sufficient to adversely affect designated beneficial uses, violate existing water quality standards, or substantially degrade water quality." The EIS/EIR provides no basis for this determination, including no comparison of baseline environmental conditions to changes in contaminated runoff as a result of any particular water transfer.

ii. The EIS/EIR fails to provide any information with which to evaluate impacts from idled crop fields, or farmlands in buyers' areas.

The EIS/EIR assumes certain agricultural practices will occur at idle rice fields, when in reality, property owners would be free to re-purpose idled fields in countless and creative ways. (EIS/EIR 3-2.30.) For idled alfalfa, corn, or tomato cropland, the EIS/EIR assumes that property owners will put in place erosion control measures to conserve soil. While this may be a reasonable assumption for some farms, others, who may prefer to purse multi-year water transfers, may not have an interest in investing in soil conservation. In addition, the EIS/EIR fails to provide analysis of the degree of effectiveness of soil conservation measures where no groundcover is in place. (EIS/EIR 3.2-29.) If proven to be effective, the EIS/EIR should require the Lead Agencies to condition water transfers on these necessary mitigation measures, and provide monitoring and reporting to ensure their continued implementation. We recommend that the Bureau and DWR require, at a minimum, that local governments select independent third-party monitors, who are funded by surcharges on Project transfers paid by the buyers, to oversee the monitoring that is proposed in lieu of Bureau and DWR staff, and that peer-reviewed methods for monitoring be required. If this is not done, the Project's proposed monitoring and mitigation outline is insufficient and cannot justify the significant risk of adverse environmental impacts.

The EIS/EIR also states that increased erosion would not be of concern in Butte, Colusa, Glenn, Solano, Sutter, and Yolo counties, due to the prevalence of clay and clay loam soils. (EIS/EIR 3.2-29.) This bare conclusion does not provide any meaningful evaluation of the proposed program's impacts. Does the EIS/EIR really mean to assert that nowhere across six entire counties does soil erosion adversely impact water quality?

The EIS/EIR contradicts itself, stating:

> In cases of crop shifting, farmers may alter the application of pesticides and other chemicals which negatively affect water quality if allowed to enter area waterways. Since crop shifting would only affect currently utilized farmland, a significant increase in agricultural constituents of concern is not expected.

(EIS/EIR 3.2-30.) Would applications be altered, or remain the same? The EIS/EIR says both. In truth, due to the programmatic nature of this EIS/EIR, although it is a "project" not a "programmatic" document, one cannot know. This level of impact must be evaluated on a project-by-project basis, yet the Lead Agencies assertion that this is a "project" level EIS/EIR precludes additional CEQA and NEPA review.

The EIS/EIR concludes that water quality impacts in the buyer area would be less than significant, but provides no evidence or assurances whatsoever regarding the ultimate use of the purchased water would be. (EIS/EIR 3.2-41.) The EIS/EIR then considers only impacts resulting from increased crop irrigation, acknowledging that "[i]f this water were used to irrigate drainage impaired lands, increased irrigation could cause water to accumulate in the shallow root zone and could leach pollutants into the groundwater and potentially drain into the neighboring surface water bodies." (EIS/EIR 3.2-41.) The EIS/EIR then dismisses this possibility, assuming that buyers would only use water for "prime or important farmlands." Missing from this section is any analysis of water quality. What does the EIS/EIR consider to be prime or important farm lands? Do all such actual farms exhibit the same water quality in irrigated runoff? The EIS/EIR provides no assurances its assumptions will be met, and moreover, fails to explain what its assumptions actually are.

The EIS/EIR then again relies on an improper ratio comparison of the amount of transfer water potentially used in buyer areas, to the total amount of all water used in the buyers' areas. The EIS/EIR adds:

> The small incremental supply within the drainage-impaired service areas would not be sufficient to change drainage patterns or existing water quality, particularly given drainage management, water conservation actions and existing regulatory compliance efforts already implemented in that area.

(EIS/EIR 3.2-41.) Again, however, any comparison ratio of transferred water to other irrigation simply provides no analysis of what water quality impacts any individual transfer would have after application on any individual farm. Moreover, if indeed a transfer is responding to a shortage, the transfer amount could actually constitute all or a majority of water usage for a particular site. Allusion to “existing regulatory compliance efforts” only suggests that regulatory compliance is not already maintained in each and every potential buyer farmland. There is no reasonable dispute that return flows from irrigated agriculture can often compromise water quality standards, but the EIS/EIR simply brushes this impact aside.

The EIS/EIR assumes that transfers may only occur during times of shortage (EIS/EIR 3.2-41), yet the proposed project itself is not so narrowly defined, and nothing in the Water Code limits transfers to circumstances where there has been a demonstrated shortfall in the buyer’s area. As a result of this open-ended project description, the true water quality impacts in the buyers’ areas are completely unknown.

iii. The EIS/EIR ignores numerous potentially significant sources of contamination to surface waters.

The EIS/EIR describes the existing environmental conditions of most of the water bodies within the potential seller areas to be impaired for numerous contaminants; and also provides sampling and monitoring data to show that in-stream exceedances of water quality objectives regularly occur. Yet, the EIS/EIR fails to ever discuss the impact of moving contaminated water from one source to another. For example, where a seller’s water is listed as impaired for certain contaminants, any movement of that water to another waterbody will simply spread this impairment. The EIS/EIR provides no information with which to determine the actual water quality of the seller’s water for any particular transfer, nor any evaluation or monitoring to determine whether moving these contaminants from one water to another would harm beneficial uses or exceed receiving water limits. The EIS/EIR should provide a more particularized review of potential contaminants and their impacts under the proposed project. For example, the EIS/EIR does not analyze water quality impacts from boron, but the BDCP EIS/EIR states, “large-scale, out-of-basin water transfers have reduced the assimilative capacity of the river, thereby exacerbating the water quality issues associated with boron.” (BDCP EIS/EIR at 8-40.) Similarly, dissolved oxygen, among other forms of contamination, pose regular problems pursuant to D-1641. These potentially significant impacts must be disclosed for public and agency review.

What selenium and boron loads in Mud Slough and other tributaries to the San Joaquin River may be expected from application of this water to western San Joaquin Valley lands?

The EIS/EIR fails to disclose whether changes in specific conductivity as a result of the program would result in significant impacts to water quality. First, as noted above, the EIS/EIR presents scattered baseline data, much of which appears to show ongoing EC exceedances, but the EIS/EIR fails to disclose what Bay-Delta EC standards are, and the frequency and magnitude of baseline exceedances. Against this backdrop, the EIS/EIR then admits that program transfers would increase EC by as much as 4.3 percent. (EIS/EIR 3.2-39.) The EIS/EIR fails to disclose whether these regular EC increases would exacerbate baseline violation conditions. In addition, the EIS/EIR only presents analysis for one monitoring location, whereas the Bay-Delta plan contains EC limits for over a dozen monitoring locations.

The EIS/EIR fails to disclose the extent to which program transfers could harm water quality by moving the “X2” location through the Delta. D-1641 specifies that, from February through June, the location of X2 must be west of Collinsville and additionally must be west of Chipps Island or Port Chicago for a certain number of days each month, depending on the previous month’s Eight River Index. D-1641 specifies that compliance with the X2 standard may occur in one of three ways: (1) the daily average EC at the compliance point is less than or equal to 2.64 millimhos/cm; (2) the 14-day average EC is less than or equal to 2.64 millimhos/cm; or (3) the 3-day average Delta outflow is greater than or equal to the corresponding minimum outflow.

The EIS/EIR relies on an improper ratio approach to its impact evaluation of increased EC concentrations in the Delta Mendota Canal as a result of San Joaquin River diversions. (EIS/EIR 3.2-40.) The EIS/EIR admits that EC in the canal would increase as a result of these diversions, but fails to disclose by how much, or against what existing environmental conditions. Instead, the EIS/EIR compares the transfer amount, approximately 250 cfs, to the total capacity of the canal, about 4,000 cfs, to conclude that EC changes would not be significant. A comparison of the transfer amount to the total canal capacity simply provides no analysis of or information about EC concentrations.

The EIS/EIR fails to meaningfully evaluate potentially significant impacts to surface water quality as a result of groundwater substitution. First, the EIS/EIR provides an improper and misleading comparison, stating that

> The amount of groundwater substituted for surface water under the Proposed Action would be relatively small compared to the amount of surface water used to irrigate agricultural fields in the Seller Service Area. Groundwater would mix with surface water in agricultural drainages prior to irrigation return flow reaching the rivers. Constituents of concern that may be present in the groundwater could enter the surface water as a result of mixing with irrigation return flows. Any constituents of concern, however, would be greatly diluted when mixed with the existing surface waters applied because a much higher volume of surface water is used for irrigation purposes in the Seller Service Area. Additionally, groundwater quality in the area is generally good and sufficient for municipal, agricultural, domestic, and industrial uses.

(EIS/EIR at 3.2-21.) The EIS/EIR’s threshold of significance asks whether any water quality objective will be violated, and this must be measured at each discharge point. In turn, any farm that substitutes surface water irrigation for groundwater irrigation must be evaluated against this threshold. The EIS/EIR fails to provide any evidence to support its conclusion that the dilution of the groundwater runoff into surface waters would avoid any significant water quality impacts. On one hand the EIS/EIR asserts that groundwater is of good quality, and on the other hand, asserts that the overall quality would improve as it is mixed with surface water irrigation runoff: *which* source provides the better water quality in this arrangement? It is widely recognized that irrigated agricultural return flows can transport significant contaminants to receiving water bodies. In addition, the EIS/EIR simply assumes that contaminated groundwater would not be pumped and applied to agricultural lands, despite the fact that groundwater extractions may mobilize PCE, TCE, and nitrate plumes under the City of Chico,[32] and fails to disclose the existence of all hazardous waste plumes in the area of origin where groundwater substitution may occur. The assertion that "groundwater is generally good" throughout 6-10 counties is insufficient to provide any meaningful information against which to evaluate any particular transfer.

For "non-Project" reservoirs, the EIS/EIR provides one piece of additional information: modeling projections showing various rates of drawdown in table 3.2-24. The EIS/EIR then concludes that because water quality in these reservoirs is generally good, the reductions would not result in any significant water quality impacts. Again, the EIS/EIR provides no evidence or analysis to support this bare conclusion. Nor does the EIS/EIR present the beneficial uses of Collins Lake, nor Dry Creek, downstream of Collins Lake (see Table 3.2-2). The EIS/EIR does note that Lake McClure, Hell Hole Reservoir, and Camp Far West Reservoir maintain beneficial uses for cold water habitat and wildlife habitat, but fails to evaluate whether these beneficial uses would be impacted. Dissolved oxygen rates will decrease with lower water levels, and any sediment-based contaminant concentration, will increase. And the fact that drawdowns increase in already-critical years only heightens the water quality concerns.

The EIS/EIR repeatedly relies on dilution as the solution, with no actual analysis or receiving water assimilative capacity, and no regulatory authority. It is well-established law that a discharger may receive a mixing zone of dilution to determine compliance with receiving water objectives if and only if the permittee has conducted a mixing zone study, submitted to a Regional Board or the State Board for approval. (See, e.g., *Waterkeepers N. Cal. v. AG Indus. Mfg.*, 2005 U.S. Dist. LEXIS 43006 ["A dilution credit is a limited regulatory exception that must be preceded by a site specific mixing zone study"]; Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California, 65 Fed. Reg. 31682 (May 18, 2000), 31701 ["All waters . . . are subject to the criteria promulgated today. Such criteria will need to be attained at the end of the discharge pipe, unless the State authorizes a mixing zone."]) The EIS/EIR entirely ignores Clean Water Act requirements for obtaining dilution credits, and, with no supporting evidence whatsoever, effectively and illegally grants dilution credits across the board. (See, EIS/EIR 3.2-31, 3.2-35, 3.2-36, 3.2-42, 3.2-59). For each instance in which the EIR/EIS wishes to apply dilution credit to its determination of whether water quality impacts will be significant, it must perform – with the approval of the State or Regional

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[32] http://www.ci.chico.ca.us/capital_project_services/NitrateArea2NPh3U1-3.asp

Water Board – a mixing zone study considering the impacted waterbody and the specific types and quantities of the proposed pollutant discharge(s). Short of that, each time the EIS/EIR relies on dilution as the solution, it fails to analyze whether any contaminant in any waterbody in any amount could protect beneficial uses or exceed receiving water standards. The more Project water goes to south-of-Delta agricultural users than to urban users, the higher would be their groundwater levels, the more contaminated the groundwater would be in the western San Joaquin Valley and the more the San Joaquin River would be negatively affected from contaminated seepage and tailwater by operation of the Project.

c. Groundwater Resources.

The modeling efforts presented by the EIS/EIR fail to accurately capture the project's groundwater impacts. First, the SACFEM2013 simulations didn't evaluate the impacts of pumping the maximum annual amount proposed for each of the 10 years of the project. Second, because the groundwater modeling effort didn't include the most recent 11 years record, it appears to have missed simulating the most recent periods of groundwater substitution transfer pumping and other groundwater impacting events, such as recent changes in groundwater elevations and groundwater storage (DWR, 2014b), and the reduced recharge due to the recent periods of drought. Without taking the hydrologic conditions during the recent 11 years into account, the results of the SACFEM2013 model simulation may not accurately depict the current conditions or predict the effects from the proposed groundwater substitution transfer pumping during the next 10 years.

The Lead Agencies are making gross assumptions about the number, size, and behavior of all the surface water resources in the state, just to be able to coerce those assumptions into data that fits into the SACFEM2013 model. The assumptions are driving the modeling instead of the model (and science) driving accurate results. Appendix D is full of inaccurate statements and clear indications that this model is deficient. For example, it's advertised as a 3D model, but it's actually a collection of linked 2D models, and those are driven not by science, but by assumptions, e.g., the model can't calculate the location of the phreatic surface: it relies on assumptions and observations for that data, and that makes the model incapable of prediction.[33]

The Draft EIS/EIR should provide the time-drawdown and distance-drawdown hydraulic characteristics for each groundwater substitution transfer well so that non-participant well owners can estimate and evaluate the potential impacts to their well(s) from well interference due to the pumping the groundwater substitution transfer well(s). This analysis is not present in the EIS/EIR.

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[33] Mish (Exhibit C) pp. 3 and 4).

The EIS/EIR wrongly assumes that stream depletion impacts from pumping occur only downstream from the point on the stream closest to the pumping well.[34] Any monitoring of the effects of groundwater substitution pumping on surface or ground water levels, rates and areas of stream depletion, fisheries, vegetation and wildlife impacts, and other critical structures needs to cover a much wider area than what is needed for a direct surface water diversion.

The EIS/EIR doesn't compare the known groundwater quality problem areas with the SACFEM2013 simulated drawdowns to demonstrate that the proposed projects won't draw in or expand the areas of known poor water quality. The EIS/EIR analysis doesn't appear to consider the impacts to private well owners. Pumping done as part of the groundwater substitution transfer may cause water quality impacts from geochemical changes resulting from a lowering the water table below historic elevations, which exposes aquifer material to different redox conditions and can alter the mixing ratio of different quality aquifer zones being pumped. Changes in groundwater level can also alter the direction and/or rate of movement of contaminated groundwater plumes both horizontally and vertically, which may expose non-participating wells to contaminants they would not otherwise encounter.

The EIS/EIR fails to evaluate any changes in the rate and direction of inter-basin groundwater flow. Inter-basin groundwater flow may become a hidden long-term impact that increases the time needed for recovery of groundwater levels from groundwater substitution transfer pumping, and can extend the impact from groundwater substitution transfer pumping to areas outside of the groundwater substitution transfer seller's boundary.

Finally, the EIS/EIR should evaluate how Project transfers could add to the already high water table in the western San Joaquin Valley? Impacts from a higher water table could include increased groundwater contamination, lower flood resistance, greater erosion, and loss of suitability of certain parcels to particular land uses.

d. <u>The SACFEM 2013 and CALSIM II Models are Inadequate.</u>

The comments herein are based largely on the attached work of Dr. Custis (Exhibit A) and Dr. Mish (Exhibit C), and we request specific responses to these attached works. The EIR/EIS fails to accurately estimate environmental effects likely to occur during water transfers. The SACFEM2013 model used to predict groundwater resources is flawed by being based on poor technology that is simply not up to the task of accurate large-scale modeling.

The SACFEM2013 model is only partially predictive, in that key aquifer responses are entered as input data instead of being computed as predictive quantities. The model requires considerable data manipulation to be used, and these manipulations are necessarily subject to interpretation. The model description in the EIR/EIS presents no validation results that can be used to provide basic quality-assurance for the analyses used in the EIR/EIS. The model is not

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[34] Custis (Exhibit A)

predictive in many important responses (as mentioned above), so its results are a reflection of past data (e.g., streamflows, phreatic surface location, etc.) instead of providing a predictive capability for future events. As described in previous sections, both the model and the input data contain gross over-simplifications that compromise the ability to provide accurate estimates of real-world responses of water resources On page 19 of Appendix B, the reader is promised that model uncertainty will be described in Appendix D, but that promise is never delivered. This lack of any formal measure of uncertainty is not an unimportant detail, as it is impossible to provide accurate estimates of margin of error without some formal treatment of uncertainty. Any physical response asserted by the model's results has a margin of error of 100% if that response involves spatial scales smaller than a kilometer or more.

The EIR/EIS makes little connection between groundwater extraction process modeled by SACFEM2013 and the all-too-real potential for surface subsidence, and the attendant irreversible loss of aquifer capacity. The problem is especially important during drought years, when groundwater substitution is most likely to occur. In a drought, the aquifer already entrains less groundwater than normal, so that additional stresses due to pumping are visited upon the aquifer skeleton. This is exactly the conditions required to cause loss of capacity and the risk of subsidence. Yet the EIR/EIS makes scant mention of these all-too-real problems, and no serious modeling effort is presented in the EIR/EIS to assess the risk of such environmental degradation.

In contrast to the shortcomings of the model, the Bureau/DWR's DTIPWT seeks information on interactions between groundwater pumping and groundwater/surface water supplies at various increments of less than one and two miles. (DTIPWT at Appendix B.) Where the EIS/EIR fails to provide information at a level of detail required by BOR and DWR to determine whether significant impacts to water supplies may occur, the EIS/EIR fails to provide information needed to support a full analysis of groundwater and surface water impacts, and fails to support its conclusions with evidence.

CalSim II is a highly complex simulation model of a complex system that requires significant expertise to run and understand. Consequently, only a few individuals concentrated in the Department of Water Resources, U.S. Bureau of Reclamation and several consulting firms understand the details and capabilities of the model. State Water Resources Control Board (SWRCB) staff cannot run the model. To the extent CalSim II is relied upon, the EIR/EIS must be transparent and clearly explain and justify all assumptions made in model runs. It must explicitly state when findings are based on post processing and when findings are based on direct model results. And results must include error bars to account for uncertainty and margin of safety.

As an optimization model, CalSim II is hardwired to assume perfect supply and perfect demand. The notion of perfect supply is predicated on the erroneous assumption that groundwater can always be obtained to augment upstream supply. However, the state and federal projects have no right to groundwater in the unadjudicated Sacramento River basin. Operating under this assumption risks causing impacts to ecosystems dependent upon groundwater basins in the areas of origin. The notion of perfect demand is also problematic, as it cannot account for the myriad of flow, habitat and water quality requirements mandated by state and federal statutes. Perfect demand assumes water deliveries constrained only by environmental constraints included in the code. In other words, CalSim II never truly measures environmental harm beyond simply projecting how to maximize deliveries without violating the incorporated environmental constraints. As a monthly time-step model, CalSim II cannot determine weekly, daily or instantaneous effects; i.e., it cannot accurately simulate actual instantaneous or even weekly flows. It follows that CalSim II cannot identify real-time impacts to objectives or requirements. Indeed, DWR admits, "CalSim II modeling should only be used in 'comparative mode,' that is when comparing the results of alternate CalSim II model runs and that 'great caution should be taken when comparing actual data to modeled data."[35]

The Department of Civil Engineering University of California at Davis conducted a comprehensive survey of members of California's technical and policy-oriented water management community regarding the use and development of CalSim II in California. Detailed interviews were conducted with individuals from California's water community, including staff from both DWR and USBR (the agencies that created, own, and manage the model) and individuals affiliated with consulting firms, water districts, environmental groups, and universities.

The results of the survey, which was funded by the CalFed Science Program and peer-reviewed, should serve as a cautionary note to those who make decisions based on CalSim II. The report cites that in interviewing DWR and USBR management and modeling technical staff: "*Many interviewees acknowledge that using CALSIM II in a predictive manner is risky and/or inappropriate, but without any other agency-supported alternative they have no other option.*"

The report continues that: "All users agree that CalSim II needs better documentation of the model, data, inputs, and results. CalSim II is data-driven, and so it requires numerous input files, many of which lack documentation," and "There is considerable debate about the current and desirable state of CalSim II's calibration and verification," and "Its representation of the SWP and CVP includes many simplifications that raise concerns regarding the accuracy of results." "The model's inability to capture within-month variations sometimes results in overestimates of the volume of water the projects can export from the Sacramento- San Joaquin Bay-Delta and makes it seem easier to meet environmental standards than it is in real operations." The study concluded by observing, "CalSim II is being used, and will continue to be used, for many other types of analyses for which it may be ill-suited, including in absolute mode."

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[35] Answering Brief for Plaintiff-Intervenor-Appellee California Department of Water Resources, Appeal from the United States District Court for the Eastern District of California, No. 1:09-cv-407, Case: 11-15871, 02/10/2012, ID: 8065113, page 15

In sum, the relied-upon models fail to accurately characterize the existing and future environment, fail to assess project-related impacts at a level of detailed required for the EIS/EIR, and fail to support the EIS/EIR's conclusions regarding significance of impacts.

e. Seismicity.

The EIS/EIR reasoning that because the projects don't involve new construction or modification of existing structures that there are no potential seismic impacts from the activity undertaken during the transfers is incorrect. The project area has numerous existing structures that could be affected by the groundwater substitution transfer pumping, specifically settlement induced by subsidence. Although the seismicity in the Sacramento Valley is lower than many areas of California, it's not insignificant. There is a potential for the groundwater substitution transfer projects to increase the impacts of seismic shaking because of subsidence causing additional stress on existing structures.

The EIS/EIR fails to inform the public through any analysis of the potential effects excessive groundwater pumping in the seller area may have on the numerous known earthquake faults running through and about the north Delta area, and into other regions of Northern California. As recently detailed in a paper published by a well-respected British scientific journal, "[u]plift and seismicity driven by groundwater depletion in central California," excessive pumping of groundwater from the Central Valley might be affecting the frequency of earthquakes along the San Andreas Fault, and raising the elevation of local mountain belts. The research posits that removal of groundwater lessens the weight and pressure on the Earth's upper crust, which allows the crust to move upward, releasing pressure on faults, and rendering them closure to failure. Long-Term Water Transfer Agreements have impacted the volume of groundwater extracted as farmers are able to pump and then forego surface water in exchange for money. The drought has exacerbated the need for water in buyer areas, and depleted the natural regeneration of groundwater supply due to the scarcity of rain.

Detailed analyses of this seismicity and focal mechanisms indicate that active geologic structures include blind thrust and reverse faults and associated folds (e.g., Dunnigan Hills) within the Coast Ranges-Sierran Block ("CRSB") boundary zone on the western margin of the Sacramento Valley, the Willows and Corning faults in the valley interior, and reactivated portions of the Foothill fault system. Other possibly seismogenic faults include the Chico monocline fault in the Sierran foothills and the Paskenta, Elder Creek and Cold Fork faults on the northwestern margin of the Sacramento Valley.[36]

f. Climate Change.

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[36] http://archives.datapages.com/data/pacific/data/088/088001/5_ps0880005.htm (Custis, Exhibit A)

The gross omissions and errors within the climate change analysis of the EIS/EIR fail to accurately describe the existing climatological conditions into which the project may be approved, fail to accurately describe the diminution of water and natural resources over recent and future years as a result of climate change, fail to integrate these changing circumstances into any future baseline or cumulative conditions, and fail to completely analyze or support the EIS/EIR conclusions regarding the project's potentially significant impacts.

i. The EIS/EIR Completely Fails to Incorporate Any Climate Change Information into its Analysis.

The EIS/EIR provides no analysis whatsoever of the extent to which climate change will affect the EIS/EIR assumptions regarding water supply, water quality, groundwater, or fisheries. Despite providing an overview of extant literature and study, all agreeing that California temperatures have been, are, and will continue to be rising, the entire EIS/EIR analysis of climate change interactions with the proposed project states:

> As described in the Section 3.6.1.3, changes to annual temperatures, extreme heat, precipitation, sea level rise and storm surge, and snowpack and streamflow are expected to occur in the future because of climate change. Because of the short-term duration of the Proposed Action (10 years), any effects of climate change on this alternative are expected to be minimal. Impacts to the Proposed Action from climate change would be less than significant.

(EIS/EIR 3.6-21 to 3.6-22; similarly, the EIS/EIR Fisheries chapter at 3.7-23 states: "Future climate change is not expected to alter conditions in any reservoir under the No Action/No Project Alternative because there will be limited climate change predicted over the ten year project duration (see Section 3.6, Climate Change/Greenhouse Gas).")

First, this "analysis" seriously misstates extant science by claiming that climate change impacts "are expected to occur in the future." The effects of climate change are affecting California's water resources at present, and have been for years. A 2007 DWR fact sheet, for example, states that "[c]limate change is already impacting California's water resources."[37] A more recent 2013 report issued by the California Office of Environmental Health Hazard Assessment states that "[m]any indicators reveal already discernible impacts of climate change, highlighting the urgency for the state, local government and others to undertake mitigation and adaptation strategies."[38] The report states that:

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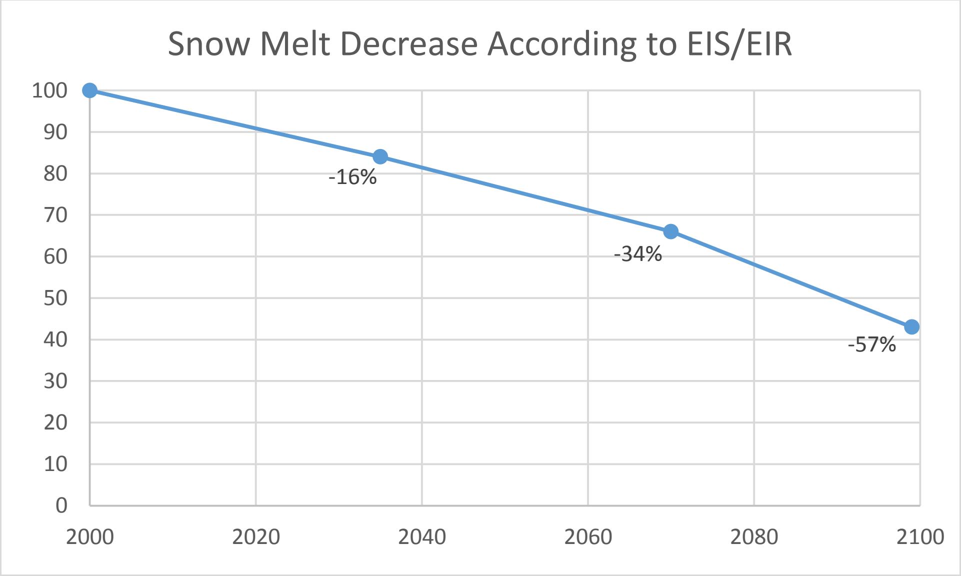
[37] http://www.water.ca.gov/climatechange/docs/062807factsheet.pdf (Exhibit AA)
[38] http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicatorsSummaryAugust2013.pdf (Exhibit BB)

> Climate is a key factor affecting snow, ice and frozen ground, streams, rivers, lakes and the ocean. Regional climate change, particularly warming temperatures, have affected these natural physical systems.
>
> From October to March, snow accumulates in the Sierra Nevada. This snowpack stores much of the year's water supply. Spring warming releases the water as snowmelt runoff. Over the past century, spring runoff to the Sacramento River has decreased by 9 percent. Lower runoff volumes from April to July may indicate: (1) warmer winters, during which precipitation falls as rain instead of snow; and (2) earlier springtime warming.
>
> Glaciers are important indicators of climate change. They respond to the combination of winter snowfall and spring and summer temperatures. Like spring snowmelt, the melting of glaciers supplies water to sustain flora and fauna during the warmer months. Glacier shrinkage results in earlier peak runoff and drier summer conditions—changes with ecological impacts—and contributes to sea level rise.
>
> With warming temperatures over the past century, the surface area of glaciers in the Sierra Nevada has been decreasing. Losses have ranged from 20 to 70 percent.
> . . .
>
> Over the last century, sea levels have risen by an average of 7 inches along the California coast.
> . . .
> Lake waters have been warming at Lake Tahoe, Lake Almanor, Clear Lake and Mono Lake since the 1990s. Changes in water temperature can alter the chemical, physical and biological characteristics of a lake, leading to changes in the composition and abundance of organisms that inhabit it.
> . . .
> Snow-water content—the amount of water stored in the snowpack—has declined in the northern Sierra Nevada and increased in the southern Sierra Nevada, likely reflecting differences in precipitation patterns.
>
> Reduced runoff means less water to meet the state's domestic, agricultural, hydroelectric power generation, recreation and other needs. Cold water fish habitat, alpine forest growth and wildfire conditions are also impacted.

In addition, climate change threatens to reduce the size of cold water pools in upstream reservoirs and raise temperatures in upstream river reaches for Chinook, and climate change will reduce Delta outflows and cause X2 to migrate further east and upstream. (See, BDCP at 5.B-310, "Delta smelt may occur more frequently in the north Delta diversions area under future climate conditions if sea level rise [and reduced Sacramento River inflow below Freeport] induces movement of the spawning population farther upstream than is currently typical.")

And, the EIS/EIR "[f]igure 3.6-1 shows the climate change area of analysis," excluding all of the Sierra Nevadas except those within Placer County, and excluding all of Sacramento County. (EIS/EIR 3.6-2.)

Instead of accounting for these factors in its environmental analysis, the EIS/EIR takes the obtuse approach of relying only on "mid-century" and year 2100 projections to cast climate change as a "long-term" and "future" problem. (See, e.g., EIS/EIR 3.6-10.) First, the U.S. Department of Interior and the California Resources Agency clearly possess better information regarding past, present, and on-going changes to water supplies as a result of climate change than presented in the EIS/EIR, and such information must be incorporated. Second, even the information presented could be more fully described, and where appropriate, extrapolated, to support any meaningful analysis. Presumably these studies and reports provide more than one or two future data points, and instead show curved projections over time. For example, the EIS/EIR states that "[i]n California, snow water equivalent (the amount of water held in a volume of snow) is projected to decrease by 16 percent by 2035, 34 percent by 2070, and 57 percent by 2099, as compared to measurements between 1971 and 2000." (EIS/EIR 3.6-11.) Are these the only three data points provided by the study? Unless the EIS/EIR assumes that the entire percent decreases will be felt exclusively in years 2035, 2070, and 2099, these data should be extrapolated, as follows, to approximate the snow melt decrease over the project term:



From this it is apparent that snow melt will decrease over the project term. This provides just one example, but the EIS/EIR itself should include meaningful analysis of climate change effects upon annual temperatures, extreme heat, precipitation, evaporation, sea level rise, storm surge, snowpack, groundwater, stream flow, riparian habitat, fisheries, and local economies over the life of the project.

Nine years ago, in 2005, then California Governor Arnold Schwarzenegger stated "[w]e know the science. We see the threat. And we know the time for action is now."[39] Here, in contrast, the EIS/EIR says, let's wait another ten years. This is simply unacceptable.

ii. The EIS/EIR Completely Ignores Increased GHG Emission in the Buyer Areas.

The EIS/EIR impact evaluation of increased GHG emissions in the buyer areas consists of a series of incomplete characterizations and unsupported conclusion. First, the EIS/EIR states: "Water transfers to agricultural users . . . could temporarily reduce the amount of land idled relative to the No Action/No Project Alternative." (EIS/EIR 3.6-22.) This is in part true, but understates the impact, as there is no guarantee that the newly-supported land-uses would either be temporary, or agricultural. Second, the EIS/EIR states that "farmers may also pump less groundwater for irrigation, which would reduce emissions from use of diesel pumps." This too is entirely speculative, and also contradicts the earlier implication that transfer water would only go to idled cropland. Third, the EIS/EIR summarily concludes that, "[t]he total amount of agricultural activity in the Buyer Service Area relative to GHG emissions would not likely change relative to existing conditions and the impact would be less than significant." This again contradicts the EIS/EIR earlier statement that a water transfer could result in less idled cropland; and also defies logic and has no support in fact to suggest that increasing provision of a scarce resource would not induce some growth. At a bare minimum, the EIS/EIR should use its own estimated GHG reduction rates achieved as a result of newly idled cropland in the sellers' service area as means of measuring the estimated GHG emission increases caused by activating idled cropland in the buyers' service areas.

iii. The EIS/EIR Threshold of Significance for GHG Emissions is Inappropriate.

The EIS/EIR reviews nearly a dozen relevant, agency-adopted, thresholds of significant for GHG emissions, and chooses to select the single threshold that sits a full order of magnitude above all others. The chosen threshold is unsupported in fact or law, and creates internal contradiction within the EIS/EIR. The CEQA Guidelines state that:

> A lead agency should consider the following factors, among others, when assessing the significance of impacts from greenhouse gas emissions on the environment:
> . . .
> Whether the project emissions exceed a threshold of significance that the lead agency determines applies to the project.

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[39] United Nations World Environment Day Conference, June 1, 2005, San Francisco; see also, Executive Order S-3-05.

> The extent to which the project complies with regulations or requirements adopted to implement a statewide, regional, or local plan for the reduction or mitigation of greenhouse gas emissions.

(CEQA Guidelines § 15064.4.) Numerous Air Districts within the affected area have established GHG thresholds of significance that the EIS/EIR improperly chooses not to apply. The EIS/EIR argues that these Air District thresholds are meant to apply to stationary sources, an exercise that "would be overly onerous and is not recommended." (EIS/EIR 3.6-18.) This must be rejected. The EIS/EIR fails to provide any reason to believe that Air District regulations would not and should not be applied to activities occurring within each respective Air District. The CEQA Guidelines require the lead agency to use "a threshold of significance that the lead agency determines applies to the project;" here, the lead agency has not determined that the local Air District thresholds do not apply to the project activities; rather, it has determined that this evaluation would be too onerous. So instead, the EIS/EIR chooses to apply the threshold of significance adopted by the Antelope Valley Air District and the Mojave Desert Air District, each of which would clearly have latitude to adopt lax air quality thresholds owing to the lack of use intensity within each district. With (hopefully) no transfer water heading to the Mojave Desert, the lead agency has no basis to determine that the Mojave Desert Air District's thresholds of significance "applies to the project." The EIS/EIR also notes that the same threshold has been adopted by USEPA for Clean Air Act, Title V permits. But the Title V standard also applies to stationary sources, which the EIS/EIR says are inapplicable. Does any project element require a Title V permit? In short, the EIS/EIR fails to evaluate the project against any threshold of significance that was adopted either (1) for the benefit of an individual air district in which project activities would occur, or (2) for the benefit of regional or statewide GHG emission goals. The EIS/EIR's unsupported grab of the most lax standard it could find, with no bearing on the project whatsoever, must be rejected.

g. Fisheries.

AquAlliance shares the widely held view that operation of the Delta export pumps is the major factor causing the Pelagic Organism Decline ("POD") and in the deteriorating populations of fall-run Chinook salmon. In 2012, the State Water Resources Control Board received word in early December that the Fall Midwater Trawl surveys for September and October showed horrendous numbers for the target species. The indices for longfin smelt, splittal, and threadfin shad reveal the lowest in history.[40] Delta smelt, striped bass, and American shad numbers remain close to their lowest levels (*Id*). The 2013 indices were even worse and the 2014 indices are also abysmal (*Id*). Tom Cannon declared in June 2014 that water transfers have been and will remain devastating to Delta smelt during dry years.[41] "In my opinion, the effect of Delta operations this summer [2014] of confining smelt to the Sacramento Deepwater ship channel

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[40] http://www.dfg.ca.gov/delta/data/fmwt/Indices/index.asp. (Exhibit CC)

[41] Cannon 2014. Declaration for Preliminary Injunction in AquAlliance and CSPA v. United State Bureau of Reclamation. (Exhibit DD)

upstream of Rio Vista due to adverse environmental conditions in the LSZ that will be exacerbated by the Transfers, both with and without relaxed outflow standards, with no evidence that they can emerge from the ship channel in the fall to produce another generation of smelt, is significant new information showing that the Transfers will have significant adverse impacts on Delta smelt." Mr. Cannon's October report observes that "habitat conditions have been very poor and the Delta smelt population is now much closer to extinction with the lowest summer index on record."

As Mr. Cannon's comments highlight, attached and fully incorporated as though stated in their entirety, herein, the EIS/EIR has inaccurately characterized the existing environment, including the assumption that delta smelt are not found in the Delta in the summer transfer season, when in fact during dry and critical years when transfers would occur, most if not all delta smelt are found in the Delta; and fails to fully assess the significant and cumulative effects to listed species in multiyear droughts when listed fish are already under maximum stress, which effects could be avoided by limiting transfers in the second or later years of drought.

The *2015-2024 Water Transfer Program* would exacerbate pumping of fresh water from the Delta, which has already suffered from excessive pumping over the last 12 years. Pumped exports cause reverse flows to occur in Old and Middle Rivers and can result in entrainment of fish and other organisms in the pumps. Pumping can shrink the habitat for Delta smelt (*Hypomesus transpacificus*) as well, since less water flows out past Chipps Island through Suisun Bay, which Delta smelt often prefer.

The EIS/EIR should also evaluate whether Project effects could alter stream flows necessary to maintain compliance with California Fish and Game Code Section 5937. A recent study issued from the University of California, Davis, documents hundreds of dams failing to maintain these required flows.[42] Both the timing and volumes of transfer water must be considered in conjunction with 5937 flows.

h. Vegetation and Wildlife.

i. The EIS/EIR reaches faulty conclusion for Project and cumulative impacts.

Section 3.8.5, *Potentially Significant Unavoidable Impacts*, declares that, "None of the alternatives would result in potentially significant unavoidable impacts on natural communities, wildlife, or special-status species." Regarding cumulative biological impacts of the proposed Project (Alternative 2), the EIS/EIR concludes, "Long-term water transfers would not be cumulatively considerable with the other projects because each of the projects would have little or no impact flows [sic] in rivers and creeks in the Sacramento River watershed or the vegetation and wildlife resources that depend on them,**"** (p. 3.8-92). This is a conclusory

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[42] https://watershed.ucdavis.edu/files/biblio/BioScience-2014-Grantham-biosci_biu159.pdf. (Exhibit EE)

statement without supporting material to justify it, only modeling that has been demonstrated in our comments as extremely deficient.

The EIS/EIR actually discloses there are very likely many significant impacts from the proposed project on terrestrial and aquatic habitat and species. Examples from Chapter 3.8 include:

- "The lacustrine natural communities in the Seller Service Area that would be potentially impacted by the alternatives include the following reservoirs: Shasta, Oroville, New Bullards Bar, Camp Far West, Collins, Folsom, Hell Hole, French Meadows, and McClure," (p. 3.8-10)
- "The potential impacts of groundwater substitution on natural communities in upland areas was considered potentially significant if it resulted in a consistent, sustained depletion of water levels that were accessible to overlying communities (groundwater depth under existing conditions was 15 feet or less). A sustained depletion would be considered to have occurred if the groundwater basin did not recharge from one year to the next," (p. 3.8-33).
- "In addition to changing groundwater levels, groundwater substitution transfers could affect stream flows. As groundwater storage refills during and after a transfer, it could result in reduced availability of surface water in nearby streams and wetlands," (p. 3.8-33).

It should also be noted that the 2008 U.S. Fish and Wildlife Service (USFWS) and 2009 National Marine Fisheries Service (NMFS) biological opinions did not evaluate potential impacts to in-stream flow due to water transfers involving groundwater substitution. How these potential impacts may adversely affect biological resources in the areas where groundwater pumping will occur, including listed species and their habitat, were also not included.[43] To reach the conclusion that the Project "would not be cumulatively considerable with the other projects" based only on modeling fails to provide the public with meaningful analysis of probable impacts.

ii. <u>The 2015-2024 Water Transfer Program has potential adverse impacts for the giant garter snake, a threatened species.</u>

As the Lead and Approving Agencies are well aware, the purpose of the ESA is to conserve the ecosystems on which endangered and threatened species depend and to conserve and recover those species so that they no longer require the protections of the Act. 16 U.S.C. § 1531(b), ESA § 2(b); 16 U.S.C. § 1532(3), ESA §3(3) (defining "conservation" as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary"). "[T]he ESA was enacted not merely to forestall the extinction of species (i.e., promote species

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[43] California Department of Fish and Game. 2013. COMMENTS ON THE DRAFT ENVIRONMENTAL ASSESSMENT (2013 DRAFT EA) AND FINDING OF NO SIGNIFICANT IMPACT (FONSI) FOR THE 2013 CENTRAL VALLEY PROJECT (CVP) WATER, p.4. (Exhibit FF)

survival), but to allow a species to recover to the point where it may be delisted." *Gifford Pinchot Task Force v. U.S. Fish & Wildlife Service*, 378 F3d 1059, 1069 (9th Cir. 2004). To ensure that the statutory purpose will be carried out, the ESA imposes both substantive and procedural requirements on all federal agencies to carry out programs for the conservation of listed species and to insure that their actions are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. 16 U.S.C. § 1536. *See NRDC v. Houston*, 146 F.3d 1118, 1127 (9th Cir. 1998) (action agencies have an "affirmative duty" to ensure that their actions do not jeopardize listed species and "independent obligations" to ensure that proposed actions are not likely to adversely affect listed species). To accomplish this goal, agencies must consult with the Fish and Wildlife Service whenever their actions "may affect" a listed species. 16 U.S.C. § 1536(a)(2); 50 C.F.R. § 402.14(a). Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to "mean all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States." 50 C.F.R. § 402.02.

The giant garter snake ("GGS") is an endemic species to Central Valley California wetlands. (Draft Recovery Plan for the Giant Garter Snake ("DRP") 1). The giant garter snake, as its name suggests, is the largest of all garter snake species, not to mention one of North America's largest native snakes, reaching a length of up to 64 inches. Female GGS tend to be larger than males. GGS vary in color, especially depending on the region, from brown to olive, with white, yellow, or orange stripes. The GGS can be distinguished from the common garter snake by its lack of red markings and its larger size. GGS feed primarily on aquatic fish and specialize in ambushing small fish underwater, making aquatic habitat essential to their survival. Females give birth to live young from late July to early September, and brood size can vary from 10 to up to 46 young. Some studies have suggested that the GGS is sensitive to habitat change in that it prefers areas that are familiar and will not typically travel far distances.

If fallowing (idling) occurs, there will be potentially significant impacts to GGS and this is acknowledged on page 3.8-69: "Giant garter snakes have the potential to be affected by the Proposed Action through cropland idling/shifting and the effects of groundwater substitution on small streams and associated wetlands." The Lead Agencies use language found in a 1997 Programmatic Biological Opinion (as well as the 1999 Draft Recovery Plan) to explain that GGS depend on more than rice fields in the Sacramento Valley. "The giant garter snake inhabits marshes, sloughs, ponds, small lakes, low gradient streams, other waterways and agricultural wetlands such as irrigation and drainage canals and rice fields, and the adjacent uplands. Essential habitat components consist of (1) adequate water during the snake's active period, (early spring through mid-fall) to provide a prey base and cover; (2) emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat; (3)

upland habitat for basking, cover, and retreat sites; and (4) higher elevation uplands for cover and refuge from flood waters." [44]

Even with the explanation above, that clearly illustrates the importance of upland habitat to GGS, the EIS/EIR concludes that idling or shifting upland crops "[a]re not anticipated to affect giant garter snakes, as they do not provide suitable habitat for this species" (p. 3.8-69). The EIS/EIR is internally contradictory and fails to provide any evidence to support its conclusion that GGS will not be impacted by idling or shifting crops in upland areas. In support of the importance of upland acreage to GGS, a Biological Opinion for Gray Lodge found that, "Giant garter snakes also use burrows as refuge from extreme heat during their active period. The Biological Resources Division (BRD) of the USGS (Wylie et al_ 1997) has documented giant garter snakes using burrows in the summer as much as 165 feet (50. meters) away from the marsh edge. Overwintering snakes have been documented using burrows as far as 820 feet (250 meters) from the edge of marsh habitat," (1998).[45]

More pertinent background information that is lacking in the EIS/EIR is found in the Bureau's Biological Assessment for the 2009 DWB that disclosed that one GGS study in Colusa County revealed the "longest average movement distances of 0.62 miles, with the longest being 1.7 miles, for sixteen snakes in 2006, and an average of 0.32 miles, with the longest being 0.6 miles for eight snakes in 2007." (BA at p.16) However, in response to droughts and other changes in water availability, the GGS has been known to travel up to 5 miles in only a few days, and the EIS/EIR should evaluate impacts to GGS survival and reproduction under such extreme conditions

As the EIS/EIR divulges, flooded rice fields, irrigation canals, streams, and wetlands in the Sacramento Valley can be used by the giant garter snake for foraging, cover and dispersal purposes. The Bureau's 2009 and 2014 Biological Assessments acknowledge the failure of the Bureau and DWR to complete the Conservation Strategy that was a requirement of the 2004 Biological Opinion (BA at p. 19-20). Research was finally initiated "since 2009," but is nowhere near the projected 10-year completion date. The unnecessary delay hasn't daunted the agencies pursuit of transfers that affect GGS despite the absence of the following information that the U.S. Fish and Wildlife Service has explicitly required since the 1990s:

- GGS distribution and abundance.
- Ten years of baseline surveys in the Sacramento Valley
- Five years of rice land idling surveys in the Sacramento Valley Recovery Unit and the Mid-Valley Recovery Unit.

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[44] Programmatic Consultation with the U.S. Army Corps of Engineers
404 Permitted Projects with Relatively Small Effects on the Giant Garter Snake within Butte, Colusa, Glenn, Fresno, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter and Yolo Counties, California

[45] http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=15453

This Project and all North-to-South and North-to-North transfers should be delayed until the Bureau and DWR have completed the Conservation Strategy they have known about for at least a decade and a half.

The Bureau and DWR continue to allow an increase in acres fallowed (2013 *Draft Technical Information for Preparing Water Transfer Proposals* ("DTIPWTP")) since the *2010/2011 Water Transfer Program* first proposed to delete or modify other mitigation measures previously adopted as a result of the Environmental Water Account ("EWA") EIR process. The EWA substantially reduced significant impacts for GGS, but without showing that they are infeasible, the Bureau and DWR proposed to delete the 160 acre maximum for "idled block sizes" for rice fields left fallow rather than flooded and to substitute for it a 320 acre maximum. (See 2003 Draft EWA EIS/EIR, p. 10-55; 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 4.) There was no evidence in 2010 to support this change nor has there been any provided to the present time. In light of the agencies failure to complete the required Conservation Strategy mentioned above and the data gathered in the Colusa County study, how can the EIS/EIR suggest (although it is not presented in the document, but in the agencies *Draft Technical Information for Preparing Water Transfer Proposals* papers) that doubling the fallowing acreage is in any way biologically defensible? The Lead and Approving Agencies additionally propose to delete the EWA mitigation measure excluding Yolo County east of Highway 113 from the areas where rice fields may be left fallow rather than flooded, except in three specific areas. [46] (See 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 2.) What is the biological justification for this change and where is it documented? What are the impacts from this change?

Deleting these mitigation measures required by the EWA approval would violate NEPA and CEQA's requirements that govern whether, when, and how agencies may eliminate mitigation measures previously adopted under NEPA and CEQA.

Additionally, the *2010/2011 Water Transfer Program* failed to include sufficient safeguards to protect the giant garter snake and its habitat. The EA for that two-year project concluded, "The frequency and magnitude of rice land idling would likely increase through implementation of water transfer programs in the future. Increased rice idling transfers could result in chronic adverse effects to giant garter snake and their habitats and may result in long-term degradation to snake populations in the lower Sacramento Valley. In order to avoid potentially significant adverse impacts for the snake, additional surveys should be conducted prior to any alteration in water regime or landscape," (p. 3-110). To address this significant impact the Bureau proposed relying on the 2009 Drought Water Bank ("DWB") Biological Opinion, which was a one-year BO. Both the expired 2009 BO and the 2014 BO highlighted the Bureau and DWR's avoidance of

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[46] USBR and DWR, 2013. *Draft Technical Information for Preparing Water Transfer Proposals.*

meeting federal and state laws stating, "This office has consulted with Reclamation, both informally and formally, seven times since 2000 on various forbearance agreements and proposed water transfers for which water is made available ["for delivery south of the delta" is omitted in 2014] by fallowing rice (and other crops) or substituting other crops for rice in the Sacramento Valley. Although transfers of this nature were anticipated in our biological opinion on the environmental Water Account, that program expired in 2007 and, to our knowledge, no water was ever made available to EWA from rice fallowing or rice substitution. The need to consult with such frequency on transfers involving water made available from rice fallowing or rice substitution suggests to us a need for programmatic environmental compliance documents, including a programmatic biological opinion that addresses the additive effects on giant garter snakes of repeated fallowing over time, and the long-term effects of potentially large fluctuations and reductions in the amount and distribution of rice habitat upon which giant garter snakes in the Sacramento Valley depend," (p.1-2). And here we are in late 2014 still without that programmatic environmental compliance that is needed under the Endangered Species Act.

If the Project is or isn't approved, we propose that the Lead and Approving Agencies commit to the following conservation recommendations from the 2014 Biological Opinion by changing the word "should" to "shall":

> 1. Reclamation should [shall] assist the Service in implementing recovery actions identified in the Draft Recovery Plan for the Giant Garter Snake (U.S. Fish and Wildlife Service 1999) as well as the final plan if issued during the term of the proposed action.
> 2. Reclamation should [shall] work with the Service, Department of Water Resources, and water contractors to investigate the long-term response of giant garter snake individuals and local populations to annual fluctuations in habitat from fallowing rice fields.
> 3. Reclamation should [shall] support the research goals of the Giant Garter Snake Monitoring and Research Strategy for the Sacramento Valley proposed in the Project Description of this biological opinion.
> 4. Reclamation should [shall] work with the Service to create and restore additional stable perennial wetland habitat for giant garter snakes in the Sacramento Valley so that they are less vulnerable to market-driven fluctuations in rice production. The CVPIA (b)(1)other and CVPCP conservation grant programs would be appropriate for such work.

iii. <u>The EIS/EIR fails to accurately describe the uppermost acreage that could impact GGS.</u>

Page 3.8-69 claims that the Proposed Action "[c]ould idle up to a maximum of approximately 51,573 acres of rice fields," but the Lead and Approving Agencies are well aware that past transfers have or could have fallowed much more acreage and that 20 percent is allowed per county under the *Draft Technical Information for Preparing Water Transfer Proposals* last written in 2013. Factual numbers for proposed water transfers that included fallowing and groundwater substitution in the last 25 years should be disclosed in a revised and re-circulated draft EIS/EIR. The companion data that should also be presented would disclose how much water was actually transferred each year by seller and delineated by acreage of land fallowed and/or groundwater pumped. This information should not only be disclosed in the EIS/EIR, but it should also be readily available on the Bureau's web site. In addition, the EIS/EIR should cease equivocating with usage of "could" and "approximately" and select and analyze a firm maximum acreage of idled land, which would provide the public with the ability to consider the impacts from a most significant impact scenario.

"In 1992, Congress passed the Central Valley Project Improvement Act (Act, or CVPIA), which amended previous authorizations of the California Central Valley Project (CVP) to include fish and wildlife protection, restoration, enhancement, and mitigation as project purposes having equal priority with power generation, and irrigation and domestic water uses."[47] The *2015-2024 Water Transfer Program* fails to take seriously the equal priority for, "[f]ish and wildlife protection, restoration, enhancement, and mitigation."

i. Economics.

Our comments are based largely upon the *EcoNorthwest* report produced for AquAlliance, attached and fully incorporated as though stated in their entirety, herein. Once again, the lack of relevant baseline information and discrete project description thwarts any ability to effectively analyze the project, and the lack of any market analysis of water prices, and prices for agricultural commodities, relegates the EIS/EIR to unsupported conclusions about the likely future frequency and amounts of water transfers and their environmental and economic consequences. The EIS/EIR further relies on obsolete data for certain key variables and ignores other relevant data and information. For example, the analysis assumes a price for water that bears no resemblance to the current reality. Growers and water sellers and buyers react to changing prices and market conditions, but the EIS/EIR is silent on these forces and how they would influence water transfers.

The EIS/EIR underestimates negative impacts on the regional economy in the sellers' area, acknowledging that negative economic impacts would be worse if water transfers happen over consecutive years, but estimating impacts only for single-year transfers, ignoring the data on the frequency of recent consecutive-year transfers.

As discussed, below, the EIS/EIR's inadequate evaluation and avoidance of subsidence will result in additional unaccounted-for economic costs. Injured third parties would bear the costs

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[47] U.S. Department of Interior. *10 Year of Progress: Central Valley Project Improvement Act 1993-2002*. http://www.waterrights.ca.gov/baydelta/docs/exhibits/SLDM-EXH-03B.pdf (Exhibit GG)

of bringing to the sellers' attention harm caused by groundwater pumping, and the ability of parties to resolve disputes with compensation is speculative. The EIS/EIR is silent on these and other ripple cost effects of subsidence.

The EIS/EIR ignores the environmental externalities and economic subsidies that water transfers support. The EIS/EIR lists Westlands Water District as one of the CVP contractors expressing interest in purchasing transfer water. The environmental externalities caused by agricultural production in Westlands WD are well documented, as are the economic subsidies that support this production. To the extent that the water transfers at issue in the EIS/EIR facilitate agricultural production in Westlands WD, they also contribute to the environmental externalities and economic subsidies of that production, but the EIS/EIR is silent on these environmental and economic consequences of the water transfers.

j. Cultural Resources.[48]

The EIS/EIR fails to adequately provide evidence that water transfers, which draw down reservoir surface elevations at Central Valley Project (CVP) and State Water Project (SWP) reservoirs beyond historically low levels, could not potentially adversely affect cultural resources. The EIS/EIR states that the potential of adverse impacts to cultural resources does exist:

> *3.13.2.4 Alternative 2: Full Range of Transfers (Proposed Action)*
> Transfers that draw down reservoir surface elevations at CVP and SWP reservoirs beyond historically low levels could affect cultural resources. The Proposed Action would affect reservoir elevation in CVP and SWP reservoirs and reservoirs participating in stored reservoir water transfers. Water transfers have the potential to affect cultural resources, if transfers result in changing operations beyond the No Action/No Project Alternative. Reservoir surface water elevation changes could expose previously inundated cultural resources to vandalism and/or increased wave action and erosion (p. 3.13-15).

This passage states that the Long Range Water Transfers undertaking may have the potential to affect cultural resources if the water transfers lowered reservoir elevations enough to expose cultural resources. The first step for analysing this would require conducting research for past studies and reports with site specific data for the CVP and SWP reservoirs. The EIS/EIR states:

> 3.13.1.3 Existing Conditions
> This section describes existing conditions for cultural resources within the area of analysis. *All data regarding existing conditions were collected through an examination of archival and current literature pertinent to the area of analysis.* Because action

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[48] Comments in this section are based on the work of Bill Helmer, prepared for AquAlliance on the 2014 Long-Term Water Transfers EIS/EIR

> alternatives associated with the project do not involve physical construction-related impacts to cultural resources, no project specific cultural resource studies were conducted in preparation of this Environmental Impact Statement/Environmental Impact Report (EIS/EIR) (EIS/EIR, p. 3.13-13, emphasis added).

However, there are no references listed for all the data collected which were "pertinent to the area of analysis." Also, the EIS/EIR states on p. 3.13-15 cited above that the lowering of the reservoir water elevations due to water transfers may affect cultural resources. Obviously, such an impact does not need to "[i]nvolve physical construction-related impacts to cultural resources," so this rationale for not conducting specific cultural resource studies contradicts its own assertion.

Instead of conducting a cultural resources study which locates historic resources and traditional cultural properties (with the use of a contemporary Native American ethnological study), and then assesses the amount of project-related water elevation changes which may affect these resources, the EIS/EIR merely stated that their Transfer Operations Model was used to show that the project's "Impacts to cultural resources at Shasta, Oroville and Folsom reservoirs would be less than significant," (3.13-15, 3.13-16). A chart on page 13.3-15 shows that the proposed project is projected to decrease reservoir elevations at the "critical" level in September by 0.5 ft. at Shasta Reservoir, 2.4 ft. at Lake Oroville, and 1.5 ft. at Folsom Reservoir. (There is no source for this chart, and the reader has to guess that it may be from the Transfer Operations Model. The definitions of the various categories in the chart are also unexplained).

Based upon the findings shown on the chart, it is stated:

> The reservoir surface elevation changes under the Proposed Action for these reservoirs would be within the normal operations and would not be expected to expose previously inundated cultural resources to vandalism or increased wave action and wind erosion. Impacts to cultural resources at Shasta, Oroville and Folsom reservoirs would be less than significant (p. 3.13-15).

However, there is no evidence to show that a project-related reservoir drop of 2.4 ft. at Lake Oroville will not uncover cultural resources documented in *The Archaeological and Historical Site Inventory at Lake Oroville, Butte County*,[49] and expose them "to vandalism or increased wave action and wind erosion," thus adversely affecting these resources. This study states that there are 223 archaeological and/or historic sites recorded in the water level fluctuation zone of Lake Oroville (p. 12). Where is the Cultural Study which shows that lowering Lake Oroville 2.4 ft. due to water transfers *will not* expose specific archaeological sites or traditional cultural properties?

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[49] Prepared for the California Department of Water Resources by the Archaeological Research Center, Sacramento, and the Anthropological Studies Center, Rohnert Park, 2004. (Exhibit HH
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Without an inventory of the cultural resources which may be uncovered by the project-related drop in reservoir elevation for all the affected reservoirs, the numbers in the chart on page 13.3-15 mean nothing. The numbers in the chart provide no evidence that the project may or may not have an adverse effect on cultural resources. In contrast, substantial documentation of cultural resources in these areas exists.[50] The threat of potential project-related impacts to cultural resources triggers a Section 106 analysis of the project under the requirements of the National Historic Preservation Act, which "[r]equires Federal agencies to take into account the effects of their undertakings on historic properties" [36 CFR 800.1(a)].

Although the issue here is the raising of the Shasta Reservoir water levels, cultural impacts related to water levels at the Shasta Reservoir has been an ongoing issue for the Winnemem Wintu Tribe. The Winnemem Wintu Tribe and all tribes within the project area (Area of Potential Effects) need to be consulted by federal and state agencies. A project-specific cultural study under CEQA is also required under *15064.5. Determining the Significance of Impacts to Archaeological and Historical Resources.* Consultation with federally recognized tribes and California Native American tribes is required for this project.

k. Air Quality.

The EIS/EIR fails to analyze the air quality impacts in all these regions, especially with regard to the Buyers Service Area. Moreover, Appendix F – Air Quality Emissions Calculations exclude portions of the Sellers Service Area in Placer and Merced Counties. Conversely, there was not data supplied in Appendix F concerning the air quality impacts from the water transfers that would affect the Bay Area AQMD counties (Alameda, Contra Costa, Santa Clara), a Monterey Bay Unified APCD county (San Benito) and San Joaquin APCD counties (San Joaquin, Stanislaus, Merced, Fresno and Kings). Consequently, air quality impacts in the Buyers and Sellers Service Areas are unanalyzed and the EIS/EIR conclusions are not supported by evidence.

The EIS/EIR attempts to classify which engines would be subject to the ATCM based on whether an agricultural engine is in an air district designated in attainment for particulate matter and ozone, and is more than a half mile away from any residential area, school or hospital (aka

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[50] Folsom Reservoir: http://online.wsj.com/articles/SB10001424052702304419104579322631095468744
Lake Oroville-
http://www.latimes.com/local/la-me-lake-oroville-artifacts-20140707-story.html#page=1 (Exhibit II)
Shasta Reservoir
http://www.winnememwintu.us/2014/09/09/press-release-dam-the-indians-anyway-winnememwar-dance-at-shasta-dam/ (Exhibit JJ)

sensitive receptors). (See p. 3.5-14). The EIS/EIR claims that the engines in Colusa, Glenn, Shasta and Tehama (part of Sellers Service Area) are exempt from the ATCM. However, 17 CCCR 93115.3 exempts in-use stationary diesel agricultural emissions not only based on the engines being remote, but all also "provided owners or operators of such engines comply with the registration requirements of section 93115.8, subdivisions (c) and (d), and the applicable recordkeeping and reporting requirement of section 93115.10," which the EIS/EIR ignores. Furthermore, the EIS/EIR fails to present any data about the "tier" the subject agricultural diesel engines fall into. While the EIS/EIR identifies the tiers and concomitant requirements for replacement or repowering, it fails to provide any analysis or evidence evaluating whether the engines being used to pump water are operating within the permissible timeframes, depending on the tier designation.

The EIS/EIR analyzes the assessment methods based on existing emissions models from the regulation, diesel emissions factors from USEPA Compilation of Air Pollutant Emission Factors (for Natural gas fired reciprocating engines and gasoline/diesel industrial engines) and CARB Emission Inventory Documentation (for land preparation, harvest operations and windblown dust); and CARB size fractions for particulate matter. None of these references is directly on point to diesel powered water pumps and the emissions caused thereby. Moreover, the EIS/EIR provides absolutely no information as to why these models are appropriate to serve as the basis for thresholds of significance.

The analysis provided in the EIS/EIR is less than complete. Here the "Significance Criteria" were only established and considered for the "sellers in the area of analysis where potential air quality impacts from groundwater substitution and crop idling transfers could occur." (See p. 3.5-25) But that is only half the equation. The unconsidered air quality impacts include what and how increased crop production and vehicle usage would affect the air quality in the Buyers Service Area. Data and evidence of those impacts were not even considered.

In establishing the significance criteria, the EIS/EIR utilized known thresholds of significance from the air districts in the Sellers Service Area that had published them. For the other districts in the Sellers Service Area, the EIS/EIR made the assumption that "[t]he threshold used to define a 'major source' in the [Clean Air Act] CAA (100 tons per year [tpy])" could be "used to evaluate significance." (See p. 3.5-26). There are several flaws with this over broad application of the "major source" threshold. First, agricultural pumps and associated agricultural activity are not typically considered "major sources," especially when compared to major industrial sources. Second, the application of the major source threshold runs counter to the legal requirement that "[u]pwind APCDs are required to establish and implement emission control programs commensurate with the extent of pollutant transport to downwind districts," as announced as a requirement of the California Clean Air Act. (See p. 3.5-11). Finally, the 100 tpy threshold is wildly disproportionate to the limits set in nearby or adjoining air district and covering the same air basin. For example, the Butte AQMD considers significance thresholds for

NOx, ROGs/VOCs and PM10 to be 137lbs/day (25 tpy); Feather River AQMD considers significance thresholds for NOx and VOCs to be 25lbs/day (4.5 tpy) and 80 lbs/day (14.6 tpy) for PM10; Tehama APCD considers significance thresholds for NOx, ROGs/VOCs and PM10 to be 137 lbs/day (25 tpy); Shasta AQMD considers significance thresholds for NOx, ROGs/VOCs and PM10 on two levels – Level "B" is 137 lbs/day (25 tpy) and Level "A" is 25lbs/day (4.5 tpy) and 80 lbs/day (14.6 tpy) for PM10; and Yolo AQMD considers significance thresholds for ROGs/VOCs and NOx to be 54.8 lbs/day (10 tpy) and 80 lbs/day (14.6 tpy) for PM10. Clearly, there is a proportional relationship between these thresholds of significance. In contrast, the EIS/EIR, with substantial evidence to the contrary, assumes that the threshold of significance for those air districts who have not published a *CEQA Handbook* should be 100 tpy, or an increase by magnitudes of 4 to 20 times more than similarly situated Central Valley air districts.

"When considering a project's impact on air quality, a lead agency should provide substantial evidence that supports its conclusion in an explicit, quantitative analysis whenever possible." (See Guide to Air Quality Assessment in Sacramento County, Sacramento Metropolitan Air Quality Management District, 2009, Ch. 2, p. 2-6). Importantly, the EIS/EIR provides no basis, other than an assumption, as to why the major source threshold of significance from the CAA should be used or is appropriate for assessing the significance of the project impacts under CEQA or NEPA. The use of the CAA's threshold of significance for major sources is erroneous as a matter of law. (See *Endangered Habitats League v. County of Orange* (2005) 131 Cal.App.4th 777, 793 ("The use of an erroneous legal standard [for the threshold of significance in an EIR] is a failure to proceed in the manner required by law that requires reversal.")) Lead agencies must conduct their own fact-based analysis of the project impacts, regardless of whether the project complies with other regulatory standards. Here, the EIR/EIS uses the CAA threshold without any factual analysis on its own, in violation of CEQA. (*Protect the Historic Amador Waterways v. Amador Water Agency* (2004) 116 Cal.App.4th 1099, 1109; citing *CBE v. California Resources Agency* (2002) 103 Cal.App.4th 98, 114; accord *Mejia v. City of Los Angeles* (2005 130 Cal.App.4th 322, 342 ["A threshold of significance is not conclusive . . . and does not relieve a public agency of the duty to consider the evidence under the fair argument standard."].) This uncritical application of the CAA's major source threshold of significance, especially in light of the similarly situated air district lower standards, represents a failure in the exercise of independent judgment in preparing the EIS/EIR.

VI. <u>The EIS/EIR Fails to Adequately Analyze Numerous Cumulative Impacts.</u>

The Ninth Circuit Court makes clear that NEPA mandates "a useful analysis of the cumulative impacts of past, present and future projects." *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). "Detail is required in describing the cumulative effects of a proposed action with other proposed actions." *Id.* CEQA further states that assessment of the project's incremental effects must be "viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects." (CEQA Guidelines § 15065(a)(3).) "[A] cumulative impact consists of an impact which is created as a result of the combination of the project evaluated in the EIR together with other projects causing related impacts." (CEQA Guidelines § 15065(a)(3).)

An EIR must discuss significant cumulative impacts. CEQA Guidelines §15130(a). Cumulative impacts are defined as two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts. CEQA Guidelines § 15355(a). "[I]ndividual effects may be changes resulting from a single project or a number of separate projects. CEQA Guidelines § 15355(a). A legally adequate cumulative impacts analysis views a particular project over time and in conjunction with other related past, present, and reasonably foreseeable future projects whose impacts might compound or interrelate with those of the project at hand. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time. CEQA Guidelines § 15355(b). The cumulative impacts concept recognizes that "[t]he full environmental impact of a proposed . . . action cannot be gauged in a vacuum." *Whitman v. Board of Supervisors* (1979) 88 Cal. App. 3d 397, 408 (internal quotation omitted).

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3) (emphasis added).

As discussed, below, and in the expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance, the EIS/EIR fails to comport with these standards for cumulative impacts upon surface and groundwater supplies, vegetation, and biological resources; and, the baseline and modeling data relied upon by the EIS/EIR that does not account for related transfer projects in the last 11 years.

a. Recent Past Transfers.

Because the groundwater modeling effort didn't include the most recent 11 years record (1970-2003), it appears to have missed simulating the most recent periods of groundwater substitution transfer pumping and other groundwater impacting events, such as recent changes in groundwater elevations and groundwater storage (DWR, 2014b), and the reduced recharge due to the recent periods of drought. Without taking the hydrologic conditions during the recent 11 years into account, the results of the SACFEM2013 model simulation may not accurately depict the current conditions or predict the effects from the proposed groundwater substitution transfer pumping during the next 10 years.

f. In 2009, the Bureau approved a 1 year water transfer program under which a number of transfers were made. Regarding NEPA, the Bureau issued a FONSI based on an EA.
g. In 2010, the Bureau approved a 2 year water transfer program (for 2010 and 2011). No actual transfers were made under this approval. Regarding NEPA, the Bureau again issued a FONSI based on an EA.
h. The Bureau planned 2012 water transfers of 76,000 AF of CVP water all through groundwater substitution.[51]
i. In 2013, the Bureau approved a 1 year water transfer program, again issuing a FONSI based on an EA. The EA incorporated by reference the environmental analysis in the 2010-2011 EA.
j. The Bureau and SLDMWA's 2014 Water Transfer Program proposed transferring up to 91,313 AF under current hydrologic conditions and up to 195,126 under improved conditions. This was straight forward, however, when attempting to determine how much water may come from fallowing or groundwater substitution during two different time periods, April-June and July-September, the reader was left to guess.[52]

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[51] USBR 2012. Memo to the Deputy Assistant Supervisor, Endangered Species Division, Fish and Wildlife Office, Sacramento, California regarding Section 7 Consultation.

[52] The 2014 Water Transfer Program's EA/MND was deficient in presenting accurate transfer numbers and types of transfers. The numbers in the "totals" row of Table 2-2 presumably should add up to 91,313. Instead, they add up to 110, 789. The numbers in the "totals" row of Table 2-3 presumably should add up to 195,126. Instead, they add up to 249,997. Both Tables 2-2 and 2-3 have a footnote stating: "These totals cannot be added together. Agencies could make water available through groundwater substitution, cropland idling, or a combination of the two; however, they will not make the full quantity available through both methods. Table 2-1 reflects the total upper limit for each agency."

These closely related projects impact the same resources, are not accounted for in the environmental baseline, and must be considered as cumulative impacts.

b. Yuba Accord

The relationship between the Lead Agencies is not found in the EIS/EIR, but is illuminated in a 2013 Environmental Assessment. "The Lower Yuba River Accord (Yuba Accord) provides supplemental dry year water supplies to state and Federal water contractors under a Water Purchase Agreement between the Yuba County Water Agency and the California Department of Water Resources (DWR). Subsequent to the execution of the Yuba Accord Water Purchase Agreement, DWR and The San Luis & Delta- Mendota Water Authority (Authority) entered into an agreement for the supply and conveyance of Yuba Accord water, to benefit nine of the Authority's member districts (Member Districts) that are SOD [south of Delta] CVP water service contractors." [53]

In a Fact Sheet produced by the Bureau, it provides some numerical context and more of DWR's involvement by stating, "Under the Lower Yuba River Accord, up to 70,000 acre-feet can be purchased by SLDMWA members annually from DWR. This water must be conveyed through the federal and/or state pumping plants in coordination with Reclamation and DWR. Because of conveyance losses, the amount of Yuba Accord water delivered to SLDMWA members is reduced by approximately 25 percent to approximately 52,500 acre-feet. Although Reclamation is not a signatory to the Yuba Accord, water conveyed to CVP contractors is treated as if it were Project water." [54] However, the Yuba County Water Agency ("YCWA") may transfer up to 200,000 under Corrected Order WR 2008-0014 for Long-Term Transfer and, "In any year, up to 120,000 af of the potential 200,000 af transfer total may consist of groundwater substitution. (YCWA-1, Appendix B, p. B-97.)." [55]

Potential cumulative impacts from the Project and the YCWA Long-Term Transfer Program from 2008 - 2025 are not disclosed or analyzed in the EIS/EIR. The *2015-2024 Water Transfer Program* could transfer up to 600,000 AF per year through the same period that the YCWA Long-Term Transfers are potentially sending 200,000 AF into and south of the Delta. How these two projects operate simultaneously could have a very significant impact on the environment and economy of the Feather River and Yuba River's watersheds and counties as well as the Delta. The involvement of Browns Valley Irrigation District and Cordua Irrigation District in both long-term programs must also be considered. This must be analyzed and presented to the public in a revised drat EIS/EIR.

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[53] Bureau of Reclamation, 2013. *Storage, Conveyance, or Exchange of Yuba Accord Water in Federal Facilities for South of Delta Central Valley Project Contractors*.

[54] Bureau of Reclamation, 2013. *Central Valley Project (CVP) Water Transfer Program Fact Sheet*.

[55] State Water Resources Control Board, 2008. ORDER WR 2008 - 0025

Also not available in the EIS/EIR is disclosure of any issues associated with the YCWA transfers that have usually been touted as a model of success. The YCWA transfers have encountered troubling trends for over a decade that, according to the draft Environmental Water Account ("EWA") EIS/EIR, are mitigated by deepening domestic wells (2003 p. 6-81). While digging deeper wells is at least a response to an impact, it hardly serves as a proactive measure to avoid impacts. Additional information finds that it may take 3-4 years to recover from groundwater substitution in the south sub-basin[56] although YCWA's own analysis fails to determine how much river water is sacrificed to achieve the multi-year recharge rate. None of this is found in the EIS/EIR. What is found in the EIS/EIR is that even the inadequate SACFEM2013 modeling reveals that it could take more than six years in the Cordua ID area to recover from multi-year transfer events, although recovery is not defined (pp, 3.3-69 to 3.3-70). This is a very significant impact that isn't addressed individually or cumulatively.

c. BDCP

The EIS/EIR fails to include the Bay Delta Conservation Plan ("BDCP") in the Cumulative Impacts section and in any analysis of the *2015-2024 Water Transfer Program*. Although we acknowledge that BDCP could not possibly be built during the 10-Year Water Transfer Program's operation, the EIS/EIR misses the point that the *2015-2024 Water Transfer Program* is a prelude to what comes later with BDCP. This connection is entirely absent. If the Twin Tunnels (the facilities identified in "Conservation Measure 1") are built as planned with the capacity to take 15,000 cubic feet per second ("cfs") from the Sacramento River, they will have the capacity to drain almost two-thirds of the Sacramento River's average annual flow of 23,490 cfs at Freeport[57] (north of the planned Twin Tunnels). As proposed, the Twin Tunnels will also increase water transfers when the infrastructure for the Project has capacity. This will occur during dry years when State Water Project ("SWP") contractor allocations drop to 50 percent of Table A amounts or below or when Central Valley Project ("CVP") agricultural allocations are 40 percent or below, or when both projects' allocations are at or below these levels (EIS/EIR Chapter 5). With BDCP, North to South water transfers would be in demand and feasible.

Communication regarding assurances for BDCP indicates that the purchase of approximately 1.3 million acre-feet of water is being planned as a mechanism to move water into the Delta to make up for flows that would be removed from the Sacramento River by the BDCP tunnels. [58] There is only one place that this water can come from: the Sacramento Valley's watersheds. It is well know that the San Joaquin River is so depleted that it will not have any capacity to contribute meaningfully to Delta flows. Additionally, the San Joaquin River doesn't flow past the proposed north Delta diversions and neither does the Mokelumne River.

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[56] 2012. *The Yuba Accord, GW Substitutions and the Yuba Basin*. Presentation to the Accord Technical Committee. (pp. 21, 22).

[57] USGS 2009. http://wdr.water.usgs.gov/wy2009/pdfs/11447650.2009.pdf Exhibit KK)

[58] Belin, Lety, 2013. E-mail regarding Summary of Assurances. February 25 (Department of Interior). (Exhibit LL)

As discussed above, the EIS/EIR also fails to reveal that the *2015-2024 Water Transfer Program* is part of many more programs, plans and projects to develop water transfers in the Sacramento Valley, to develop a "conjunctive" system for the region, and to place water districts in a position to integrate the groundwater into the state water supply. BDCP is one of those plans that the federal agencies, together with DWR, SLDMWA, water districts, and others have been pursuing and developing for many years.

d. <u>Biggs-West Gridley</u>

The *Biggs-West Gridley Water District Gray Lodge Wildlife Area Water Supply* Project, a Bureau project, is not mentioned anywhere in the Vegetation and Wildlife or Cumulative Impacts sections. [59] This water supply project is located in southern Butte County where Western Canal WD, Richvale ID, Biggs-West Gridley WD, and Butte Water District actively sell water on a regular basis, yet impacts to GGS from this project are not disclosed. This is a serious omission that must be remedied in a recirculated draft EIS/EIR.

e. <u>Other Projects</u>

Court settlement discussions between the Bureau and Westlands Water District over provisions of drainage service. Case # CV-F-88-634-LJO/DLB will further strain the already over allocated Central Valley Project with the following conditions:

k. A permanent CVP contract for 890,000 acre-feet of water a year exempt from acreage limitations.
l. Minimal land retirement consisting of 100,000 acres; the amount of land Westlands claims it has already retired (115,000 acres) will be credited to this final figure. Worse, the Obama administration has stated it will be satisfied with 100,000 acres of "permanent" land retirement.
m. Forgiveness of nearly $400 million owed by Westlands to the federal government for capital repayment of Central Valley Project debt.
n. Five-Year Warren Act Contracts for Conveyance of Groundwater in the Tehama-Colusa and Corning Canals – Contract Years 2013 through 2017 (March 1, 2013, through February 28, 2018).

Additional projects with cumulative impacts upon groundwater and surface water resources affected by the proposed project:

a. The DWR Dry Year Purchase Agreement for Yuba County Water Agency water transfers from 2015-2025 to SLDMWA.[60]

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[59] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=15381

[60] SLDMWA Resolution # 2014 386
http://www.sldmwa.org/OHTDocs/pdf_documents/Meetings/Board/Prepacket/2014_1106_Board_PrePacket.pdf

b. GCID's *Stony Creek Fan Aquifer Performance Testing Plan* to install seven production wells in 2009 to extract 26,530 AF of groundwater as an experiment that was subject to litigation due to GCID's use of CEQAs exemption for research.

c. Installation of numerous production wells by the Sellers in this Project many with the use of public funds such as Butte Water District,[61] GCID, Anderson Cottonwood Irrigation District,[62] and Yuba County Water Authority [63] among others.

VII. The EIS/EIR Fails to Develop Legally Adequate Mitigation Measures.

CEQA requires that the lead agency consider and adopt feasible mitigation measures that could reduce a project's adverse impacts to less than significant levels. Pub. Resources Code §§ 21002, 21002.1(a), 21100(b)(3), 21151, 22081(a). An adequate environmental analysis in the EIS/EIR itself is a prerequisite to evaluating proper mitigation measures: this analysis cannot be deferred to the mitigation measure itself. *See, e.g., Vineyard Area Citizens for Responsible Growth v. City of Rancho Cordova* (2007) 40 Cal.4th 412. Moreover, mitigation measures must A mitigation measure is inadequate if it allows significant impacts to occur before the mitigation measure takes effect. *POET, LLC v. State Air Resources Board* (2013) 218 Cal.App.4th 681, 740. An agency may not propose a list of measures that are "nonexclusive, undefined, untested and of unknown efficacy." *Communities for a Better Environment v. City of Richmond* (2010) 184 Cal.App.4th 70, 95. Formulation of mitigation measure should generally not be deferred. CEQA Guidelines § 15126.4(a)(1)(B). If deferred, however, mitigation measure must offer precise measures, criteria, and performance standards for mitigation measures that have been evaluated as feasible in the EIR, and which can be compared to established thresholds of significance. *E.g.*, *POET, LLC v. State Air Resources Board* (2013) 218 Cal.App.4th 681; *Preserve Wild Santee v. City of Santee* (2012) 210 Cal.App.4th 260; *Sacramento Old City Association v. City Council* (1991) 229 Cal.App.3d 1011; CEQA Guidelines § 15126.4(a)(1)(B); *Defend the Bay v. City of Irvine* (2004) 119 Cal.App.4th 1261, 1275. Economic compensation alone does not mitigate a significant environmental impact. *See* CEQA Guidelines § 15370; *Gray v. County of Madera* (2008) 167 Cal.App.4th 1099, 1122. Where the effectiveness of a mitigation measure is uncertain, the lead agency must conclude the impact will be significant. *Citizens for Open Govt. v. City of Lodi* (2012) 70 Cal.App.4th 296, 322; *Fairview Neighbors v. County of Ventura* (1999) 70

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[61] Prop 13. Ground water storage program: 2003-2004 Develop two production wells and a monitoring program to track changes in ground.

[62] "The ACID Groundwater Production Element Project includes the installation of two groundwater wells to supplement existing district surface water and groundwater supplies." http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=8081

[63] Prop 13. Ground water storage program 2000-2001: Install eight wells in the Yuba-South Basin to improve water supply reliability for in-basin needs and provide greater flexibility in the operation of the surface water management facilities. $1,500,00;

Cal.App.4th 238, 242. An EIR must not only mitigate direct effects, but also must mitigate cumulative impacts. CEQA Guidelines § 15130(b)(3).

Under NEPA, "all relevant, reasonable mitigation measures that could improve the project are to be identified," including those outside the agency's jurisdiction,[64] and including those for adverse impacts determined to be less-than-significant (40 C.F.R. § 1502.16(h)).

As discussed, below, and in the expert reports submitted by *Custis*, *EcoNorthwest*, *Cannon*, and *Mish* on behalf of AquAlliance, the EIS/EIR fails to comport with these standards.

The EIS/EIR illegally defers the development of and commitment to feasible mitigation measures to reduce or avoid a whole host of potentially significant project impacts. The EIS/EIR relies on mitigation measures WS-1 and GW-1 to reduce or avoid significant project effects through the entire environmental review document, not just for surface and ground water supplies, but also for impacts to vegetation, subsidence, regional economics, . (3.7-26, 3.7-56, 3.10-37, 3.10-51.) Unfortunately, these mitigation measures fail all standards for CEQA compliance, deferring analysis of the impact in question to a future time, including no criteria or performance standards by which to evaluate success, and failing to demonstrate that the measures are feasible or sufficient.

But the precise relationship of these mitigation measures is unclear. For example, the EIS/EIR relies on GW-1 to mitigate impacts to vegetation and wildlife as a result of stream flow loss; why doesn't the EIS/EIR consider the streamflow mitigation measure for this impact?

a. Streamflow Depletion.

WS-1 requires that a portion of transfer water be held back to offset streamflow depletion caused by groundwater substitution pumping, but fails to include critical information to ensure that any such mitigation measure could work. First, it is not clear that any transfer release and the groundwater substitution pumping would simultaneously occur, in real time. If groundwater pumping causes streamflow depletion at any time other than exactly when the transfer is made, then the transfer deduction amount will not avoid streamflow drawdown. And, indeed, it is well known that streamflow depletion can continue, directly and cumulatively, after the transfer activity ends. (E.g., figures B-4, B-5 and B-6 in Draft EIS/EIR Appendix B).

Next, the EIS/EIR fails to include any meaningful information to determine whether the applicable "streamflow depletion factor" to be applied to any single transfer project will mitigate significant impacts.

The EIS/EIR provides that "The exact percentage of the streamflow depletion factor will be assessed and determined on a regular basis by Reclamation and DWR, in consultation with buyers and sellers, based on the best technical information available at that time." (EIS/EIR at

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[64] http://ceq.hss.doe.gov/nepa/regs/40/40p3.htm

3.1-21.) More information is required. It is unclear whether WS-1 considers the cumulative volume of water pumped for each groundwater substitution transfers, or the instantaneous rate of stream depletion caused by the pumping. Any factor must be the outcome of numerous measured variables, such as the availability of water to capture, the rate and duration of recharge, the streambed sediment permeability, the duration of pumping, the distance between the well and stream, and others; but the EIS/EIR fails to provide any means of evaluating these various factors. How good must the "best technical information available at that time" be? What is the likelihood it will be available, what constraints does this face, and what requirements are in place to ensure that sufficient information is obtained? Why hasn't this information been analyzed in the EIS/EIR? What roles do the buyers and sellers have in reaching this determination?

Moreover, the EIS/EIR fails to identify the threshold of significance below which significant impacts would not occur. WS-1 purports to avoid "legal injury," but fails to define any threshold or criteria that will be applied in the performance of WS-1 to clearly determine when legal injury would ever occur.

b. Groundwater Overdraft.

The EIS/EIR illegally defers formulation and evaluation of mitigation measure GW-1 in much the same way as WS-1. In reliance on GW-1, the EIS/EIR goes so far as to defer the environmental impact analysis that should be provided now, as part of the EIS/EIR itself. Moreover, GW-1 fails to include clear performance standards, criteria, thresholds of significance, evaluation of feasibility, analysis of likelihood of success, and even facially permits significant impacts to occur. And importantly, GW-1 does not, in fact, reduce potentially significant impacts to less-than-significant levels, but rather, attempts to monitor for when significant effects occur, then purports to provide measures to slow the impact from worsening.

GW-1 begins by referencing the *DRAFT Technical Information for Preparing Water Transfer Proposals* ("DTIPWTP")(Reclamation and DWR 2013) and Addendum (Reclamation and DWR 2014). First, it is worth noting that this document is in DRAFT form, as have all such previous iterations of the Technical Information for Preparing Water Transfer Proposals, leaving any guidance for a final mitigation measure uncertain. Second, the DTIPWTP itself requires a project-specific evaluation of then-existing groundwater and surface water conditions to determine potentially significant impacts to water supplies; but this is exactly the type of impact analysis that must occur now in the self-described project EIS/EIR before any consideration of mitigation measures is possible. Even still, the exact scope of future environmental review is unclear as well. "Potential sellers will be required to submit well data," but the EIS/EIR does not explain what data or why. (EIS/EIR at 3.3-88.)

GW-1 next requires potential sellers "to complete and implement a monitoring program," but a monitoring program itself cannot prevent significant impacts from occurring. " The monitoring program will incorporate a sufficient number of monitoring wells to accurately characterize groundwater levels and response in the area before, during, and after transfer pumping takes place.' (EIS/EIR 3.3-88.) Again, this should be done now, for public review, to determine the significance of project impacts before the project is approved. Moreover, the EIS/EIR fails to provide any guidance on what constitutes "a sufficient number of monitoring wells." GW-1 then requires monitoring data no less than on a monthly basis, but common sense suggests that significant groundwater pumping could occur in less than a month's time. GW-1 requires that "Groundwater level monitoring will include measurements before, during and after transfer-related pumping," but monitoring after transfer-related pumping can only show whether significant impacts *have* occurred; it cannot prevent them. Yet this is exactly what the EIS/EIR proposes: "The purpose of Mitigation Measure GW-1 is to monitor groundwater levels during transfers to avoid potential effects. If any effects occur despite the monitoring efforts, the mitigation plan will describe how to address those effects." (EIS/EIR 3.3-91.) Hence, GW-1 only requires elements of the mitigation plan to kick in after monitoring shows significant impacts, which are extremely likely to occur given the fact that monitoring alone amounts to no mitigation or avoidance measure.

Even still, the proposed mitigation plans don't mitigate significant impacts. The mitigation plan includes the following requirements: "Curtailment of pumping until natural recharge corrects the issue." This, of course, could take years and is acknowledged in the EIS/EIR (p. 3.1-17 and 18), and really amounts to no mitigation of the significant impact at all. "Reimbursement for significant increases in pumping costs due to the additional groundwater pumping to support the transfer." In what amount, at what time, as decided by who? Monetary compensation is not always sufficient to cover damages to business operations. "Curtailment of pumping until water levels raise above historic lows if non-reversible subsidence is detected (based on local data to identify elastic versus inelastic subsidence)." It does not follow that any water level above the *historic lows* avoids or offsets damage from non-reversible subsidence. -only admits that irreversible subsidence may occur. Finally, "[o]ther actions as appropriate" is so vague as to be meaningless. (EIS/EIR 3.3-90.)

The wholesale deferral of these mitigation measures is particularly confusing since the lead agencies should already have monitoring and mitigation plans and evaluation reports based on the requirements of the DTIPWTP for past groundwater substitution transfers, which likely were undertaken by some of the same sellers as the proposed 10-year transfer project. The Draft EIS/EIR should provide these existing Bureau approved monitoring programs and mitigation plans as examples of what level of technical specificity is required to meet the objectives of GW-1.

The DTIPWRP doesn't add any additional monitoring or mitigation requirements for subsidence, stating that areas that are susceptible to land subsidence may require land surface elevation surveys, and that the Project Agencies will work with the water transfer proponent to develop a mutually agreed upon subsidence monitoring program. The monitoring locations in "strategic" locations are similarly deferred with no guiding criteria.

Lastly, groundwater quality monitoring only appears to be required after a transfer has begun, which again is too late to prevent any significant impact from occurring. (EIS/EIR 3.3-89.)

Mitigation measure GW-1 calls for stopping pumping after significant impacts are detected and then waiting for natural recovery of the water table. This might not be in time for groundwater dependent farms or riparian trees (cottonwoods & willows) to recover from the impact or could greatly extend the time to recovery. In the meantime, riparian-dependent wildlife including Swainson's hawks would be without nesting habitat, migration corridors, and foraging areas. The mitigation measure should require active restoration of important habitat such as riparian and wetland, not natural recovery. Recovery to an arbitrary water level is not necessarily the same as recovery of wildlife habitat and populations of sensitive species.

The water level monitoring in the mitigation measure should give explicit quantitative criteria for significant impact. Stating that a reduction in flow or GW level is "within natural variation" and therefore not significant is deceptive. The natural variation includes extreme cases and the project should not be allowed to add an additional increment to an already extreme condition. The extremes are supposed to be rare, not long-term and chronic. For example, Little Chico Creek may be essentially dry at times but it is not totally dry and that may be all that allows plants and animals to persist until wetter conditions return. If everything dies because the creek becomes totally dry due to the project, then it may never recover.

VIII. The EIS/EIR Fails to Analyze a Reasonable Range of Alternatives.

The EIS/EIR is required to evaluate and implement feasible project alternatives that would lessen or avoid the project's potentially significant impacts. Pub. Resources Code §§ 21002, 21002.1(a), 21100(b)(4), 21150; *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553, 564. This is true even if the EIS/EIR purports to reduce or avoid any or all environmental impacts to less than significant levels. *Laurel Heights Improvement Assn. v. Regents of Univ. of Cal.* (1988) 47 Cal.3d 376. Alternatives that lessen the project's environmental impacts must be considered even if they do not meet all project objectives. CEQA Guidelines § 15126.6(a)-(b); *Habitat & Watershed Caretakers v City of Santa Cruz* (2013) 213 Cal.App.4th 1277, 1302; *Center for Biological Diversity v. County of San Bernardino* (2010) 185 Cal.App.4th 866. Further, the EIS/EIR must contain an accurate no-project alternative against which to consider the project's impacts. CEQA Guidelines § 15126.6(e)(1); *Mira Mar Mobile Community v. City of Oceanside* (2004) 119 Cal.App.4th 477.

Under NEPA, the alternatives analysis constitutes "the heart of the environmental impact statement" (40 C.F.R. § 1502.14). The agency must "rigorously explore and objectively evaluate all reasonable alternatives" (40 C.F.R. § 1502.14(a), 40 C.F.R. § 1502.14(b)), and to identify the preferred alternative (40 C.F.R. § 1502.14(e)). The agency must consider the no action alternative, other reasonable courses of action, and mitigation measures that are not an element of the proposed action (40 C.F.R. § 1508.25(b)(1)-(3)).

a. No Environmentally Superior Alternative is Identified.

The EIS/EIR fails to follow the law and significantly misleads the public and agency decision-makers in declaring that none of the proposed alternatives are environmentally superior. (EIS/EIR 2-39.) First, neither CEQA nor NEPA provide the lead agencies with discretion to sidestep this determination. As the Council on Environmental Quality (CEQ) has explained, "[t]hrough the identification of the environmentally preferable alternative, the decision maker is clearly faced with a choice between that alternative and the others, and must consider whether the decision accords with the Congressionally declared polices of the Act."[65] CEQA provides that "[i]f the environmentally superior alternative is the "no project" alternative, the EIR shall also identify an environmentally superior alternative among the other alternatives." (CEQA Guidelines § 15126.6(e)(2).)

First, the EIS/EIR fails to identify whether the "no project" alternative is environmentally superior to each other alternative. If that is the case, the EIS/EIR must then identify the next most environmentally protective or beneficial alternative. Here, the EIS/EIR presents evidence that Alternative 3 and Alternative 4 each would lessen the environmental impacts of the proposed project. The EIS/EIR however then shirks its responsibility to identify the environmentally superior alternative by casting the benefits of Alternatives 3 and 4 as mere "trade-offs." This gross mischaracterization misleads the public and agency decision-makers, as the only "trade-off" between the proposed alternative and Alternatives 3 or 4 would be more or less adverse environmental effect.

The EIS/EIR argument that its conclusion that no project impacts are significant and unavoidable misses the point. Just as an EIS/EIR may not simply omit any alternatives analysis when there is purported to be no significant and unavoidable impact, neither can the agencies decline to identify the environmentally superior alternative. In fact, the proposed project would cause numerous significant and adverse environmental effects, and the EIS/EIR relies on wholly deferred and inadequate mitigation measures to lessen those effects, even allowing some level of significant impacts to occur before kicking in. But mitigation measures alone are not the only way to lessen or avoid significant project effects: the alternatives analysis performs the same function, and should be considered irrespective of the mitigation measures proposed.

b. Feasible Alternatives to Lessen Project Impacts are Excluded.

In light of the oversubscribed water rights system of allocation in California, changing climate conditions, and severely imperiled ecological conditions throughout the Delta, the EIS/EIR

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[65] Forty Most Asked Questions Concerning CEQ's NEPA Regulations, 48 Fed. Reg. 18,026 (Mar.16, 1981) Questions 6a.

should consider additional project alternatives to lessen the strain on water resources. Alternatives not considered in the EIS/EIR that promote improved water usage and conservation include:

***Fallowing in the area of demand*.** The EIS/EIR proposes fallowing in the area of origin to supply water for the transfers yet fails to present the obvious alternative that would fallow land south of the Delta that holds junior, not senior, water rights. This would qualify as an, "immediately implementable and flexible" alternative that is part of the Purpose and Need section (p.1-2). Whether or not this is a preference for the buyers, this is a pragmatic alternative that should be fully explored in a recirculated EIS/EIR.

Crop shifting in the area of demand. The EIS/EIR proposes crop shifting in the area of origin to supply water for the transfers yet fails to present the obvious alternative that would shift crops south of the Delta for land that holds junior, not senior, water rights. Hardening demand by planting perennial crops (or houses) must be viewed as a business decision with its inherent risks, not a reason to dewater already stressed hydrologic systems in the Sacramento Valley. This would qualify as an, "immediately implementable and flexible" alternative that is part of the Purpose and Need section (p.1-2). Whether or not this is a preference for the buyers, this is a pragmatic alternative that should be fully explored in a recirculated EIS/EIR.

Mandatory conservation in urban areas. In the third year of a drought, an example of urban areas failing to require serious conservation is EBMUD's flyer from October's bills that reflects the weak mandates from the SWRCB.

- Limit watering of outdoor landscapes to two times per week maximum and prevent excess runoff.
- Use only hoses with shutoff nozzles to wash vehicles.
- Use a broom or air blower, not water, to clean hard surfaces such as driveways and sidewalks, except as needed for health and safety purposes.
- Turn off any fountain or decorative water feature unless the water is recirculated.

While it is laudable that EBMUD customers have cut water use by 20 percent over the last decade,[66] before additional water is ever transferred from the Sacramento River watershed to urban areas, mandatory usage cuts must be enacted during statewide droughts. This would qualify as an, "immediately implementable and flexible" alternative that is part of the Purpose and Need section (p.1-2). This alternative should be fully vetted in a recirculated EIS/EIR.

***Land retirement in the area of demand*.** Compounding the insanity of growing perennial crops in a desert is the resulting excess contamination of 1 million acres of irrigated land in the San Joaquin Valley and the Tulare Lake Basin that are tainted with salts and trace metals like selenium, boron, arsenic, and mercury. This water drains back—after leaching from these soils

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[66] https://www.ebmud.com/water-and-wastewater/latest-water-supply-update

the salts and trace metals—into sloughs and wetlands and the San Joaquin River, carrying along these pollutants. Retirement of these lands from irrigation usage would stop wasteful use of precious fresh water resources and help stem further bioaccumulation of these toxins that have settled in the sediments of these water bodies. The Lead and Approving Agencies have known about this massive pollution of soil and water in the area of demand for over three decades. [67] Accelerating land retirement could diminish south of Delta exports and provide water for non-polluting buyers. Whether or not this is a preference for all of the buyers, this is a pragmatic alternative that should be fully explored in a recirculated EIS/EIR.

***Adherence to California's water rights*.** As mentioned above, the claims to water in the Central Valley far exceed hydrologic realty by more than five times. Unless senior water rights holders wish to abandon or sell their <u>rights</u>, junior claimants must live within the hydrologic systems of their watersheds. This would qualify as an, "immediately implementable and flexible" alternative that is part of the Purpose and Need section (p.1-2). Whether or not this is a preference for the buyers, this is a pragmatic alternative that should be fully explored in a recirculated EIS/EIR.

IX. The EIS/EIR Fails to Disclose Irreversible and Irretrievable Commitment of Resources, and Significant and Unavoidable Impacts.

Under NEPA, impacts should be addressed in proportion to their significance (40 C.F.R. § 1502.2(b)), and all irreversible or irretrievable commitment of resources must be identified (40 C.F.R. § 1502.16). And CEQA requires disclosure of any significant impact that will not be avoided by required mitigation measures or alternatives. CEQA Guidelines § 15093. Here, the EIS/EIR does neither, relegating significant impacts to groundwater depletion, land subsidence, and hardened demand for California's already-oversubscribed water resources, to future study pursuant to inadequately described mitigation measures, if discussed at all.

a. Groundwater Depletion.

As discussed, above, the EIS/EIR groundwater supply mitigation measures rely heavily on monitoring and analysis proposed to occur *after* groundwater substitution pumping has begun, perhaps for a month or more. Only after groundwater interference, injury, overdraft, or other harms (none of which are assigned a definition or significance threshold) occur, would the EIS/EIR require sellers to propose mitigation measures, which are as of yet undefined. As a result, significant and irretrievable impacts to groundwater are fully permitted by the proposed project.

b. Subsidence.

Here, again, the EIS/EIR suffers the same flaw of only catching and proposing to mitigate

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[67] http://www.usbr.gov/mp/cvpia/3408h/

subsidence after it occurs. But damages caused by subsidence can be severe, permanent, and complicated. The EIS/EIR does not purport to avoid these impacts, nor possibly mitigate them to less than significant levels. Instead, the EIS/EIR provides for "Reimbursement for modifications to infrastructure that may be affected by non-reversible subsidence." This unequivocally provides for significant and irreversible impacts to occur.

c. Transfer Water Dependency.

The EIS/EIR fails to account for long-term impacts of supporting agriculture and urban demands and growth with transfer water. Agriculture hardens demand by expansion and crop type and urban users harden demand by expansion. Both sectors may fail to pursue aggressive conservation and grapple with long-term hydrologic constraints with the delivery of more northern California river water that has been made available by groundwater mining and fallowing. Since California has high variability in precipitation year-to-year (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST) (Exhibit Y), and how will purchased water be used and conserved? Should agricultural water users be able to buy Project water, how will DWR and the Bureau assure that transferred water for irrigation is used efficiently? Could purchased water be used for any kind of crop or landscaping, rather than clearly domestic purposes or strictly for drought-tolerant landscaping?

Without a hierarchy of priority uses among agricultural or urban users for purchasing CVP and non-CVP water, the EIS/EIR fails to ensure that California water resources will not go to waste, and will not be used to harden unsustainable demands.

X. The EIS/EIR Fails to Adequately Evaluate Growth-Inducing Impacts.

The EIS/EIR gives short shrift to the growth inducing impact analyses required under both CEQA and NEPA by absolutely failing to realize or by obfuscating the obvious: these types of Long-Term Water Transfers inherently lead to economic and population growth. Not only are the amount of water sales and types of water sales unknown to the Lead Agencies and the public, but once water is sold and transferred to the buyer agency, there are no use limitations or priority-criteria imposed on the buyer. Whether agricultural support or municipal supply, hydraulic fracturing, industrial use, or onward transfer, the potential growth inducing impacts, both economically and physically are limitless. And once agencies and communities are hooked on buying water to sustain economic conditions or to support development and population growth, while drought conditions continue or are exacerbated, unwinding the clock may prove impossible.

Growth inducing impacts are addressed in Section 15126.2(d) of the CEQA Guidelines, and the Council on Environmental Quality NEPA Sections 1502.16(b) and 1508.8(b). CEQA Section 15126.2(b) requires an analysis of a project's influence on economic or population growth, or increased housing construction and the future developments' associated environmental impacts. The CEQA Guidelines define growth inducing impacts as "…the ways in which the proposed project could foster economic or population growth, or the construction of additional housing, either directly or indirectly, in the surrounding environment." Under NEPA, indirect effects as declared in Section 1508.8(b) include reasonably foreseeable growth inducing effects from changes caused by a project.

A project may have characteristics that encourage and facilitate other activities that could significantly affect the environment, either individually or cumulatively. CEQA Guidelines section 15126.2(d) admonishes the planner not to assume that growth in any area is necessarily beneficial, detrimental, or of little significance to the environment. Included here are projects that would remove physical obstacles to growth, such as provision of new water supply achieved through Long Term Water Transfers. Removal of a barrier such as water shortages may lead to the cultivation of crops with higher-level water dependency and higher profit margins at market, or may supplement perceived and actual advantages of living in population-dense locales, leading to increased population growth.

The EIS/EIR states that direct growth-inducing impacts are typically associated with the construction of new infrastructure while projects promoting growth, like increased water supply in dry years, could have indirect growth inducing effects. Claiming that growth inducing impacts would only be considered significant if the ability to provide needed public services is hindered, or the potential for growth adversely affects the environment, the EIS/EIR then incorrectly concludes that the proposed water transfer from willing sellers to buyers, to meet existing demands, would not directly or indirectly affect growth beyond what is already planned. But the EIS/EIR does not describe "what is already planned," nor how binding such plans would be.

Similar to the drought period in the late 1980's and early 1990's, urban agencies demand was approximately 40 percent of the transfer market. During that drought period, dry-year purchases were short term deals, intended to offset lower deliveries. However, this time around most of the transfer water is available to support longer-term growth, not solely to make up for shortfalls during droughts. Under current law, urban water agencies must establish long-term water supply to support new development, and long term transfers can provide this necessary evidence.[68]

Adding to these concerns is the increase in fracking interests throughout the state, requiring large-scale water demand to extract oil and gas, run by companies with the financial ability to influence water rights through payment. While one county directly south of the boundary involving this proposed transfer agreement recently banned fracking, other counties in

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[68] California Senate Bills 221 and 610, entered into law, 2001: requires agencies with over 5000 service connections and those with under 5000 service connections to demonstrate at least 20 years of available water supply respectively, for projects in excess of 500 residential units, or equivalent in combined residential and other demand (large service agencies), or for projects demanding least 10 percent growth in local water needs (small service agencies).

California are either involved in the practice of fracking, have yet to ban the practice, or have no interest in a fracking ban. Notably, the Monterey Shale Formation that stretches south through central California is in the buyer-area of the water districts served by this potential Long-Term Water Transfer Agreement. Without use limitations upon water transfers proposed within this agreement, water transferred under this plan may well be used for fracking

The EIS/EIR inappropriately fails to evaluate or disclose these reasonably foreseeable growth-inducing impacts.

XI. Conclusion

Taken together, the Bureau, SLDMWA, and DWR treat these serious issues carelessly in the EIS/EIR, the *Draft Technical Information for Water Transfers in 2013*, and in DWR's specious avoidance of CEQA review. In so doing, the Lead and Approving Agencies deprive decision makers and the public of their ability to evaluate the potential environmental effects of this Project and violate the full-disclosure purposes and methods of both the National Environmental Policy Act and the California Environmental Quality Act. For each of the foregoing reasons, we urge that the environmental review document for this project be substantially revised and recirculated for public and agency review and comment before any subject project is permitted to proceed.

Sincerely,

B. Vlamis

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Barbara Vlamis, Executive Director
AquAlliance

Bill Jennings

____
Bill Jennings, Executive Director
California Sportfishing Protection Association

Jason

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

california water impact network

April 2, 2014

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Subject: Comments on the *Draft Environmental Assessment/Initial Study 2014 San Luis & Delta Mendota Water Authority Water Transfers*

Dear Mr. Hubbard and Ms. Mizuno:

AquAlliance submits the following comments and questions for the Bureau of Reclamation ("Bureau") and the San Luis Delta Mendota Water Authority's ("SLDMWA") ("Agencies") *Draft Environmental Assessment* ("EA") and *Initial Study* ("IS") ("EA/IS"), for the *2014 San Luis & Delta Mendota Water Authority Water Transfers* program ("Project"). We include by reference the comments and documents submitted by AquAlliance's Executive Director for the *2009 Drought Water Bank* ("DWB"), the *2010-2011 Water Transfer Program*, and the *2013 Water Transfer Program* with other items in Appendix A that disclose the environmental impacts associated with these types of serial "temporary" transfers.

I. Lead Agency

SLDMWA is not the proper Lead Agency for the Project. California Environmental Quality Act ("CEQA") Guidelines section 15367 and Section 15051 require that the California Department of Water Resources, as the operator of the California Aqueduct and who has responsibility to protect the public health and safety and the financial security of bondholders with respect to the aqueduct, is the more appropriate lead agency. In *PCL v DWR*, the court found that DWR's attempt to delegate lead agency authority impermissibly insulated the department from "public awareness and possible reaction to the individual members' environmental and economic values."[1] DWR clearly has approval authority for parts of the Project and is guiding the transfer process as noted on page 3-41: "Potential sellers will be required to submit well data for Reclamation and, where appropriate, DWR review, as part of the transfer approval process. Required information is detailed in the *DRAFT Technical Information for Preparing Water Transfer Proposals* (Reclamation and DWR 2013) and Addendum (Reclamation and DWR 2014) for groundwater substitution transfers."

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[1] *Planning and Conservation League et al. v Department of Water Resources* (2000) 83 Cal.App.4th 892, 907, citing Kleist v. City of Glendale (1976) 56 Cal. App. 3d 770, 779.

Additionally, the EA/IS p 1-2 says: "Other transfers not involving the SLDMWA and its Participating Members could occur during the same time period. The Tehama-Colusa Canal Authority (TCCA) is releasing a separate EA/IS to analyze transfers from a very similar list of sellers to the TCCA Member Units. These two documents reflect different potential buyers for the same water sources; that is, the sellers have only the amounts of water listed in Section 2 available for transfer, but the water could be purchased by SLDMWA or TCCA members." This is another reason that DWR should be the lead agency: environmental review of transfers should be unified and comprehensive, and cumulative across both geography and over time.

II. Document Presentation

Document Identification

A foundational requirement under the National Environmental Policy Act ("NEPA") and CEQA is disclosure. This begins with the proper identification of the document that is circulated for public review. The title page of the environmental review document provided for the proposed Project states that it is a *Draft Environmental Assessment/Initial Study 2014 San Luis & Delta Mendota Water Authority Water Transfers*. The headers on alternate pages throughout the document and the appendices identify the document with: *2014 San Luis & Delta-Mendota Water Authority Water Transfers Draft Environmental Assessment/Initial Study*. From these titles, the Bureau appears not to be a party to the document.

The Notice of Intent that was mailed to AquAlliance, but was not available on the Bureau's web site (http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=16681), asserts that SLDMWA plans to adopt a Mitigated Negative Declaration and refers the reader to the Bureau's web site provided above for the EA/IS. In addition, the CEQA cover sheets that were initially attached to the EA/IS when it was first released on the Bureau's web site, but are now absent from the site, also asserted the intent to adopt a Mitigated Declaration. Included in the CEQA cover sheets are two pages signed by Frances Mizuno on March 11, 2014 entitled *MITIGATED NEGATIVE DECLARATION FOR 2014 SAN LUIS & DELTA-MENDOTA WATER AUTHORITY WATER TRANSFERS* that refers the reader to the Bureau's web site for the EA/IS, but, as stated above, these four cover pages are no longer available on the Bureau's web site (http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=16681). Lastly, to add to the confusion, there is no mention of a Mitigated Negative Declaration anywhere in the EA/IS.

As discussed above, there is an absence of clarity regarding 1) the intent to adopt a Mitigated Declaration under CEQA and 2) the ownership of the NEPA/CEQA document. On March 14, 2014, the day after the formal release of the EA/IS on the Bureau's web site, the cover pages that informed the reader that SLDMWA intended to adopt a Mitigated Negative Declaration vanished. What has been available for public review since that date is confusing and deficient. It must also be emphasized that the NEPA/CEQA document is only available at the Bureau's web site. Next, regarding the lead agencies for the NEPA/CEQA document, we acknowledge that page 1-1 reveals the lead agency roles of the Bureau and SLDMWA, but we find that the lack of clear, dual ownership in the document's title and page headers confusing and deficient for the public.

Document Navigation

The Index fails to provide details for Chapter 3 with the CEQA check list headings and pages making the document less than user-friendly.

III. Purpose and Need

The Bureau's *Reclamation's NEPA Handbook* (2012) states, "The need for an accurate (and adequate) purpose and need statement early in the NEPA process cannot be overstated. This statement gives direction to the entire process and ensures alternatives are designed to address project goals." (p.11-1) While "need" is disclosed in section 1.2 (p. 1-3), there is no coherent discussion of that "need" that would establish how SLDMWA members find themselves in the current situation. Merely stating that, "As a result of the significantly reduced allocation, the SLDMWA is in need of water for irrigation, primarily of permanent crops to prevent the long term impacts of allowing these crops to die," lacks context, specificity, and rigor. First, the hydrologic conditions described on page 1-3 apply to the entire state, including the region where buyers are sought, not just the areas served by SLDMWA as presented here. Second, SLDMWA has chronic water shortages due to its contractors' junior position in water rights, risks taken by growers to plant permanent crops, and serious long-term overdraft in its service area. Where is this divulged? Third, SLDMWA or its member agencies have sought to buy and actually procured water in many past water years to make up for poor planning and risky business decisions. which violates CEQA's prohibition against segmenting a project to evade proper environmental review?[2]

In reference to the Bureau, the EA/IS states, "Reclamation's need is to approve the transfer of Base Supply or Project Water that may require the use of CVP facilities, consistent with state and federal law, the Sacramento River Settlement Contract, and the Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project Improvement Act (Title XXXIV of Public Law 102-575). This "need" statement, highlights the conflicts in the Bureau's mission, deficiencies in planning for 2014, and the inadequacy of the EA/IS that should provide, among other things, the following background.

- During Bureau meetings held in 2013[3], the Bureau and DWR knew full well that 2013 was a dry year and that reservoir levels at the dams were exceedingly low[4]. Despite that awareness, the same federal and state agencies continued to export almost 2,400,000 AF of water to South State interests between June and December 2013. (*Id at p. 8*)
- In 2011 the Bureau gave away approximately 450,000 AF of additional storage water and DWR exported more than 826,000 AF of water above what it disclosed it could in 2013.[5]
- After taking the above actions, the Bureau (p. 1-3) and DWR are diminishing water allocations to senior water rights holders in and north of the Delta and yet asking some of the same water districts to actually sell water.

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[2] Laurel Heights Improvement Association v. Regents of the University of California, 1988, 47 Cal.3d 376
[3] http://www.usbr.gov/mp/Waters_Supply_Meetings/About.html
[4] Bureau WY 2013 Handout (4)
[5] http://calsport.org/news/wp-content/uploads/St-Bd-Drought-Wkshp.pdf

The Proposed Action Alternative is poorly specified and needs additional clarity before decision makers and the public can understand the human and environmental consequences of the *2014 Water Transfers*. The EA describes the Proposed Action Alternative as one reflecting the Bureau's intention to approve transfers of Central Valley Project water from willing sellers who contract with the Bureau ordinarily to use surface water on their croplands. Up to 195,126 AF of CVP water are offered from these sellers, according to Table 2-1. (EA/IS p. 2-3). In contrast to the EA/FONSI for the 2009 Drought Water Bank (p. 3-88), the Project EA/IS contains no "priority criteria" to determine water deliveries and simply acknowledges that CVP river water will be transferred to San Luis & Delta Mendota Water Authority contractors. The EA/IS fails to indicate how much water has been requested by the buyers of CVP or non-CVP water, which is also in contrast to the 2009 DWB EA/FONSI and DWR's addendum for the 2009 DWB. Potential buyers of non-CVP water are also not disclosed. These significant omissions eliminate the public's ability to consider, assess, and comment on possible impacts in the receiving areas. This denial of information further obfuscates the need for the Project.

The Bureau and SLDMWA's draft environmental review of the Project does not comply with the requirements of NEPA[6] or CEQA[7] for the reasons described below.

IV. An EIS/EIR is Required

The Bureau must prepare an environmental impact statement ("EIS") and DWR, as the proper lead agency (not SLDMWA), must prepare an environmental impact report ("EIR") on this proposal. The current project is similar to the 2009 Drought Water Bank project that allowed up to 600,000 acre-feet (AF) of surface water transfers, up to 340,000 AF of groundwater substitution, and significant crop idling. At that time, DWR staff conceded that the 2009 Drought Water Bank project would have significant environmental impacts. The 2009 Drought Water Bank (2009 DWB) was a water transfer program very similar to the current proposal. Litigation of the 2009 DWB disclosed internal DWR emails showing DWR staff's view that the 2009 DWB would have significant impacts on the environment.[8] (See Supplemental Administrative Record ("Suppl. AR") 2007 [email from Curt Spencer stating: "Without an air override, we face a limited water supply, See Suppl. AR 2020, 203.)[9] DWR staff were also concerned the proposed addendum would not meet CEQA's requirements because the mitigation measures for impacts on the giant garter snake were based on an expired 2003 biological opinion. (See Suppl. AR 2010, 2014, 2022, 2044, and 2056.) Other concerns included the adequacy of the mitigation measures to protect the giant garter snake given the lack of up to date scientific information on the species (see Suppl. AR 2026, 2028, and 2034). Indeed, even after invoking the emergency exemption, DWR continued to express concerns regarding the project's potentially significant environmental impacts and whether these impacts would be mitigated. (See Suppl. AR 2064, 2066, and 2070 [emails discussing concern re air impacts]; Suppl. AR 2054 [email planning

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[6] 42 U.S.C. §4321 *et seq*

[7] Public Resources Code §21000 *et seq*

[8] DWR E-mail Regarding 2009 Drought Water Bank.

[9] Pages of the Suppl AR are attached hereto as Exhibit __.

"CEQA analysis [that] will focus on the emissions impacts associated with the increased use of diesel [ground water] pumps."].)

The proposed Project also mirrors the *2010-2011 Water Transfer Program* that sought approval for 200,000 AF of CVP related water and assumed NEPA coverage for additional non-CVP transfer water up to 195,910 AF and the *2013 Water Transfer Program* that sought approval for 37,505 AF of CVP water made available by groundwater substitution and NEPA coverage for an additional 92,806 AF of North State water from groundwater substitution and 65,000 AF from reservoir storage.

NEPA requires federal agencies to prepare a detailed EIS on all "major Federal actions significantly affecting the quality of the human environment . . . ."[10] and CEQA has similar requirements and criteria. NEPA regulations promulgated by the Council on Environmental Quality identify factors that the Bureau must consider in assessing whether a project may have significant environmental effects, including:

> (1) "The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks." 40 C.F.R. §1508.27(b)(5).
> (2) "The degree to which the effects on the quality of the human environment are likely to be highly controversial." *Id.* §1508.27(b)(4).
> (3) "Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate on a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).
> (4) "The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration." *Id.* §1508.27(b)(6).
> (5) "The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973." *Id.* §1508.27(b)(9).

Here, the Bureau and the state agency have failed to take a hard look at the environmental impacts of the Project. As elucidated below, there are substantial questions about whether the Project's proposed water transfers will have significant effects on the region's environment, biology, and hydrology. There are also substantial questions about whether the Project will have significant adverse environmental impacts when considered in conjunction with the other related water projects underway, planned, and proposed in the region. The Bureau and the state agency simply cannot, consistent with NEPA, allow these foreseeable environmental impacts to escape full analysis in an EIS of the proposed Project. AquAlliance's comments below will further highlight the EA/IS deficiencies in disclosure, analysis, and justification for its conclusions.

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[10] 42 U.S.C. §4332(2)(C).

The EA/IS Violates NEPA and CEQA Rules Against Segmenting Environmental Review of Projects

It is noteworthy that the Bureau and the state agency assert that the Project is not part of a "Program" as it has for past water transfers (p. 1-2) and that a draft Findings of No Significant Impact ("FONSI") has not been provided with the release of the EA/IS as is the Bureau's custom.

The Bureau and DWR have known for over a decade that programmatic environmental review was and is necessary for water transfers from the Sacramento Valley. The following examples highlight the Bureau and DWR's deficiencies in complying with NEPA and CEQA.

- The Sacramento Valley Water Management Agreement was signed in 2002, and the need for a programmatic EIS/EIR was clear at that time it was initiated but never completed.[11]
- In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken.
- Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate.
- Last, but not least, is the attempt by the Bureau and SLDMWA to analyze the 10-Year Plan, which also has failed to materialize since the scoping period in January 2011.

The Bureau's most recent transfer approvals include:

- In 2009, the Bureau approved a 1 year water transfer program under which a number of transfers were made. Regarding NEPA, the Bureau issued a FONSI based on an EA.
- In 2010, the Bureau approved a 2 year water transfer program (for 2010 and 2011). No actual transfers were made under this approval. Regarding NEPA, the Bureau again issued a FONSI based on an EA.
- In 2013, the Bureau approved a 1 year water transfer program, again issuing a FONSI based on an EA. The EA incorporates by reference the environmental analysis in the 2010-2011 EA.

These Water Transfer approvals are "programmatic" in the sense that they cover a large geographic area, and applicants for specific water transfers must still obtain additional approvals (from the Bureau and from the SWRCB) before executing any specific water transfer. The additional approvals include:

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[11] The Bureau and DWR actually began a joint Programmatic EIS/EIR to facilitate water transfers from the Sacramento Valley and the interconnected actions that are integrally related to the transfers, but never completed it. The Bureau has impermissibly broken out this current segment of the overall Program for piecemeal review in the present draft EA. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "includ[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" *Id.* At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").

- A specific authorization from the Bureau, based on an application defined by a document entitled: "Draft Technical Information for Water Transfers in 2013."
- A specific approval from the State Water Board of a petition for change in place or purpose of use under Water Code § 1725 et seq).

In sum, the Bureau and the state have approved water transfer programs (either 1-year or 2-year programs) in 5 out of the last 6 years. Therefore, it is clear that the need for such programs in the future (to the extent a need exists at all), is virtually certain. Therefore, to avoid violating the rules under both NEPA and CEQA against segmenting environmental review of projects, the Bureau and state are required to include future water transfers in the current environmental analysis, either as (1) part of the project description, as reasonably foreseeable future activities associated with the project, and/or as part of the assessment of cumulative impacts. The EA/IS fails to do so,

V. Chapter 2, Alternatives

The most fundamental deficiency of the EA/IS is the lack of alternatives considered, which, once again, continues the Bureau's failure to comply with NEPA and DWR's failure to comply with CEQA. NEPA's implementing regulations call analysis of alternatives "the heart of the environmental impact statement," 40 C.F.R. §1502.14, and they require an analysis of alternatives within an EA. *Id.* §1408.9. The statute itself specifically requires federal agencies to:

> study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning available uses of resources.

42 U.S.C. §4332(2)(E). CEQA has parallel requirements for alternatives to be analyzed in an EIR. Here, because the Bureau's EA considers only the proposed Project and a "No Action" alternative, the EA violates NEPA.

The case law makes clear that an adequate analysis of alternatives is an essential element of an EA, and is designed to allow the decision-maker and the public to compare the environmental consequences of the proposed action with the environmental effects of other options for accomplishing the agency's purpose. The Ninth Circuit has explained that "[i]nformed and meaningful consideration of alternatives … is … an integral part of the statutory scheme."[12] An EA must consider a reasonable range of alternatives, and courts have not hesitated to overturn EAs that omit consideration of a reasonable and feasible alternative.[13]

Here, there are only two alternatives presented: the No Action and the Proposed Action. The lack of *any* alternative action proposal is unreasonable and is by itself a violation of NEPA's requirement to consider a reasonable range of alternatives. 42 U.S.C. § 4332(2)(E).

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[12] *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228 (9th Cir. 1988) (holding that EA was flawed where it failed adequately to consider alternatives).

[13] *See People ex rel. Van de Kamp v. Marsh*, 687 F.Supp. 495, 499 (N.D. Cal. 1988); *Sierra Club v. Watkins*, 808 F.Supp. 852, 870-75 (D.D.C. 1991).

2.2 Proposed Action/Proposed Project

Pages 2-3 to 2-6 present the sellers and the amounts of water that may be transferred under two different scenarios: Current Hydrologic Conditions and Improved Conditions. Table 2-1, *The Maximum Potential Transfer by Seller (Acre Feet)* indicates that the total under current hydrologic conditions may be 91,313 and under improved conditions may be 195,126. This is straight forward. However, when attempting to determine how much water may come from fallowing or groundwater substitution during two different time periods, April-June and July-September, the reader is left to guess.

The numbers in the "totals" row of Table 2-2 presumably should add up to 91,313. Instead, they add up to 110, 789. The numbers in the "totals" row of Table 2-3 presumably should add up to 195,126. Instead, they add up to 249,997. Both Tables 2-2 and 2-3 have a footnote stating: “These totals cannot be added together. Agencies could make water available through groundwater substitution, cropland idling, or a combination of the two; however, they will not make the full quantity available through both methods. Table 2-1 reflects the total upper limit for each agency.”

This "explanation" is no explanation at all. As a result, the reader cannot know how much water is expected to be generated by groundwater substitution versus crop idling. This amount of uncertainty regarding potential sources of the water and the nature of the Project is confusing and impairs the public's ability to assess its environmental impacts.

The following paragraph is found on page 2-9:

> An objective in planning a groundwater substitution transfer is to ensure that groundwater levels recover to their seasonal high levels under average hydrologic conditions. Because groundwater levels generally recover at the expense of stream flow, the wells used in a groundwater substitution transfer should be sited and pumped in such a manner that the stream flow losses resulting from pumping are primarily during the wet season, when losses to stream flow minimally affect other legal users of water. For the purposes of this EA/IS, the stream flow losses are assumed to be 12 percent of the amount pumped for transfer. The quantity of water available for transfer would be reduced by these estimated stream flow losses.

The EA's use of “average hydrologic conditions” as the baseline for assessing degree of impact and effectiveness of mitigation measures is unlawful for several reasons. "Average hydrologic conditions" is undefined. The EA asserts elsewhere that hydrologic conditions in 2014 are not "average." The assumption that “[s]tream flow losses are assumed to be 12 percent of the amount pumped for transfer” is unsupported for any location, including the locations where groundwater substitution transfers will occur. The suggestion that "the wells used in a groundwater substitution transfer should be sited and pumped in such a manner that the stream flow losses resulting from pumping are primarily during the wet season" is not embodied in any enforceable condition or mitigation measure. Since there is no guarantee this suggestion will be honored, it does not support a FONSI for impacts related to stream flow losses. Also, the EA/IS considers the effects of stream flow losses on other water users, and fails to assess the effect of stream flow losses (either below or above the 12% threshold) on other environmental values and resources, such as:

Page 2-11, bullet one states that, "Historical amounts of idled land vary year-to-year by close to 20 percent, which indicates that the local economy has adjusted to similar amounts of crop idling." What data support this assertion? Where is it presented in the EA/IS? If it is presented in the EA/IS, why is not cited with the above quotation? If GCID planned to idle about 15 percent of the district's rice land with a 75 percent CVP allocation, it is fair to conclude that it would more than double with what is currently proposed at a 40 percent allocation. (EA/IS p. 4-5). The impacts from increased fallowing due to decreased CVP allocations, let alone in combination with the proposed transfers, are not presented here.

As the Agencies well know, the overall economy and the environment are supposed to be protected from unreasonable effects according to California Water Code Section 1810 and the CVPIA. Page 2-11, bullet two states that, "Cropland idling has not generally resulted in economic impacts outside of the historical variations." What data support this assertion? How is "generally" defined in this context? What data are used to evaluate economic impacts from fallowing if there are unusual conditions? Where are these issues presented in the EA/IS? If they are presented in the EA/IS, why are they not cited with the above quotation? If the Agencies have data that support the quoted assertion, although it is not cited or presented in the EA/IS for public review, aren't the current, unusually dry conditions (presented in Section 1.2, *Need for Proposal and Project Objectives*) combined with unprecedented cuts to CVP water deliveries a time when unusually significant impacts might occur? Over a decade ago David Gallo assessed the impacts on local economies from fallowing and concluded that the costs ranged from $157 - $170 per acre foot of water sold.[14] This is what should have been analyzed and evaluated in the EA/IS, or better yet, in what the Agencies know is necessary: an EIS/EIR (EA/IS p.1-4).

In Chapter 2, Alternatives, page 2-11, bullet three states that, "Water Code Section 1745.05(b) requires a public hearing under some circumstances in which the amount of water from land idling exceeds 20 percent of the water that would have been applied or stored by the water supplier absent the water transfer in any given hydrologic year. Third parties would be able to attend the hearing and could argue to limit the transfer based on its economic effects." With water deliveries potentially cut to 50 percent for senior SWP contractors and 40% for senior CVP contractors, what is the potential to exceed the 20 percent figure, particularly when cropland idling transfers are added to the cumulative impacts? Is a public hearing scheduled? How will potentially affected and interested parties receive notice of a hearing? It is noticeable that the EA/IS bullet language fails to disclose where a public hearing might be held and before what governmental body.

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[14] Gallo, David. Estimating Third Party Impacts From Water Transfers Through Riceland Fallowing: A Suggested Approach.

Section 2.3, *Recent Environmental Documents*, proudly touts the production of the *2010/2011 Water Transfer Program* Environmental Assessment. Although discussion of the document's failings are not disclosed here, AquAlliance presented many of them in our comments on the EA/FONSI and filed litigation to challenge it. During the litigation the Bureau decided to initiate the 10-Year Water Transfer Program (600,000 AF per year) with scoping meetings for an EIS/EIR in concert with SLDMWA. Despite the acknowledgment that an EIS/EIR is necessary for the repetitious water transfers, the release of the EIS/EIR has been delayed year-after-year while the Bureau continues to pursue one-year, so-called "temporary" transfers.

Mitigation and Monitoring

Where are the data that are referenced on page 2-12? "As part of the monitoring plans required by the EA/IS, the transferring parties have collected monitoring data starting pre-transfer. To date (through January 2014), the available monitoring data indicates that the groundwater aquifer is recovering to pre-transfer levels, as described in the EA. Final monitoring reports that describe the monitoring data will be available in May 2014." If the public doesn't have access to the "pre-transfer" data and the Agencies will not have final reports until May 2014, how can the public adequately comment and how can the Agencies reach a conclusion? This gaping hole in the assessment of the impacts from the 2013 water transfers indicates at a minimum that the 2014 Project EA/IS was circulated prematurely.

In light of the EA/IS's deficit in presenting groundwater conditions in the Sacramento Valley after the 2013 groundwater substitution transfers or historic trends, we attach the most current DWR maps that illustrate the serious condition of the groundwater basins in the Sacramento Valley. These DWR maps[15] present a very different picture than what is supplied in Appendix F's attempt at modeling. There is a clear and significant downward trend in regional groundwater levels.

- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2012 to Fall 2013, Shallow Aquifer Zone
- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2012 to Fall 2013, Intermediate Aquifer Zone
- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2012 to Fall 2013, Deep Aquifer Zone
- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2004 to Fall 2013, Shallow Aquifer Zone
- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2004 to Fall 2013, Intermediate Aquifer Zone
- Northern Sacramento Valley Change In Groundwater Elevation Map Change in Deep Fall 2004 to Fall 2013, Deep Aquifer Zone

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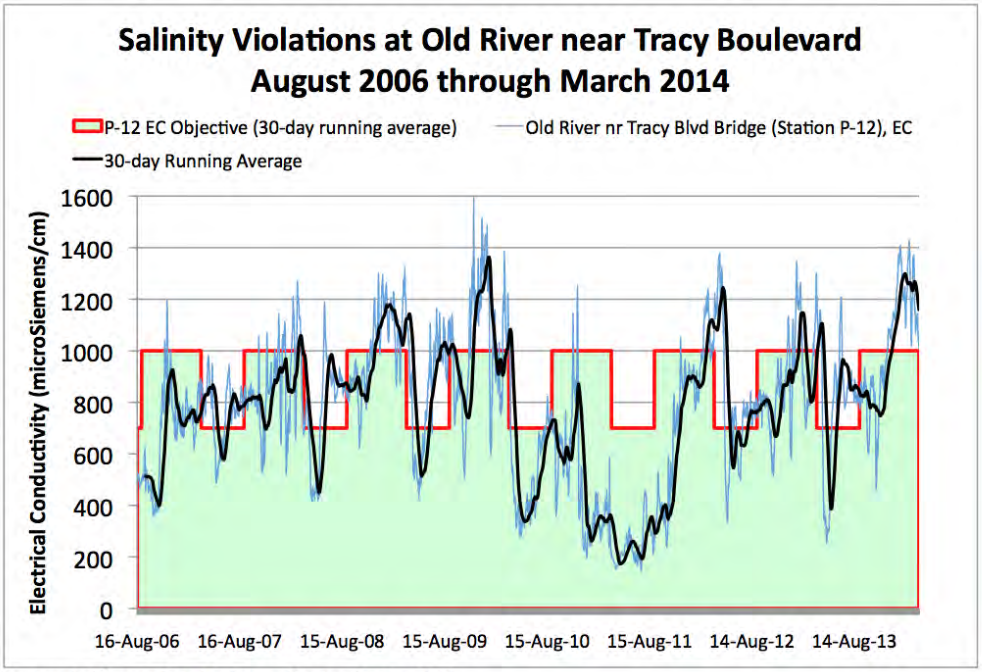
[15] http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Level%20Monitoring%20Reports%20and%20Maps

Environmental Commitments

Page 2-12 (also p. A-1) attempts to assure the public that, "Carriage water will be used to maintain water quality standards in the Delta." With that promise in mind, the Bureau and DWR have a record of violating these standards. [16]



Source: California Data Exchange Center, Station OLD.

On what basis should decision-makers or the public rely on the promises made by the Bureau and DWR, let alone the buyer, SLDMWA, which facilitates some of the most destructive practices in California: growing permanent crops in a desert, creating massive amounts of polluted water and soil,[17] and crying foul when the spigot is dry?

Page 2-12 continues with assurances that, "Well reviews and monitoring and mitigation plans will be implemented to minimize potential effects of groundwater substitution on nearby surface and groundwater water resources. Well reviews, monitoring and mitigation plans will be coordinated and implemented in conjunction with local ordinances, basin management objectives, and all other applicable regulations." The Agencies are asking the public to trust that this will happen and that the mitigation and monitoring plans will be adequate. The public has no mechanism to verify how well this has or hasn't been handled in the past and isn't presented with an opportunity for this year. Mitigation and Monitoring Plans must be available concurrently

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[16] Stroshane chart and table 2014, Salinity Violations at Old River Near Tracy Blvd. August 2006-August 2013.

[17] According to the December 2000 United States Geological Survey Open File Report 00-416, even if irrigation of drainage problem areas were halted today, it would take 63 to 300 years to drain contaminated water from the Western San Joaquin Valley's aquifer underlying contaminated soils in WWD. The USGS report reiterates the findings in the Rainbow Report [USGS, Gilliom et.al. 1989] that the drainage problem area in 1990 was 450,000 acres. If irrigation continues without a resolution, the problem area will be 950,000 acres in 2040.

with NEPA and CEQA documents, so the public, knowledgeable about the areas where transfer sales are proposed, may evaluate and provide comments on their efficacy. This has been a repeated failure by the Bureau and DWR.

Geology and Soils (2.5.4)

Page 2-17 states, "There are some earthquake faults in the region but earthquakes are generally associated with coastal California, west of the Central Valley." This casual statement fails to disclose significant history and information that is easily available.[18] The major faults in the region should, at minimum, be disclosed.

VI. Chapter 3 - Environmental Impacts

Biological Resources (IV)

a) Check list item "a" fails to include the National Marine Fisheries Service ("NMFS") as a jurisdictional agency over species that may be affected by the Project (p.3-11) although they are referenced in the discussion on pages 3-12 to 3-13. This lack of clarity and consistency contributes to difficulty reviewing the EA/IS.

b) On page 3-13, the EA/IS continues its discussion to support the finding of *Less Than Significant Impact* for, "[a]ny species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Wildlife or U.S. Fish and Wildlife Service," with NMFS excluded as noted above (p.3-11). The EA/IS concludes that, "The incremental effects of transfers on special status fish species in the Delta from water transfers would be less than significant." What data and analysis support this conclusion and where is the material found? Analysis conducted by Thomas Cannon contradicts the *Less Than Significant Impact* finding with disturbing results from the summer of 2013.[19] His research reveals that summer water transfers are devastating, especially in dry years when the low salinity zone is in the western Delta and smelt are stuck within the Delta and threatened by warm water, which has been made available for transfer by either fallowing or groundwater substitution, and predators,

c) The Bureau and DWR, not SLDMWA, should prepare an EIR because the Project will likely have significant environmental effects on the Giant Garter Snake (*Thamnophis gigas*)("GGS"), a listed threatened species under the federal Endangered Species Act and California Endangered Species Act. 40 C.F.R. §1508.27(b)(9).

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[18] "Detailed analyses of this seismicity and focal mechanisms indicate that active geologic structures include blind thrust and reverse faults and associated folds (e.g., Dunnigan Hills) within the CRSB boundary zone on the western margin of the Sacramento Valley, the Willows and Corning faults in the valley interior, and reactivated portions of the Foothill fault system. Other possibly seismogenic faults include the Chico monocline fault in the Sierran foothills and the Paskenta, Elder Creek and Cold Fork faults on the northwestern margin of the Sacramento Valley." http://archives.datapages.com/data/pacific/data/088/088001/5_ps0880005.htm

[19] *Summer 2013: The demise of Delta smelt under D-1641 Delta Water Quality Standards*

The draft EA/IS fails to comprehensively describe or analyze the species, its baseline condition (that should at a minimum start with the CalFed ROD's approval in 2000), movements, habitat requirements, critical habitat, or recovery plan. Is the GGS part of any draft of final HCPs or NCCPs? The Agencies' *Environmental Commitments* are described on pages 2-12 to 2-14 (repeated verbatim in Appendix A) and seem to be the extent of what the Agencies' deem to be their responsibilities under NEPA and CEQA.

We would like to remind the Agencies that flooded rice fields and irrigation canals in the Sacramento Valley can be used by the giant garter snake for foraging, cover and dispersal purposes. The snake gives birth from July to September, months that the Project would be implemented. The Agencies must explain to decision-makers and the public just how the multiple strains of past and Project fallowing and groundwater substitution transfers, cuts in CVP and SWP deliveries, and recently past and existing dry conditions in the area of origin could significantly increase the potential impact to GGS habitat and the species itself. GGS depend on more than only rice fields in the Sacramento Valley.[20] "The giant garter snake inhabits marshes, sloughs, ponds, small lakes, low gradient streams, other waterways and agricultural wetlands such as irrigation and drainage canals and rice fields, and the adjacent uplands. Essential habitat components consist of: (1) adequate water during the snake's active period, (early spring through mid-fall) to provide a prey base and cover; (2) emergent, herbaceous wetland vegetation, such as cattails and bulrushes, for escape cover and foraging habitat…" (Id at p. 3) What analysis has occurred that removes GGS from consideration for potential significant impacts? How will the Project affect streams, wetlands, and emergent, herbaceous wetland vegetation? How will it be monitored? Crafting an *Environmental Commitment* to provide Reclamation with "[a]ccess to the land to verify how the water transfer is being made available and to verify that the actions to protect the GGS are being implemented," doesn't pass the blush test (2-13). As AquAlliance has stated repeatedly in previous water transfer comments, an *independent*, third-party monitor, with no financial ties to the Agencies, DWR, or any buyers and sellers is the only acceptable and credible monitor. See AquAlliance comments for the *2010/2011 Water Transfer Program* and the Bureau's *2013 Water Transfer Program*.

Hydrology and Water Quality (IX)

The draft EA does not provide sufficient evidence to support its conclusion that the Project will not have significant hydrological impacts.

a) The EA/IS lacks detailed information, such as the most basic conditions in the local and regional environment in the area of origin, which has also experienced multi-year dry conditions and significantly lower precipitation. This essential background description is found neither in the *Background* section of Chapter 1 or in this section of Chapter 3, *Hydrology and Water Quality.* Without disclosing current site specific, local, and

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[20] **Programmatic Consultation with the U.S. Army Corps of Engineers**
404 Permitted Projects with Relatively Small Effects on the Giant Garter Snake within Butte, Colusa, Glenn, Fresno, Merced, Sacramento, San Joaquin, Solano, Stanislaus, Sutter and Yolo Counties, California

regional conditions, it is impossible to evaluate the potential environmental impacts that should be made available to decision-makers and the public before the Bureau reaches a conclusion. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989).

b) Item "a" considers if the Project will "Violate any water quality standards or waste discharge requirements?" and concludes that there will be a *Less than Significant Impact*.

- Proposed Action. 1) The EA/IS fails to disclose historic and ongoing degradation of water quality that has been caused by the CVP in the Delta and the SLDMWA import area.[21][22] [23]2) It also fails to consider that groundwater extractions may mobilize PCE, TCE, and nitrate plumes under the City of Chico[24] (p.4) or in other Sacramento Valley communities and the potential risks to human health and the environment. The EA/IS fails to even *disclose* the existence of all the hazardous waste plumes in the area of origin where groundwater substitution may occur. These are just more examples of the issues that should be considered and evaluated in an EIS/EIR.

c) Item "b" discussed on pages 3-27 - 3-42 is considered a *Less than Significant Impact*. There are significant faults with the finding and the material that supports it in the EA/IS.

- No Action Alternative. Why do Figures 3-1, 3-2, and all the hydrographs in Appendix F end at 2002? Extending the timeline and using actual well monitoring data, not simply modeling, would provide valuable information for the Agencies, decision-makers, and the public. Figures 3-1, and 3-2 provide "[b]aseline modeling trends," but present only a picture of possible groundwater responses when there is genuine historical and current data[25] that are ignored. The exercise in modeling actually obfuscates the demonstrable responses that have occurred during all measure of hydrologic conditions.
- No Action Alternative. "In the Sacramento Valley, reductions in supply have historically resulted in increased groundwater pumping and decreased groundwater levels; however, the water levels have rebounded quickly after the dry period." This conclusory statement fails to provide the decision-makers and the public with important factual data. For example, a summary of conditions in the Durham area of Butte County find that while water levels may recover after dry periods with intense use, wells aren't returning to previous levels, but moving

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[21] SWRCB D-1641, "The source of much of the saline discharge to the San Joaquin River is from lands on the west side of the San Joaquin Valley which are irrigated with water provided from the Delta by the CVP, primarily through the Delta-Mendota Canal and the San Luis Unit." "The USBR, through its activities associated with the in the San Joaquin River Basin, is responsible for significant deterioration of water quality in the Southern Delta."

[22] Drainage Problem area in 1990 was 450,000 acres. If no resolution, problem area will be 950,000 acres in 2040 (Rainbow Report)

[23] If no more irrigation of the western San Joaquin Valley were to occur and the San Luis Drain were completed, it would still take 63-300 years to drain the accumulated Se from the aquifer at a rate of 43,500 lbs./year. (USGS Open File Report 00-416)

[24] 2005. California GAMA Program: Groundwater Ambient Monitoring and Assessment Results for the Sacramento Valley and Volcanic Provinces of Northern California

[25] http://www.water.ca.gov/waterdatalibrary/

steadily in a downward trajectory.[26] Additionally, even the Yuba River area, often touted by state and federal agencies as a successful conjunctive use program, takes 3-4 years to recover from groundwater substitution in the south sub-basin[27] although the Yuba County Water Agency analysis fails to determine how much river water is sacrificed to achieve the multi-year recharge rate. (pp. 21, 22). More examples of what the EA/IS fails to provide are found in the most current DWR maps listed above in our comments regarding Chapter 2 that demonstrate the serious condition of the groundwater basins in the Sacramento Valley.

- No Action Alternative “Figures 3-1 and 3-2 show baseline groundwater trends (in addition to modeling results for the Proposed Action) at the groundwater table and in the deep aquifer, respectively, in the Sacramento Valley near Sycamore Mutual Water Company.” There is a noticeable absence of information north of Chico on either side of the Sacramento River (recall that Figures 3-3 and 3-4 stop before the northern Butte County line); south and east of Chico east of the Sacramento River in general; and west of Interstate 5. There may not be planned groundwater substitution transfers in some of this area, but that is no reason not to provide tangible data for this part of the common Tuscan groundwater basin. For examples of existing conditions see Table 1 below that is based on data provided by DWR. In addition, grave concern was expressed in the minutes of a December 2013 Glenn County Water Advisory Committee: “The report emphasized that despite the small upward trend in water levels observed on an annual basis in some areas, there is a general decline observable in the long term data across the majority of the region, particularly in the Northwestern portion of Glenn County.”

Table 1. Example of wells of concern in Butte and Tehama counties

3 yrs data multi completion. ~1mile west of Butte Creek Country Club, declining trend
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=24664
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=24665
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=24440

3 yrs data multi, ~6miles SW of Chico, declining trend
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=48992
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=48990
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=48991

4yr data multi, ~6miles WSW of chico, declining
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=38214
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=24975
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=24974

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[26] Buck, Christina 2014. *Groundwater Conditions in Butte County*.

[27] 2012. *The Yuba Accord, GW Substitutions and the Yuba Basin*. Presentation to the Accord Technical Committee.

11 yrs, irrigation, ~8miles NW of Chico, declining trend
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=25770

12 yrs, cana-pine creek, -10'
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=25770

>40 yr data Near 99 and ~6miles E of Corning, dipping below 60' shallow aquifer (valley oak depth)
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=19988

Near Deer Creek ~10miles NE of Corning, 14 years, declining trend, monitoring well multi
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=19993
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=34741

Multi comp monitoring well, ~10miles NE Corning, 14 years, declining below valley oak roots, near deer creek
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=19047
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=19046
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=19045

Multi comp monitoring, 13 yrs, ~8miles SE of Durham, Declining toward valley oak limits if trend continues
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=35608
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=17160
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=17161

~2.5 miles NW of Thermal to Forebay, 14 yrs, 10-20' decline
http://www.water.ca.gov/waterdatalibrary/groundwater/hydrographs/brr_hydro.cfm?CFGRIDKEY=16799

- No Action Alternative. “Appendix F, Groundwater Modeling Results, contains hydrographs at additional locations throughout the valley.” As noted above, presenting only modeling when historic records exist, conceals factual material and presents a false picture. The Agencies must produce the data from decades of well monitoring to provide a genuine look at the groundwater basins, both the Sacramento *and* Redding, More discussion was presented above.
- No Action Alternative. “The groundwater basin is likely to experience groundwater level declines similar to those that occurred during historic droughts (such as 1976- 1977 and 1987-1992), caused by increased pumping to address reduced surface water supplies. In the San Joaquin Valley, reductions in supply would also lead to increased groundwater pumping, but the groundwater historically has not recovered during subsequent dry years.” (p. 3-27). The EA/IS fails to provide any scientific research and analysis that leads to its conclusory

assertion that conditions in the Sacramento Valley groundwater basins will perform as they did during droughts between 38 and 22 years ago. As in much of California, the population has increased in the Sacramento Valley and the amount of irrigated agricultural has as well, placing greater demands on the groundwater basins. As noted above, the San Joaquin Valley groundwater basins are a casualty of very flawed state and federal policy combined with exuberance to place profit over human health, safety, and the environment.

- Proposed Action. The environmental checklist for Hydrology impacts, at section IX.b, finds that the Project impact to "Substantially deplete groundwater supplies ... such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level" is 'less-than-significant."
- This conclusion is, however, the result of failing to proceed in the manner required by law: (1) in assessing the significance of this impact, (2) in developing specific mitigation measures to reduce this impact; (3) in assessing the effectiveness of such mitigation measures; and (4) in adopting such mitigation measures. This conclusion is also unsupported by substantial evidence in the record. In addition, there is substantial evidence that this impact is significant. Therefore, CEQA requires preparation and certification of an EIR and NEPA requires preparation and certification of an EIS before Project approval.
- **The EA/IS fails to discharge the lead agencies' duty to find out and disclose all that they reasonably can. (14 CCR § 14144.)**

  With respect to Sacramento Valley groundwater, the EA/IS states: "In the Sacramento Valley, reductions in supply have historically resulted in increased groundwater pumping and decreased groundwater levels; however, the water levels have rebounded quickly after the dry period." (Page 3-27.) The EA/IS makes this assertion based on modeling results, while ignoring contrary empirical information. For example, a summary of conditions in the Durham area of Butte County find that while water levels may recover after dry periods with intense use, wells aren't returning to previous levels, but moving steadily in a downward trajectory.[28] Significantly more material is found in our comments on the *2013 Water Transfer Program*.

  In another example, even the Yuba River area, often touted by state and federal agencies as a successful conjunctive use program, takes 3-4 years to recover from groundwater substitution in the south sub-basin.[29] The Yuba River analysis, however, fails to determine how much river water is sacrificed to achieve the groundwater recharge rate mentioned (pp. 21, 22). It is highly likely that the Yuba River becomes a losing stream due to excess use of the groundwater. More examples of what the EA/IS fails to provide are found in the most current DWR

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[28] Buck, Christina 2014. *Groundwater Conditions in Butte County*.

[29] 2012. *The Yuba Accord, GW Substitutions and the Yuba Basin*. Presentation to the Accord Technical Committee.

maps listed above in our comments regarding Chapter 2 that demonstrate the serious condition of the groundwater basins in the Sacramento Valley.

- In short, the EA/ IS fails to disclose all that it reasonably can. "If the local agency has failed to study an area of possible environmental impact, a fair argument may be based on the limited facts in the record. Deficiencies in the record may actually enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences." *Sundstrom v. County of Mendocino* (1988) 202 Cal.App.3d 296, 311.
- **There is substantial evidence that this impact is significant.**

  The EA/IS concedes the Project may cause impacts to the groundwater basin from groundwater substitution transfers, including (1) increased groundwater pumping costs due to increased pumping depth; (2) decreased yield from groundwater wells due to reduction in the saturated thickness of the aquifer; (3) decrease of the groundwater table to a level below the vegetative root zone, which could result in environmental effects; and 4) third-party impacts to neighboring wells. (P. 3-29.) But the EA/ IS deems these impacts less-than-significant. In a confusing twist, however, the EA/ IS concedes there are uncertainties surrounding how this Project will affect specific locations, stating: “uncertainty of how groundwater levels could change, especially during a very dry year,” in the Redding basin (p. 3-30) and “[t]he model results may not reflect all specific local conditions throughout the Sacramento Valley” (p. 3-37); and that, as a result, mitigation measures will be employed, stating: "Therefore, minimization measures described below would include development of monitoring and mitigation plans to monitor and address potential groundwater level changes that could affect third parties or biological resources." (P. 3-37.)
- This is confusing because the agencies cannot require mitigation measures unless impacts are deemed significant. (See e.g., 14 CCR § 15041(a).) This gives rise to an inference that the Project may cause these impacts to be significant, thus requiring an EIS/EIR.
- Further, the EA/IS unlawfully defers the development of specific mitigation measures until after project approval because there is no basis for assuming they will be effective, there are no objective criteria to judge whether they are successful in avoiding significant impacts, and nothing about them is definitive enough to be enforceable. In short, there is no reason to assume the “minimization measures” and the mitigation and monitoring plans that the EA/IS references will reduce these impacts to "less-than-significant"
- Proposed Action. The Redding Groundwater Basin discussed on pages 3-29 to 3-30 is not included in Figures 3-3 and 3-4. SacFEM modeling may not have been done for the Redding Groundwater Basin, but it would have been beneficial for readers to have the entire area of origin depicted in the only maps provided for the Project.

- Proposed Action. In addition, the Anderson Cottonwood Irrigation District ("ACID") that is located in the Redding Groundwater Basin is going at the groundwater substitution transfers somewhat blind. It has not benefited from any modeling, but has instead, "[t]ested operation of these wells in the past at similar production rates and has observed no substantial impacts on groundwater levels or groundwater supplies (Anderson-Cottonwood ID 2013)." In attempting to review the reference from p. 5-1 for the: *Initial Study and Proposed Negative Declaration for Anderson-Cottonwood Irrigation District's 2013 Water Transfer Program. Available at:* *http://www.andersoncottonwoodirrigationdistrict.org/library.html or at:* *http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=13310*, we found that the only environmental documents at the ACID web site relate to a 2011 Bureau EA/FONSI for the *Anderson-Cottonwood Irrigation District Integrated Regional Water Management Program – Groundwater Production Element Project* and the Bureau's web site is for the EA/FONSI for the 2013 Water Transfer Program. The public has been obstructed from reviewing the referenced material to evaluate the efficacy of the findings in the Bureau/SLDMWA EA/IS that, "[g]roundwater substitution transfers are unlikely to have significant effects on groundwater levels." (p. 3-30).
- Proposed Action. Table 3-8 fails to include ACID and Tule Basin Farms in the table. The last three listed *Potential Sellers* are not listed in alphabetical order with the other possible sellers.
- Proposed Action. Groundwater/Surface Water Interaction. The EA/IS acknowledges the potential for impacts and assumes a "[1]2 percent depletion factor to prevent any adverse impacts associated with surface water-groundwater interaction…" (p.3-39) This number is not supported with any documentation or analysis and runs counter to modeling done by CH2M HILL in a memo to DWR in 2010. "The effect of groundwater substitution transfer pumping on stream flow, when considered as a percent of the groundwater pumped for the program, is significant. The impacts were shown to vary as the hydrology of the periods following the transfer program varied. The three scenarios presented here estimated effects of transfer pumping on stream flow when dry, normal, and wet conditions followed transfer pumping. Estimated stream flow losses in the five-year period following each scenario were 44, 39, and 19 percent of the amount of groundwater pumped during the four month transfer period."[30] Even with this modeling information in hand since 2010, the Agencies and DWR continue to use a 12 percent deduction for stream flow. The results of the model run are the best predictions available to date and suggests caution above all else, even though they are preliminary and the model subject to modification.[31] By adhering to a 12 percent loss for stream flow, it is clear that the Bureau, SLDMWA, and DWR are

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[30] Lawson 2010. *Groundwater Substitution Transfer Impact Analysis, Sacramento Valley*.

[31] WRIME 2011. *Peer review of Sacramento valley Finite Element Groundwater Model (SacFEM)*

not erring on the side of caution and may be causing considerable legal injury to other users and the environment.

- The base map for Figures 3-3 and 3-4 lacks clarity. It is difficult to discern the approximate locations of wells # 1 through 6, 9, 15, 16, 19, 20, 21, 22, 28, and 30.
- This Project is part of serial, so-called "temporary" water transfers[32] and is also part of a much larger Program that was introduced by the Agencies on page 1-4, *Long Term Water Transfers*. As noted above, the Project and the *Long Term Water Transfers* reach back much further and are components of the following programs, plans, and studies:
    - i. CalFed Bay-Delta Program, Record of Decision (August 2000)
    - ii. Sacramento Valley Water Management Agreement (Phase 8), (October 2001)
    - *iii.* Sacramento Valley Integrated Regional Water Management Plan (2006)
    - iv. Sacramento Valley Regional Water Management Plan (January 2006)
    - v. Stony Creek Fan Conjunctive Water Management Program
    - vi. Draft Initial Study for 2008-2009 Glenn-Colusa Irrigation District Landowner Groundwater Well Program
    - vii. Regional Integration of the Lower Tuscan Groundwater Formation into the Sacramento Valley Surface Water System Through Conjunctive Water Management (June 2005) (funded by the Bureau)
    - viii. Stony Creek Fan Aquifer Performance Testing Plan for 2008-09
    - ix. Annual forbearance agreements (2008 had an estimated 160,000 acre feet proposed).
    - x. The Delta Stewardship Council's Plan and EIR approved in 2013.
    - xi. The Bay Delta Conservation Plan and EIS/EIR currently out for public review and comment.
- **Proposed Action. Land Subsidence.** The first paragraph on subsidence on page 3-39 is actually a useful summary of the hazards presented by the Project. The subsequent material also highlights the potential significant, adverse impacts, such as:
    - i. "Land subsidence has not been monitored in the Redding Groundwater Basin. However, there would be potential for subsidence in some areas of the basin if groundwater levels were substantially lowered. The groundwater basin west of the Sacramento River is composed of the Tehama Formation; this formation has exhibited subsidence in Yolo County and the similar hydrogeologic characteristics in the Redding Groundwater Basin could allow subsidence."

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[32] AquAlliance 2014. *Past Water Transfers from the Sacramento Valley Through the Delta.*

ii. Most areas of the Sacramento Valley Groundwater Basin have not experienced land subsidence that has caused impacts to the overlying land. However, portions of Colusa and Yolo counties have experienced subsidence; historically land subsidence occurred in the eastern portion of Yolo County and the southern portion of Colusa County, owing to groundwater extraction and geology. As much as four feet of land subsidence due to groundwater withdrawal has occurred east of Zamora over the last several decades.

The EA/IS then concludes that there will be a *Less Than Significant Impact* by using the "guidance" set forth in the *DRAFT Technical Information for Preparing Water Transfer Proposals* (Bureau and DWR 2013) and Addendum (Bureau and DWR 2014) to, "[m]inimize potential effects to other legal users of water; to provide a process for review and response to reported third party effects; and to assure that a local mitigation strategy is in place prior to the groundwater transfer." In addition, "Reclamation's transfer approval process and groundwater minimization measures set forth a framework that is designed to avoid and minimize adverse groundwater effects. Reclamation will verify that sellers adopt these minimization measures to minimize the potential for adverse effects related to groundwater extraction."

Even if minimizing subsidence is possible in the Sacramento Valley where groundwater substitution is planned, which we will argue it is not (see below), minimizing an impact is not *avoiding* an impact. The mere acknowledgment that minimizing will be necessary to avoid potentially adverse impacts, points once again to the need for an EIS/EIR. The EA/IS, the *Draft Technical Information for Water Transfers* in 2013, and the 2014 Addendum don't appear to weigh the significance of avoidance of impacts, pre-Project mitigation, during-Project mitigation, or post-Project mitigation. This fails to create objective standards and merely defers responsibility to the "willing sellers," a broadly unsuspecting public, and a voiceless environment.

There is substantial evidence that this impact is significant.
As noted above, the EA/IS concedes the Project may cause land subsidence impacts in both the Redding Groundwater Basin, where it says previous subsidence has not been a problem (p. 3-39), and the Sacramento Groundwater Basin (p. 3-40), where it says previous subsidence from groundwater pumping has been a problem.

Regardless of these different histories, both are purportedly required to develop so-called mitigation and monitoring plans to deal with the assessment of whether pumping will cause significant subsidence and to develop mitigation measures to reduce this impact.

Again, because agencies cannot require mitigation measures unless impacts are deemed significant, this requirement indicates the Project may cause significant subsidence impacts, thereby requiring an EIS/EIR.

Further, the EA/IS unlawfully defers the assessment of whether pumping will cause significant subsidence. The EA/IS unlawfully defers the development of mitigation measures to reduce this impact until after project approval, but there is no basis for assuming they will be effective, there are no objective criteria to judge whether they are successful in avoiding significant impacts, and nothing about them is definitive enough to be enforceable. In short, there is no reason to assume the “minimization measures” and the mitigation and monitoring plans that the EA/IS references will reduce this impact to "less-than-significant"

The following evidence, however, demonstrates that the Project's subsidence impacts may be significant. AquAlliance has provided expert opinion on the issue of subsidence monitoring repeatedly during past water transfer environmental review. Despite its credibility, the findings of Dr. Kyran Mish, Presidential Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma, have been ignored. Dr. Mish relates: “It is important to understand that *all* pumping operations have the potential to produce such settlement, and when it occurs with a settlement magnitude sufficient enough for us to notice at the surface, we call it *subsidence*, and we recognize that it is a serious problem (since such settlements can wreak havoc on roads, rivers, canals, pipelines, and other critical infrastructure).”[33] Dr. Mish further explains that “[b]ecause the clay soils that tend to contribute the most to ground settlement are highly impermeable, their subsidence behavior can continue well into the future, as the rate at which they settle is governed by their low permeability.” *Id.* “Thus simple real-time monitoring of ground settlement can be viewed as an *unconservative* measure of the potential for subsidence, as it will generally tend to underestimate the long-term settlement of the ground surface.” *Id.* (emphasis added).

- Proposed Action. The environmental checklist for Hydrology impacts, at section IX.d, finds "No Impact" with respect to, “Substantially alter the existing drainage pattern of the site or area” is "Not Significant." But the text of the EA/IS contradicts this check box, and finds that Project could have land subsidence impacts that could " alter drainage patterns" (pp. 3-39-3-40.). By sowing confusion rather than clarity, the EA/IS fails to inform.

  This conclusion is, however, the result of failing to proceed in the manner required by law: (1) in assessing the significance of this impact, (2) in developing specific mitigation measures to reduce this impact; (3) in assessing the effectiveness of such mitigation measures; and (4) in adopting such mitigation measures. This conclusion is also unsupported by substantial evidence in the record. In addition, there is substantial evidence that this impact is significant.

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[33] Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.

> Therefore, CEQA requires preparation and certification of an EIR and NEPA requires preparation and certification of an EIS before Project approval.

Minimization Measures (pp. 3-40, 3-41)

The *Draft Technical Information for Water Transfers* in 2013 and the 2014 Addendum contain *minimal* objectives and requirements elements of the monitoring and mitigation component of the Project. "Water transfer proponents transferring water via groundwater substitution transfers must establish a monitoring program capable of identifying any adverse transfer related effects before they become significant." However, the reader (and possibly the sellers) are left wondering what exactly is "a monitoring program capable of identifying any adverse transfer related effects before they become significant," since there are no standards or particular guidance to manage and analyze the very complex hydrologic relationships internal to groundwater and the connection to surface waters.

Certainly the public has no idea or ability to comment, which fails the full-disclosure mandate in NEPA and CEQA. Page 38 of the *Draft Technical Information for Water Transfers* in 2013 briefly lists "Potentially significant impacts identified in a water transfer proposals [that] must be avoided or mitigated for a proposed water transfer to continue, including:

- Contribution to long-term conditions of overdraft;
- Dewatering or substantially reducing water levels in nonparticipating wells;
- Degradation of groundwater quality that substantially impairs beneficial uses or violates water quality standards; and
- Affecting the hydrologic regime of wetlands and/or streams to the extent that ecological integrity is impaired.

The *Draft Technical Information for Water Transfers* in 2013 continues with suggestions to curtail pumping from lower bowls and pay higher energy costs to ease the impacts to owners of third-party wells (p. 38-39). While this bone thrown at mitigation is appreciated, the glaring omissions are notable. The *Draft Technical Information for Water Transfers* in 2013 completely fails to mention, even at a very general level, how individual well owners who may be harmed by the Project, will determine and prove where the impacts to their wells are coming from and that water quality and health could become a significant impact for impacted wells, users, and streams. The onus for coping with and disclosing potential impacts is deflected onto the nonparticipating public, species, and environment. How does this meet the requirements of NEPA and CEQA? Since wetlands and streams would require human observation or adequate monitoring to report an impact, how will, "Affecting the hydrologic regime of wetlands or streams to the extent that ecological health is impaired," be avoided or mitigated without standards and requirements from the Bureau and DWR? (*Draft Technical Information for Water Transfers* p. 38) There also appears to be no consideration for species monitoring, just "practices" or "conservation measures" to "minimize impacts to terrestrial wildlife and waterfowl," (*Id* pp. 16, 20, 22-24).

Another example of the inadequacy of the proposed monitoring is that the draft EA/IS fails to include any coordinated, programmatic plan to monitor stream flow of creeks and rivers located in proximity to the "willing sellers" that will evacuate more groundwater than has been used historically. The potential for immediate impacts would be very close to water sellers' wells, but the long term impacts could be more subtle and geographically diverse. What precautions has the Bureau and DWR made for the cumulative impacts that come not only from this one-year Project, but in combination with the water sales from the last dozen years and those that are planned by the Bureau into the future (see list in g, iv below)? Bureau and DWR water transfers are not just one- or two-year transfers, but many serial actions in multiple years by the agencies, sellers, and buyers without the benefit of comprehensive environmental analysis under NEPA and CEQA.

As discussed above, adequate monitoring is vital to limit the significant risks posed by the Project to the health of the region's groundwater, streams, and fisheries (more discussion below). Moreover, to the extent this Project is conceived as an ongoing hardship program that will provide knowledge for future groundwater extraction and fallowing, its failure to include adequate monitoring protocols is even more disturbing and creates the risk of significant long-term, perhaps irreversible impacts from the Project.

One glaring omission in the EA/IS is the failure to disclose that the Project, when implemented under the State Water Resources Control Board's ("SWRCB") Temporary Urgency Change Petition Order(s), will exacerbate impacts in the area of origin, which is already suffering from dry conditions. Mismanaging storage in Shasta and Oroville dams, either intentionally or incompetently in the past three years (see above), created a scenario where the federal and state agencies plead hardship to some of the most senior water rights holders in California. Potentially cutting senior SWP contractors to 50 percent and senior CVP contractors to 40 percent allocations (EA/IS p. 2-2), portends dire consequences for local and regional groundwater that would not have been necessary without failures by the federal agency circulating this EA/IS and the 'hidden' state agency that should be the lead agency for the Project: DWR.[34]

Mandatory Findings of Significance (XVIII)

The EA/IS fails to disclose that the Project is likely to have a cumulatively significant impact on the environment (p. 3-53). In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an

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[34] http://calsport.org/news/wp-content/uploads/St-Bd-Drought-Wkshp.pdf

environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3).

Here, as detailed below, instead of assessing the cumulative impacts of the proposed action as part of the larger program that even the Bureau has at least twice recognized should be subject to a programmatic EIS (but for which no programmatic EIS has been completed), the Bureau again attempts to breaks this program into component parts and approve it through an inadequate EA and has joined with the improper CEQA lead agency to play lip service to CEQA. Further, the Bureau has failed to take into account the cumulative effects of other groundwater and surface water projects in the region, the development of "conjunctive" water systems, and the planned integration of Sacramento Valley groundwater into the state water system.[35]

The draft EA/IS briefly mentions that the Project is part of the *Long-Term Water Transfers* (p. 1-4). However, it fails to adequately describe that Program and how the Project relates to the Program, and further fails to describe the numerous other programs of which this Project is a small component part (see list of programs, plans, and studies above in section VI). It is clear that that this Project is an "interdependent part of a larger action," and that it "depend[s] on the larger action for [its] justification." 40 C.F.R. §1508.25(a)(1)(iii). This is exactly the sort of segmentation that NEPA prohibits. Instead, NEPA requires that "[p]roposals or parts of proposals which are related to each other closely enough to be, in effect, a single course of action shall be evaluated in a single impact statement." 40 C.F.R. §1502.4.

- Item "a" asserts that the proposed Project would have a *Less Than Significant* impact to all species within the region and local areas of water transfer is without any apparent scientific basis. (EA/IS p. 3-54). This conclusory assertion certainly does not constitute sufficient analysis of the potential impact of the Project on endangered, threatened, or special status species as described above. At a minimum, such conclusions rely on an improperly segmented and overly narrow view of the proposed action, which does not consider the larger project (p. 1-4) as described above or the cumulative impacts as also described above.

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[35] *U.S. Bureau of Reclamation September 2006. Grant Assistance Agreement with Glenn Colusa Irrigation District.* "GCID shall define three hypothetical water delivery systems from the State Water Project (Oroville), the Central Valley Project (Shasta) and the Orland Project reservoirs sufficient to provide full and reliable surface water delivery to parties now pumping from the Lower Tuscan Formation. The purpose of this activity is to describe and compare the performance of three alternative ways of furnishing a substitute surface water supply to the current Lower Tuscan Formation groundwater users to eliminate the risks to them of more aggressive pumping from the Formation and to optimize conjunctive management of the Sacramento Valley water resources."

VII Conclusion

The 2014 water transfer Project clearly has the potential to affect the human and natural environments, both within the Sacramento Valley as well as in the areas of conveyance and delivery. It is entirely likely that injuries to other legal users of water will occur, including those entirely dependent on groundwater in the Sacramento Valley, if this project is approved. Groundwater, groundwater basins, and aquatic and terrestrial habitat that are essential for fishery and wildlife resources are also likely to suffer great harm. And the economic effects of the proposed Project are at best poorly disclosed and will reverberate through the communities in the Sacramento Valley.

Taken together, the Bureau, SLDMWA, and DWR treat these serious issues carelessly in the EA/IS, the *Draft Technical Information for Water Transfers in 2013*, the 2014 Addendum, and in DWR's specious avoidance of acting as the CEQA lead agency. In so doing, the Agencies and DWR deprive decision makers and the public of their ability to evaluate the potential environmental effects of this Project and violate the full-disclosure purposes and methods of both the National Environmental Policy Act and the California Environmental Quality Act.

Sincerely,

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References

Anderson Cottonwood Irrigation District 2014. Web page copy from April 1, 2014.

Anderson, Michael. 2009. *Future California Droughts in a Climate Change World*.

AquAlliance 2014. Table of impacted wells in Butte and Tehama counties.

AquAlliance 2014. Past Water Transfers from the Sacramento Valley Through the Delta, 2001-2013**.**

AquAlliance, California Sportfishing Protection Alliance, and California Water Impact Network *Testimony on Water Availability Analysis for Trinity, Sacramento, and San Joaquin River Basins Tributary to the Bay--Delta Estuary*. 2012.

AquAlliance 2011. Comments on the *Draft Environmental Assessment/Initial Study and Finding of No Significant Impact/Mitigated Negative Declaration for the Anderson-Cottonwood Irrigation District Integrated Regional Water Management Program – Groundwater Production Element Project*.

AquAlliance 2011. Scoping comments for the 10-Year Water Transfer Plan.

AquAlliance et. al 2010. Comments on the *2010/2011 Water Transfer Program*.

Bacher, Dan. 2013. *Bay-Delta salmon population just one fifth of mandated goal*. http://www.indybay.org/newsitems/2013/05/15/18736849.php

Buck, Christina 2014. *Groundwater Conditions in Butte County.*

Bureau of Reclamation. 1993. *Interim Guidelines for Implementation of the Water Transfer Provisions of the Central Valley Project Improvement Act (Title XXXIV of Public Law 102-575).*

Bureau of Reclamation, et al. 2003. *Environmental Water Account*, Draft EIS/EIR.

Bureau of Reclamation 2006. Sacramento Valley Regional Water Management Plan. p. 5-8 to 5-10.

Bureau of Reclamation 2009. Drought Water Bank Environmental Assessment.

Bureau of Reclamation 2013. Water Year Handout.

Butte Basin Water Users Association 2007. *2007 Butte Basin Groundwater Status Report* p. 23 and 30.

Butte Basin Water Users Association 2008. *2008 Butte Basin Groundwater Status Report*

Butte County 2007. Summary of Spring 07 Levels.

Butte County Department of Water and Resource Conservation 2003. *Urban Water Demand Forecast*.

Butte County DWRC June 2007. *Tuscan Aquifer Monitoring, Recharge, and Data Management Project*, Draft.

Butte County DWRC 2013. *Groundwater Status Report, 2012 Water Year*.

a) Esquon Subinventory Unit report
b) Pentz Subinventory Unit report
c) Vina Subinventory Unit

California State Water Resources Control Board 2009. *GAMA Domestic Well Project, Tehama County Focus Area*.

California Water Impact Network, et al 2011. Complaint for Declaratory and Injunctive Relief.

Cannon, Thomas 2013. *SUMMER 2013: The demise of Delta smelt under D-1641 Delta Water Quality Standards*.

CH2Mhill 2006, *Sacramento Valley Regional Water Management Plan*, Figure 1-4.

Dudley, Toccoy et al. 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update.*

Dudley, Toccoy 2007. Letter to Lester Snow as presented to the Butte County Board of Supervisors as part of agenda item 4.05.

DWR 2008. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

DWR 2009. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report.

DWR 2009. E-mail correspondence regarding the 2009 *Drought Water Bank*.

Fleckenstein, Jan; Anderson, Michael; Fogg, Graham; and Mount, Jeffrey 2004. *Managing Surface Water-Groundwater to Restore Fall Flows in the Cosumnes River*, Journal of Water Resources Planning and management, opening page of article.

Friend, Scott 2008. *City of Chico General Plan Update Existing Conditions Report;* Pacific Municiple Consulting.

Gallo, David circa 2000. *Estimating Third Party Impacts From Water Transfers Through Riceland Fallowing: A Suggested Approach*.

Glenn County. Board of Supervisors. 2001. California Ordinance No. 1115, Ordinance Amending the County Code, Adding Chapter 20.03, Groundwater Management.

Glenn County. Management Plan: Development of a Locally Driven Groundwater Management Plan Ordinance #1115 amended by ordinance 1237 (2912). Accessed May 15, 2013 at: http://www.glenncountywater.org/management_plan.aspx.

Glenn County Water Advisory Committee 2013. Minutes from December 2013.

Glenn-Colusa Irrigation District 2008-2009. *Initial Study And Proposed Negative Declaration Landowner Groundwater Well Program*.

Governor's Advisory Drought Planning Panel 2000. *Critical Water Shortage Contingency Plan*.

Hennigan, Barbara 2007. Testimony, Monterey Agreement hearing in Quincy, California. (http://www.water.ca.gov/environmentalservices/docs/mntry_plus/comments/Quincy.txt).
Hennigan, Robert 2010. Personal communication with Barbara Vlamis on January 17, 2010.

Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

Lawson, Peter 2010. *Groundwater Substitution Transfer Impact Analysis, Sacramento ValleyI.*

Lippe, Gaffney, Wagner LLP. 2009. Letter to DWR regarding the Drought Water Bank Addendum.

Maslin, Paul E., et. al, 1996. *Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon: 1996 Update*.

Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.

Msangi, Siwa and Howit, Richard E. 2006. *Third Party Effects and Asymmetric Externalities in Groundwater Extraction: The Case of Cherokee Strip in Butte County, California.* International Association of Agricultural Economists Conference, Gold Coast, Australia.

Natural Resources Defense Council and Golden Gate Salmon Association. 2012. *Salmon Doubling Index: Natural Production of Sacramento-San Joaquin Basin Chinook Salmon, Expressed as Percentage of the CVPIA Salmon Doubling Goal, from 1992 to 2011*. http://goldengatesalmonassociation.com/wp-content/uploads/2012/06/Salmon-Graph-11-12-12.jpg

Sacramento County Water Agency. 2011. *Ground Water Management Plan.*

Scalmanini, Joseph C. 1995. *VWPA Substatiation of Damages*. Memo. Luhdorff and Scalmanini Consulting Engineers.

Shasta County Water Agency. 2007. *Redding Basin Water Resources Management Plan Environmental Impact Report*.

Shutes, Chris et al. 2009. *Draft Environmental Assessment DeSabla – Centerville Project (FERC No. 803)*. Comments. California Sportfishing Protection Alliance.

Spangler, Deborah L. 2002. *The Characterization of the Butte Basin Aquifer System, Butte County, California*. Thesis submitted to California State University, Chico.

State Water Resources Control Board. 2005. California *GAMA Program: Groundwater Ambient Monitoring and Assessment Results for the Sacramento Valley and Volcanic Provinces of Northern California*.

State Water Resources Control Board. 2008. *Hydrogeologically Vulnerable Areas*. http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf

Staton, Kelly 2007. *Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California*. California Department of Water Resources.

The Bay Institute. 2012. *Fresh Water Flows in the Central Valley A primer on their importance, status, and projected changes under the BDCP*.

The Natural Heritage Institute, et al. 2012 *Feasibility Investigation of Re-Operation of Shasta and Oroville Reservoirs in Conjunction with Sacramento Valley Groundwater Systems to Augment Water Supply and Environmental Flows in the Sacramento and Feather Rivers*.

USFWS 1999. Draft Recovery Plan for the Giant Garter Snake.

USFWS 2006. Giant Garter Snake Five Year Review: Summary and Evaluation.

USFWS 2008 Biological Opinion for Conway Ranch.

USFWS 2009 Biological Opinion for the Drought Water Bank.

Vlamis, Barbara 2006.Comments on the Supplemental Environmental Water Account EIR/EIR.

Vlamis, Barbara 2009. Letter to DWR regarding the Drought Water Bank Addendum from Lippe Gaffney Wagner LLP, 2009.

Vlamis, Barbara 2009. Letter to DWR regarding the 2009 Drought Water Bank Addendum.

Vlamis, Barbara, et al 2008. Letter to DWR regarding the 2009 Drought Water Bank Addendum.

WRIME 2011. *Peer review of Sacramento Valley Finite Element Groundwater Model (SacFEM)*.

Comments on:

LONG TERM TRANSFERS EIR/EIS

REVIEW OF EFFECTS ON SPECIAL STATUS FISH

1. INTRODUCTION

Long term transfers represent Reclamation and San Luis Delta Mendota Water Authority's ability to move water from north of the Delta to south of the Delta using its Central Valley Project storage, conveyance, and export facilities, and associated authorities. The EIS/EIR describes the details and effects of Reclamation's actions to carry out such transfers. Water for transfers would come from stored and saved water north of the Delta that would be delivered in summer south of the Delta. The amount of water proposed for transfer by Reclamation could be up to 600,000 af (Federal Register and EIS/EIR at p. 1-5), but is likely to be over 200 thousand acre-ft. Reclamation's EIS/EIR covers myriad proposed transfers. Some additional proposed State transfers are addressed in the EIS/EIR cumulative impacts assessment.

CSPA has undertaken a review of transfers and the EIS/EIR effects analysis on special status fish species. The species addressed include Chinook salmon, Steelhead, Green and White sturgeon, and Longfin and Delta smelt. These fish all depend on Central Valley river and Delta flows and habitats for portions of their life cycles. A summary of this review is presented in this report.

2. SUMMARY OF CSPA COMMENTS ON SECTION 3.7

A. Effects of Transfers

1. Change in timing and amount of river flows

Table C2 shows that summer Delta inflows from the Sacramento River in dry and critical water years may increase by several thousand cfs to accommodate transfer Delta exports. With non-CVP transfers the total change is not inconsequential. With minimum river flows of 3000-5000 cfs, transfers can double river flow and Delta inflow in summer of drier years when reservoir levels are low and water deliveries are cut back. **Holding Delta outflow near minimum and nearly doubling inflow and exports warms the Delta, increases loss of Delta fishes to export pumps, and degrades freshwater and low salinity zone habitat. For more discussion of this effect see Attachments A and B.**

River flows in winter can be lower by 10-20% in dry years as previous year's transfer releases are made up by reservoir water retention. Rivers flows may be reduced by over 1000 cfs although usually in higher precipitation months. **The refill of reservoirs the year after summer transfers reduces winter river flows and Delta inflow. The effect is greatest in drier years when river flows and reservoir releases are at a minimum. These indirect winter effects though not as dramatic as direct summer transfer effects have consequences to drier year winter river rearing and migration habitat of salmon and smelt.**

Overall effects from flow changes:

- **Significant negative effect on winter run salmon: (1) young rearing in lower Sacramento River in summer, (2) smolt migration in winter, (3) adult upstream migration in winter.**
- **Significant negative effect on delta smelt: (1) young rearing in the Delta in summer of drier years, (2) adults migrating upstream into Delta during winter.**

2. Changes in Delta Exports

Tables C8 and C9 show expected increases in drier year summer exports in the range of 20-60% from CVP transfers. With non-CVP transfer exports of similar magnitude, total drier year exports are near double or even more in critical years like 2014. **Higher exports increase entrainment and salvage losses of fish and degrade Delta rearing habitat (higher water temperatures, lower turbidity, and lower primary and secondary production).**

Overall effects from export increases in summer:

- **Significant negative effect on delta smelt: (1) from increased entrainment of young rearing in the Delta in summer of drier years, (2) from degradation of rearing habitat of young.**

3. Changes in water source

Water released from reservoirs for transfers in summer is not the same water exported from the Delta. Exports from the South Delta in summer of drier years typically take the cooler, slightly brackish, productive upper low salinity zone that has been in residence in the Delta for some time. The exported water includes nearly all the higher productivity water of the San Joaquin River that enters the Delta. Exported water is replaced by reservoir water including that released for transfers. The added reservoir water in higher Delta inflows degrades Delta habitat with fresher, warmer, clearer water.

Overall effects from changes:

- **Significant negative effect on delta smelt from degradation of rearing habitat of young in north, south, and west Delta, and eastern Suisun Bay.**

4. Changes in reservoir storage

As it may take several years or more to replace reservoir water released for transfers, reservoir storage is depleted by transfers in multiyear droughts. Reservoir depletion over several years may reach 500,000 ac-ft or more total. Long term droughts already deplete reservoirs to the point of affecting cold water pools and winter-spring releases that benefit fish especially in droughts. Storage releases in the summer of 2014 were in fact higher than planned or believed needed to sustain transfers, other water demands, and outflow and water quality requirements. Thus the true effect of transfers on reservoir storage is unknown.

Reductions in cold water pools can lead to (1) adult salmon being susceptible to diseases from warm water, (2) delays in salmon spawning, (3) reduced survival of eggs and embryos, (4) lower young survival during rearing, and (5) and delays and lower survival of smolts during emigration.

Overall effects from reservoir storage reductions:

- **Significant negative effect on winter run salmon in multiyear droughts: (1) young rearing in lower Sacramento River in summer, (2) migrating smolts in winter, (3) eggs and embryos in summer, and (4) adults from lower winter attraction flows in multiyear droughts.**

B. Cumulative Effects

We believe the addition of water transfers places significant added burden on the special status fish species over that already imposed by climate change, drought, increasing water supply use, record-high Delta diversions, increasing demands on surface and groundwater, as well as increased demand forecasted under the BDCP. The EIS fails to address these factors, although it does mention the potential of added effects from other Central Valley transfers through the Delta (i.e., by State Water Project and non-project water) not covered by the EIS. The EIS acknowledges these effects, but simply states that the added and cumulative effects are insignificant without any analyses as to whether the severely depressed populations and habitats of special status species are potentially affected by the added stress. Based on our assessment of cumulative effects, significant added stresses would occur on the fish and their habitats:

1. Winter Run Salmon

The cumulative effects of the above stresses with addition of water transfers will put winter-run in continuing jeopardy and inhibit their recovery. Transfers reduce reservoir storage in multiyear droughts as transfer storage releases cannot be made up until wet years again occur. Low storage limits the amount of Shasta Reservoir cold water pool to sustain winter run through summer spawning, incubation, and rearing. Continuing low fall releases limits the extent of rearing habitat and early emigration cues. Higher August and September flows from reservoir transfer releases may improve early rearing habitat in the upper Sacramento River near Redding, but may also deplete the cold-water pool and send emigration cues that may push young into warmer portions of the lower Sacramento River. Low storage levels in multiyear droughts limit the available water for storage releases in winter to sustain young emigration and upstream adult migration through the Delta and Bay to and from the Pacific Ocean.

2. *Spring and Fall Run Salmon*

Lower river flows in winter and spring in drier years would effect downstream emigration success of fry to the Delta. Poor dry year Delta rearing habitat would be further degraded by lower Delta inflows. High late summer transfers would encourage early migrations and maturation of adult fall run only to subsequently be subjected to lower fall flows and higher water temperatures.

3. *Delta Smelt and Longfin Smelt*

Adult migration and spawning success would be negatively affected by lower Delta winter and spring inflows in multiyear droughts. Lower Delta inflow in late winter and springs of multiyear droughts will reduce survival of young smelt. Higher summer Delta inflows will reduce survival of rearing pre-adult smelt in the Delta from degradation of the low salinity zone and direct and indirect losses to higher Delta exports.

C. Are the Effects of Transfers Unreasonable?

Reclamation argues that the effects of transfers are not “unreasonable”. Their main argument is that the BOs state that planned summer transfers up to 600,000 ac-ft would not constitute jeopardy, and that NMFS and USFWS have “OK’d” individual transfers in summer 2014 and past years. The facts are that winter-run salmon and delta smelt populations have further declined significantly since the BOs were prepared. Based on the present situation after two recent periods of drought (6 of last 8 years being dry or critical) we believe the predicted added stress of the whole array of planned transfers is an unreasonable threat to listed salmon and smelt.

D. Reasonableness of Reclamation’s Assessment in EIS

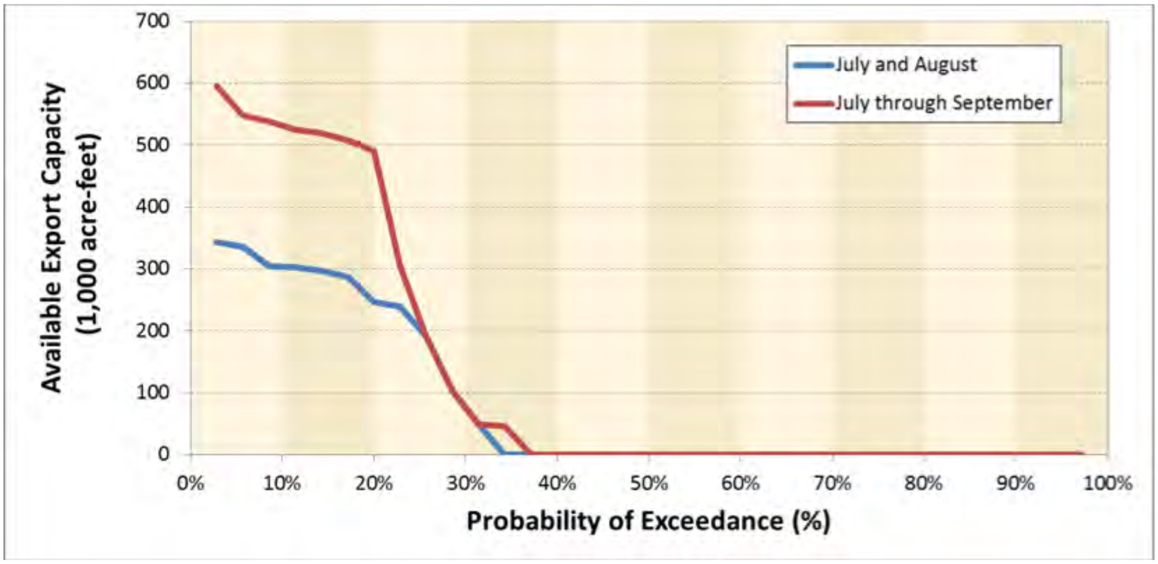
As shown in Tables 2-9 and 2-10, the Proposed Action in Reclamation’s opinion would not have any significant, unavoidable adverse impacts. From our review the proposed transfers have significant potential effects that are avoidable. Our review shows that potential effects are greatest in multiyear droughts when listed fish are already under maximum stress. Many of the most significant effects can be avoided by limiting transfers in the second or later years of drought. A more detailed review might yield specific criteria or rules that would allow some transfers to occur under certain circumstances. If transfers cannot be avoided, then other types of restrictions on water supply storage or deliveries could be considered to reduce effects of transfers and risks to the listed species.

E. Flaws in Reclamation’s Assessment

Major flaws in Reclamation’s assessment are as follows:

1) Reclamation assumes delta smelt are not found in the Delta in the summer transfer season, when in fact during dry and critical years when transfers would occur most if not all delta smelt are found in the Delta (see Attachments A and B).

2) Reclamation downplays the potential total amount of all transfers, when in fact the capacity exists for transfer amounts up to 600,000 ac-ft (see EIS/EIR CHART BELOW). *"The "up to" amount of transfer water that could be made available in any year is approximately 473,000 acre-feet. However, it is unlikely that this amount of water could be transferred in any year due to Delta regulatory and other constraints*." (Source: http://www.usbr.gov/mp/PA/water/docs/2014_water_plan_v10.pdf)
3) Reclamation has not assessed the effect on Delta habitat in terms of water temperature, turbidity, and location of the Low Salinity Zone.
4) Reclamation has failed to address population level effects on listed fish.
5) Reclamation has failed to follow the State Board's recommendation: ""The key is to follow the water, not the agreements. Focus on the source of the actual water moving to the transferee. This is the water being transferred and will guide the types of changes in water rights that may be needed." (p 10-3 of SWRCB Guide to Water Transfers.). Reclamation has failed to identify that the water they divert for transfer in the Delta is not the water released upstream for transfer.
6) Reclamation has failed to assess the cumulative effects on listed fish in multi-year droughts and the consequences of adding transfers on top of emergency drought actions designed to save storage by reducing water demands, exports, and relaxing water quality standards. Reclamation failed to mention its own requests to the State Board for Temporary Urgency Changes in 2013 and 2014 including provisions to exempt transfers from the TUCs that allowed lower Delta outflow and higher salinities in the Delta in summer 2014. Neither BO allowed for transfers under these conditions.



F. Reclamation has not followed its own rules

1. • *Transfer may not cause significant adverse effects on Reclamation's ability to deliver CVP water to its contractors.*
   In 2014 Reclamation had to release more water than expected to meet export demands including transfers. The unplanned release of "extra" Shasta and Folsom storage water adversely affects Reclamation's ability to meet its contractural demands and permit requirements. For example, North-of-Delta contractors were initially threatened with a 40 percent allocation that was later changed to 75 percent delivery.

2. • *Transfer will be limited to water that would be consumptively used or irretrievably lost to beneficial use.*
   Water diverted from the Delta is not water that would be consumptively used; it is water that would have eventually move to San Francisco Bay.

3. • *Transfer will not adversely affect water supplies for fish and wildlife purposes.*
   Transfers results in storage levels lower than predicted, which limit cold-water pools and the ability to maintain downstream "fish flows".

4. • *Transfers cannot exceed the average annual quantity of water under contract actually delivered.*
   The amount of CVP storage necessary to meet transfer export demands may be double the contracted amount.

G. Comments on Impact Statements in the EIR/EIS

1. *"Water supplies on the rivers downstream of reservoirs could decrease following stored reservoir water transfers, but would be limited by the refill agreements".* The whole subject of "refill agreements" is not adequately covered by Reclamation. The fact that it may take several years or more to refill is a significant effect not addressed.
2. "*Water transfers could change reservoir storage in CVP and SWP reservoirs and could result in water quality impacts."* No information as to the specific effects on Shasta, Trinity, or Folsom reservoir storage or downstream tailwater flows was provided.
3. *"Water transfers could change reservoir storage non-Project reservoirs participating in reservoir release transfers, which could result in water quality impacts."* The effect on reservoir and tailwater water quality in non-refill years of multiyear droughts was not addressed.
4. *"Water transfers could change river flow rates in the Seller Service Area and could affect water quality."* Effects on specific rivers and reaches were not addressed.

5. *"Water transfers could change Delta outflows and could result in water quality impacts." "Water transfers could change Delta salinity and could result in water quality impacts."* Specific effects on Delta water temperature, salinity, and turbidity in drought years like 2014 were not addressed.

6. *"Transfer actions could alter hydrologic conditions in the Delta, altering associated habitat availability and suitability"* Specific effects of transfers on Delta hydrology in drought years like 2014 were not addressed.

H. Specific Comments on Cumulative Impact Assessments in the EIR/EIS

"*The cumulative analysis evaluates potential SWP transfers, but they are not part of the action alternatives for this EIS/EIR*." Given the difficulty of separating these actions and there effects, and that other environmental assessments and biological opinions address joint actions, we see no reason to not address the joint action of transfers through the Delta in this EIR/EIS, especially given the following EIR/EIS statement: "*Most of the pumping capacity available would be at the Banks Pumping Plant except for very dry years. Banks is an SWP facility, so SWP-related transfers would have priority. Agreements with DWR would be required for any transfers using SWP facilities*. "

Note: In 2013, DWR facilitated about 265 thousand acre-feet of water transfers through State Water Project facilities, nearly double the amount anticipated for CVP transfers. (http://www.water.ca.gov/watertransfers/docs/2014/Transfer_Activities_v11.pdf)

I. Specific Comments on Section 3.7 Fisheries

1. *"Water transfers, which would occur from July through September, would coincide with the spawning period of winter-run Chinook salmon. However, spawning occurs upstream of the areas potentially affected by the transfers. Due in part to elevated water temperatures in these downstream areas during this period, emigration would be complete before water transfers commence in July*." P3.7-12

Water transfers also come from Shasta storage releases. Downstream emigration of fry from spawning reaches near Redding commences in July and continues through September.

2. *"Summer rearing of CV steelhead would overlap with water transfers occurring in the Seller Service Area (July-September), both in the Sacramento and San Joaquin River and their tributaries (see specific tributaries listed above). Thus water*

transfers have the potential to affect steelhead. The majority of rearing, however, would occur in the cooler sections of rivers and creeks above the influence for the water transfers." P3.7-14. The "majority" of rearing occurs in tailwaters, which would be affected by transfers (e.g., the lower American River tailwater below Folsom Reservoir).

3. *" (Delta smelt) Larvae and juveniles are generally present in the Delta from March through June. Delta smelt have typically moved downstream towards Suisun Bay by July because elevated water temperatures and low turbidity conditions in the Delta are less suitable than those downstream (Nobriga et al. 2008). Some delta smelt reside year-round in and around Cache Slough (Sommer et al. 2011). Delta smelt in Suisun Bay and Cache Slough would be outside of the influence of the export facilities."* P3-7-16. In dry and critical years, delta smelt reside primarily in the Delta in summer in the direct path of water moving across the Delta to South Delta export pumps (see Attachments A and B for details).

4. Consistency of Section 3.7 with the provisions of the California Environmental Quality Act (CEQA) and the CEQA Guidelines. Section 3.7 concludes that all effects are less than significant (e.g., p37-37). Using CEQA criteria - *An alternative would have a significant impact on fisheries resources if it would*:

    a. *Cause a substantial reduction in the amount or quality of habitat for target species.* YES
    b. *Have a substantial adverse effect, such as a reduction in area or geographic range, on any riverine, riparian, or wetland habitats, or other sensitive aquatic natural community, or significant natural areas identified in local or regional plans, policies, regulations, or by CDFW, NOAA Fisheries, or USFWS that may affect fisheries resources.* YES
    c. *Conflict with the provisions of an adopted HCP, NCCP, or other approved local, regional, or state habitat conservation plan.* YES (Delta Water Quality Control Plan)
    d. *Cause a substantial adverse effect to any special-status species, – Have a substantial adverse effect, either directly or through habitat modifications, on any endangered, rare, or threatened species, as listed in Title 14 of the California Code of Regulations (sections 670.2 or 670.5) or in Title 50, Code of Federal Regulations. A significant impact is one that affects the population of a species as a whole, not individual members.* YES (WINTER RUN, DELTA SMELT)
    e. *Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by CDFW, NOAA Fisheries, or USFWS, including substantially reducing the number or restricting the range of an*

endangered, rare, or threatened species. YES (WINTER RUN, DELTA SMELT)

f. *Cause a substantial reduction in the area or habitat value of critical habitat areas designated under the federal ESA or essential fish habitat as designated under the Magnusson Stevens Fisheries Act.* YES (WINTER, SPRING, FALL, LATE FALL RUN; STEELHEAD, GREEN AND WHITE STURGEON, DELTA AND LONGFIN SMELT)

g. *Conflict substantially with goals set forth in an approved recovery plan for a federally listed species, or with goals set forth in an approved State Recovery Strategy (Fish & Game Code Section 2112) for a state listed species.* YES, RECOVERY PLANS FOR CV SALMON, DELTA SMELT, AND LONGFIN SMELT.

3. ATTACHMENTS

A. Summer 2014 Water Transfers

Transfers were conducted in the summer of 2014 under a Finding of No Significant Impact NEPA document. Our review of the proposed 2014 transfers is presented in Attachment A.

B. Summer 2014

As background on the overall effect of summer transfers, we present an assessment of the overall effect on Delta Smelt in summer 2014 in Attachment B.

A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California

Submitted to the

California Bay Delta Authority Science Program
Association of Bay Governments
Oakland, California

by

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December 4, 2003

Executive Summary

1. Summary

The central all-encompassing question put to the panel is whether the CALFED program has adopted an appropriate approach to modeling the CVP-SWP-Central Valley system. Is the general CALSIM modeling approach appropriate for predicting the performance of the general facilities and for use in allocation planning, assessing water supply reliabilities and for carrying out operational studies? We believe the use of an optimization engine for simulating the hydrology and for making allocation decisions is an appropriate approach and is in fact the approach many serious efforts of this kind are using. It is a substantial improvement of the previous modeling approaches and provides a basis for consensus among federal and state interests. The modeling approach addresses many of the complexities of the CVP-SWP system and its water management decisions.

There exists a common tension between those who wish for greater detail and those who want less detail from the model. This argues for a more comprehensive, modular and flexible approach than is now available. In this report we suggest some ways this might be accomplished in the future. We also propose some management procedures that could be considered to improve model and model application quality control and documentation. The openness and availability of the model is admirable and very important given the numerous stakeholders who have interests in the management and allocation of water in the state. To increase the public's confidence in the many components and features of CALSIM II, we suggest that these components of CALSIM be subjected to careful technical peer review by appropriate experts and stakeholders.

2. Background

The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) have developed a computer model called CALSIM II that simulates much of the water resources infrastructure in the Central Valley of California and the Delta region. This infrastructure is referred to as the CVP-SWP system. In particular CALSIM II provides quantitative hydrologic-based information to those responsible for planning, managing and operating the State Water Project (SWP) and the federal Central Valley Project (CVP). As the official model of those projects, CALSIM II is the default system model for any inter-regional or statewide analysis of water in the Central Valley of California.

CALSIM II has a central role in the analysis of many CVP-SWP and related issues, some of which require capabilities beyond those included in the model. California needs a large-scale relatively versatile inter-regional operations planning model and CALSIM II currently serves that purpose reasonably well. As the primary State and Federal-sponsored model available for water operations and planning, CALSIM II is critical to the study of many technical and policy issues related to water supply reliability, environmental management and performance, water demands, economics, hydrology and climate, and regulatory compliance.

CALSIM II is a particular application of the California Water Resources Simulation Model called CALSIM. It uses a mixed integer linear programming model solver to route water through a network over time. Currently it uses monthly time steps. Policies and priorities are implemented through the use of user-defined weights applied to the flows in the system (represented by arcs of the network). Simulation cycles at different temporal scales allow for successive implementation of constraints. The model can simulate the operation of relatively complex environmental water accounts and state and federal environmental regulations. In our judgment CALSIM II represents a very impressive modeling effort on the part of all those involved with its development and application.

The CALFED Science Program commissioned this external review panel (Appendix D) to 1) provide an independent analysis and evaluation of the strengths and weaknesses of CALSIM and CALSIM II, and 2) to offer suggestions on the appropriate uses of these modeling tools, on ways their use might complement or be complemented by other models, and on further development, quality assurance, and use in major water systems operations and planning in California.

The panel received background documents (Appendix B), including a survey by the University of California at Davis of stakeholder responses to questions about CALSIM II. We subsequently met for one and a half days in Sacramento for discussions and presentations (Appendix A) by CALFED, DWR and USBR staff. The discussions concluded with a summary presentation by the panel outlining our tentative conclusions.

The information we received and the shortness of our meetings with modeling staff precluded a thorough technical analysis of CALSIM II. We believe such a technical review should be carried out. Only then will users of CALSIM II have some assurance as to the appropriateness of its assumptions and to the quality (accuracy) of its results. By necessity our review is more strategic. It offers some suggestions for establishing a more complete technical peer review, for managing the CALSIM II applications and for ensuring greater quality control over the model and its input data, and for increasing the quality of the model, the precision of its results, and their documentation.

In this review we were asked to address the following questions:

1. Is CALSIM a reasonable modeling approach for current and proposed applications and problems?
2. Do other modeling approaches show similar or greater promise and flexibility for such problems? If so, how?
3. What are the major comparative strengths and weaknesses of the current CALSIM approach and alternative approaches?
4. What are major scientific, technical, and institutional limitations, uncertainties, and impediments for current and proposed applications of CALSIM?
5. What model, software, and data developments, special studies or tests would be beneficial to improve CALSIM for current and proposed uses?
6. How might CALSIM development and applications be managed and overseen to improve the quality assurance of model results for current and proposed applications?

7. What are your suggestions for long-term use, development, or replacement of the current suite of models and data available for the current and proposed uses of CALSIM?

The following sections of this summary present our responses to these questions. The main parts of this report and its appendices provide additional detail.

3. CALSIM Modeling Approach

CALSIM II is a simulation model developed as a joint venture between the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (USBR) to (i) provide a significant modernization and upgrading of the DWRSIM and PROSIM models developed and used by these organizations, (ii) develop a comprehensive modeling system that simultaneously addresses the current and future needs of both the SWP and CVP systems; and (iii) develop a generalized modeling system that could be applied in any river basin system, in contrast with the previous models that were less generalized and more specifically designed for the existing SWP and CVP systems. In this respect, CALSIM II represents a state-of-the-art modeling system that is similar in general concept, while differing in specific details, to other data-driven river basin modeling systems such as ARSP, MODSIM, OASIS, REALM, RiverWare and WEAP.

CALSIM uses linear programming to solve sets of equations that simulate water movement through the CVP-SWP system in accordance with various objectives and constraints. This is a modeling approach which has been used successful in California (Johnson et al., 1991). In a complex system such as that being modeled, it is essential to have some mathematical representation of system flows that reflects all of the interconnections and constraints. Use of an optimization algorithm allows good decisions to be identified from among all possible and feasible decisions. To the extent this simulates what actually occurs, it is a good modeling approach. To the extent it optimizes when in reality no such optimization is implemented, it has the potential to produce inaccurate and overly optimistic outputs.

Most successful applications of optimization that attempt to simulate the behavior of a system have calibrated their objective functions (i.e., set the weights that prioritize flows over time and space) so that the model results correspond to what actually happens or would happen under a particular hydrologic and demand scenario. In these cases the model's decisions correspond to those the operators would make, as often prescribed by rules that have been worked out in a legal/political process. It does not appear that such a calibration of the objective function weights in CALSIM has yet been completed.

4. Other Modeling Approaches

There are two aspects of modeling, the model structure and algorithms used, and the model software. The use of linear optimization algorithms to solve simultaneous equations for simulating hydrology is a common way of avoiding a typically long list of procedural rules for simulating regional water systems. Such sets of procedures can be difficult to generate for complex systems, and very different and new rule sets may be needed if structural or significant policy changes are to be investigated. In addition the performance of the system when simulated will be less than that which can be achieved in practice if a good set of rules is not provided. Optimization models are generally easier to reformulate when system changes are to be investigated. However unless the optimization is calibrated in such a way as to actually resemble what takes place in practice it can produce an optimistic description of system performance. This is particularly true if the optimization model is allowed to have perfect foresight of future events that in practice would not be available to system operators.

Large simulation models using optimization and procedural rules both need to have internal checks to ensure to the extent possible that errors in mass balances, for example, do not occur due to errors made when the model is being defined or created. Such internal checking is not apparent to us in our admittedly brief review of CALSIM II. Nor were calibration procedures well defined.

One obvious limitation of using linear optimization procedures is its inability to model accurately and efficiently some of the non-linear hydrologic and decision processes that occur in systems as complex as the CVP-SWP. One approach to addressing this issue of model accuracy, and possibly for decreasing the computational time as well, is to link linear optimization models to non-linear simulation models in a way that permits the simulation to represent the hydrology in any spatial and temporal detail desired. The optimization is used to determine what the decisions should be at every site where a water allocation, reservoir release, or other management decisions must be made. The time steps for simulation could be daily, or weekly or longer, depending on the needs of the user, but would likely be of shorter durations than the optimization time steps. After a predetermined number of simulation time steps, the optimization model would be run. The initial state of the optimization should be set at the beginning of each optimization time step. The optimization component should include multiple future time periods, with imperfect hydrologic and demand forecasts, but once solved only the current period's solutions are implemented – i.e., these decision variable values are sent to the simulation component. The decisions indicated for future periods are ignored. When appropriate, the initial state of the multi-period optimization model is updated and the model is again solved. And so on. Such a modeling approach may prove to be both more realistic, more accurate, and require less time, once developed. We believe such an approach might be worth considering for future development.

CALSIM II currently consists of a combination of software modules developed in several languages, including FORTRAN, Java and C. Several of the modules require proprietary software packages in order to run CALSIM II (Lahey FORTRAN and XA Solver). DWR and USBR staff have said that these components are being replaced by public domain software that can be obtained free of charge. We agree with this decision. Very good public domain software packages of optimization, visualization, file management, and data base support are currently available, and new ones will continually be produced. Periodic updates should be anticipated as part of the business of maintaining the modeling system.

Significant thought should be given to the sustainability of the CALSIM II software. How will future programmers be able to maintain this software? How will future software developments be incorporated into the system? Will the solver currently being developed by LBNL be adequate in terms of accuracy and computation speed? Will other solvers need to be tested? Can the system accommodate these future developments without major modifications? What reasonable modifications could be made now in anticipate of future developments?

5. Comparative Strengths and Weaknesses

Many of the stakeholder perceived strengths and weaknesses of CALSIM and CALSIM II are very well identified in the survey report from the University of California at Davis (Ferreira, et al. 2003). Our background materials and briefings covered various strengths and weaknesses, but without first hand experience, all we can do here is to summarize those that we have heard expressed by others.

Here we provide a brief summary list.

5.1 Some Prominent Strengths

The strengths of CALSIM II are many. Most are expressed in comparison to previous DWRSIM and PROSIM models DWR and USBR were using. Some of these strengths include:

- Consensus model. CALSIM II is the official joint modeling environment of the State DWR and USBR. This includes a common schematic, hydrologic representation of the system, common set of facility capacities, and common representation of system operating policies. This helps all parties improve representations, rather than compete over representations.

- Common effort. The joint development of CALSIM II by USBR and DWR has provided more focused and effective use of resources and expertise than previous development of agency-specific models. CALSIM II development has also involved other agencies and consulting expertise more than pervious models of this system.

- Data-driven model. CALSIM II is a rather data-driven simulation model with an optimization engine. This modeling approach provides:
    a. greater flexibility than its predecessors and traditional water resources simulation approaches.
    b. a promising framework for improving transparency, data, and model documentation, compared to other approaches.

- Public domain. The model and data are substantially in the public domain, facilitating transparency and adaptability for California's decentralized water system.

- Steady improvements. Data improvements have been steadily pursued following the adoption of CALSIM II, although deficiencies remain.

- Improved Delta water quality representation. Although problems appear to remain, the model developers have made substantial gains in representing Delta water quality operating criteria and performance.

- Better groundwater representation. Efforts to better include groundwater and non-CVP-SWP project operations merit continuation and expansion.

- Benchmark Studies. The development of documented benchmark studies have resulted in significant model improvements and aided in the development of comparative model applications. Such exercises should be continued and improved.

- Long-term vision. The vision of a more transparent and publicly available model that can be employed by those outside the major agencies is excellent. This is a major change in direction, and achieving this vision will require adjustments over time. Often, these adjustments will be externally driven. Externally-driven improvements are a price of success and evidence of success for an open, public, modeling policy.

- Important CALSIM II features:
    a. CALSIM II is able to simulate the operation of the complete CVP-SWP system in all areas that contribute flow to the Delta in monthly time-steps.
    b. CALSIM II is being applied to examine a diverse range of options including flood control, water conservation and supply, power generation, recreation, water transfers, groundwater banking, recycling, desalination, conjunctive use, the purchase of options and streamflow and water quality protection.
    c. CALSIM II has successfully been applied by both DWR and USBR to examine both structural and non-structural changes to the CVP-SWP system as well as to ascertain the risks involved with different potential operating scenarios and to quantify the impacts of proposed actions.
    d. CALSIM II can dynamically model operation of environmental water accounts.
    e. Demands may vary according to various levels of development (e.g. 2001, 2020) and to hydrologic conditions.
    f. The regulatory environment under which the projects must operate can be simulated.
    g. CALSIM II can link to external modules as needed, e.g., to estimate the salinity at water quality stations within the Delta.

5.2 Some prominent weaknesses

As its strengths are many, so are its weaknesses. It seems worth saying, however, that no model can perfectly (meaning efficiently and effectively) serve all interests in a system as complex as the CVP-SWP. Tradeoffs need to be made. This can result in what some would call weaknesses. Such weaknesses are often accepted to gain strengths in another ways.

We heard that the CALSIM II model was too complex. We also heard that it did not handle particular components of the system with sufficient detail. And such is the dilemma of any complex model, such as CALSIM II. The model is clearly too complex, and not complex enough. The root of this difficulty is that when such a model is constructed, it is not clear what level of detail is needed, so the model must be made sufficiently complex to ensure it is complex enough. And the complexity needed to address some issues will remain in the model when it is used to address other less complex issues, or the same issues at less complex locations. One approach to addressing this issue is to develop different linkable modules of CALSIM II having different complexities. In this way the level of detail can be varied to be consistent the application or study at hand, and level of sophistication and resources available to the user.

Other weaknesses model users would like addressed include:

- The model provides limited and inadequate coverage of non CVP or SWP water and of the California water system south of the Delta.
- The model assumes that facilities, land-use, water supply contracts and regulatory requirements are constant over this period, representing a fixed level of development rather than one that varies in response to hydrologic conditions or changes over time.
- Groundwater has only limited representation in CALSIM II.
- Groundwater resources are assumed infinite, i.e., there is no upper limit to groundwater pumping.
- The linear programming model considers only the current month, and hence CALSIM II operating rules are required to determine annual water allocations, to establish reservoir carryover storage targets, and to trigger transfers from north of Delta to south of Delta storage.
- Better quality control is needed both for the model and its current version and the input data. Procedures for model calibration and verification are also needed. Currently many users are not sure of the accuracy of the results. A sensitivity and uncertainty prediction capability and analysis is needed.
- Need improved ways of altering the model's geographic scope and resolution and its temporal resolution to better meet the needs of various analyses and studies.
- Need to improve the model's comparative as well as absolute (or predictive) capabilities.
- CALSIM II needs better capabilities for analyzing economic, water quality, and groundwater issues.
- Need improved documentation explaining how the model works, its assumptions, its limitations, and its applicability to various planning and management issues.
- DWR and USBR have not provided a centralized source of support for CALSIM II. More training for CALSIM II is needed. There is a need for more people who can run CALSIM II. There is a need for a well-publicized user group. A more extensive users' guide is needed.
- Improved capabilities are needed for real-time operations especially during droughts, gaming involving stakeholders during a simulation run, handling of evapotranspiration and agriculture demand changes over time, water transfers, Delta storage, carryover contract rights, refuge water demands and more up to date representation of Feather River, Stanislaus River, Upper American River, San Joaquin River and Yuba River operations.

- Need an improved graphical user interface to facilitate input of model data, setting of model constraints and weights, operating the model, and displaying and post analysis of model results.
- Need to be able to change the model time period durations for improved accuracy of model results.

6. Limitations, Uncertainties, and Impediments

6.1 Absolute Values or Comparative Results

Modelers sometimes make a distinction between the use of a model for *absolute* versus *comparative* analyses. In an absolute analysis one runs the model once to predict an outcome. In a comparative analysis, one runs the model twice, once as a baseline and the other with some specific change, in order to assess change in outcome due to the given change in model input configuration. The suggestion is that, while the model might not generate a highly reliable absolute prediction because of errors in model specification and/or estimation, nevertheless it might produce a reasonably reliable estimate of the relative change in outcome. The panel is somewhat skeptical of this notion because it relies on the assumption that the model errors which render an absolute forecast unreliable are sufficiently independent of, or orthogonal to, the change being modeled that they do not similarly affect the forecast of change in outcome; they mostly cancel out. This feature of the model is something that would need to be documented rather than merely assumed.

In our opinion CALSIM II has not yet been calibrated or validated for making absolute predictions values. Yet it is apparent that there has been a distinct need by model users for absolute predictions. In the absence of alternatives, users are adopting CALSIM II results as the best absolute prediction available and they are likely to continue to do so. We recommend that model developers recognize the requirement for CALSIM II to provide absolute predictions. To satisfy this new purpose, additional calibration of the model will be required to ensure that the output it produces is fit for this purpose. Regardless of how possible it is to match the model closely with observed behavior, statistics on the accuracy of the calibration run should be supplied to users to enable them to gauge the likely errors involved with using the model output.

6.2 Sensitivity and Uncertainty Analyses

Sensitivity analyses would be useful to identify which parameters and input data have major impacts on decisions and system performance criteria of concern. Uncertainty analyses would help users of the model understand better the risks of various decisions and the confidence they can have in various predictions.

6.3 Graphical User Interface

Having a graphical user interface would substantially aid those who use the model in managing both input and output data, and in controlling or managing model operations. This model will not likely become as available to and as well understood by the public, to the extent desired by the model developers, until an effective menu-driven GUI has been created that can help create and draw from a database of system parameters and characteristics, and simulation results.

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6.4 Documentation and Training

When if ever is adequate documentation and training available? Rarely, but we believe there is a serious need to improve the documentation as well as the training available for all those interested in using CALSIM II.

7. Options for Improving CALSIM

7.1 CALSIM Model Software

We encourage the developers of CALSIM to convert their present software to that which is publicly available and to develop a useful graphic based user interface that can facilitate the input, editing, and display of all the data that are input to and output from CALSIM II. There are many options, some of which we have discussed with the model developers.

The CALSIM package should be made more modular and capable of linking to other more complex models of components of the CVP-SWP system. If the changes in code and modeling approach result in a quicker running model, it might be possible to link, when desired, modules that facilitate position analyses and other types of uncertainty analyses. A modular system would allow alternative representations of different components of the system. Thus different levels of spatial detail, or representations of the fundamental processes, would be allowed within the overall system representation and record of California hydrology. This will allow the use of more general and streamlined models for use of preliminary investigation and general planning, as well as a more detailed representation of the system for final analyses and more detailed studies. This would be very useful.

7.2 Sensitivity and uncertainty analyses

Both sensitivity analyses need to be performed, and procedures need to be developed to enable the estimation of measures of uncertainty associated with model output. Perhaps workshops focused on just these needs should be scheduled to better determine how best to meet these needs. There are numerous procedures available that could be applied. Appendix H contains some approaches for performing sensitivity and uncertainty analyses.

7.3 Model calibration

There is a need to develop the model so that it is able to provide absolute estimates of key model outputs rather than limiting the use of the model to comparative studies. One way to do this is to subject the model to a comprehensive calibration process where it is fine-tuned until it is able to reproduce the historical behavior of the system with sufficient accuracy to provide absolute results. The calibration of the model should aim to test all the key outputs of model including water quality in the San Joaquin River and in the Delta. It is necessary to test the monthly values of outputs for those outputs for which the monthly pattern is important.

7.4 Other extensions and improvements

- The opportunity of improving the collection of data on the use of water (preferably broken down by irrigation district and water source) should be investigated. The use of groundwater should be included in this investigation.
- It would be useful to expand the geographic extent of the model so that it includes all the components of the linked water supply system, including both the San Joaquin and Tulare Lake Basins of the Central Valley. The model should also account in some manner for imported supplies of water to users in southern California from the Colorado River.
- The linkage between surface water and groundwater would appear to be of critical importance and output that would enable the impact of surface water use on groundwater extractions would appear to be useful.
- Examination of the report *'CALSIM II Simulation of Historical SWP/CVP Operations',* DWR (2003) indicates that the current formulation of CALSIM II:
    - Overestimates water deliveries to SWP and CVP contractors,
    - Determines carryover storage target values that differ from those the operators have determined in the past, and
    - Operates the San Luis Reservoir at lower levels and fills it later in the season than operators have in the past.

8. Managing CALSIM Development and Applications

The predicted impacts and other information derived from CALSIM II applied to the CVP and SWP can influence major investment decisions. It is thus self evident that those who use the model results need to have some confidence as to their precision. Is the science behind the information derived from CALSIM II been reviewed and judged correct? Is the model software free from errors? Are the assumptions made when performing the modeling the correct ones? Are the model results accurately and fully reported? In other words, just how much credence should decision makers place in the model output? Users of the model results should be assured that they are credible and unbiased. One way to help ensure this is to have the models, their associated software, and their applications under the control of some interagency organization that can oversee and provide quality control over model development, application and documentation. They can also plan and implement needed peer reviews.

One possible means of facilitating the peer review processes and for maintaining control on the particular versions of CALSIM II and accompanying models used for CVP-SWP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and other stakeholder organization (including university) personnel if they are interested and want to participate. This center would be responsible for maintaining a toolbox of 'acceptable' models for use by the agencies and contractors. The models placed in the toolbox should be peer reviewed with respect to their applicability and suitability for use in particular applications. Those that are not peer reviewed should be considered for peer review. New models proposed for use in California should be peer reviewed with respect to their suitability, and for their strengths and limitations, before being placed in the toolbox. The review should be of the theory underlying the model, the model's software, the documentation of the model as well as of its software, the model's functions and capabilities including those pertaining to model data input and output, the input data themselves, model calibration and verification, capabilities for sensitivity and uncertainty analyses, user control of all model operations including pre and post analyses (GUIs), spatial and temporal resolutions, and its limiting assumptions.

9. Future Use, Development, or Replacement of CALSIM

9.1 A coupled optimization simulation approach

Given a system as complex as the SWP/CVP system, it seems to us it might make sense to consider the development of a more detailed simulation 'engine' and couple it to an optimization or management 'engine'. The simulation component can more accurately model hydrologic processes. For example it can include the deterministic non-linear routing of flows and their quality constituents through the system on a smaller time step (e.g., daily) and hence much more realistically or accurately, than can linear optimization using longer time steps, even with all the known tricks for linearizing separable (single variable) non-linear functions and 'if-then-else' statements. The simulation engine itself may require a simultaneous equation solver, especially for the Delta. But the simulation engine needs to know what to do, i.e., what decisions to make. Periodic use of the optimization, say once a week or even less frequently if conditions are relatively constant, for determining the decisions to be simulated, e.g., the water allocation and reservoir release decisions, eliminates much of the maze of rules that otherwise would be required and which developers of CALSIM II are avoiding through the use of optimization. Each time the optimization or management 'engine' is run it is first updated with the current state of the system as determined from the more precise simulation 'engine'. The optimization component would include multiple time periods only to the extent that the current period's solution is not affected by the time horizon in the optimization. The other time period solutions are ignored. This coupled optimization-simulation approach has the potential to be both more accurate as well as quicker to execute. In our opinion it is worth considering for future development.

9.2 Models as hypotheses

CALSIM II is really about the future, not the past. Benchmarking studies can help establish the credibility of the model and provide estimates of its accuracy by comparing its performance to actual historical operations. A concern is how well the model reproduces historical operations, not whether it is valid or invalid on some absolute scale of perfection. But the real issue is how well CALSIM can predict what might happen in the future with sets of hydrological and meteorological conditions that have not yet been experienced, and may be significantly different from the past if climate variability and climate change are considered. In these cases the ability of the model to forecast what will happen depends both upon its ability to describe what would happen should a particular system operating policy, priorities and water demands be adopted. In this sense CALSIM II modeling studies should be thought of as the exploration of a hypothesis that particular policies and priorities have been adopted. Our ability to predict the future has generally been poor, but it is the obligation of agencies such as DWR and USBR to attempt to ensure that should water demands, water supplies, and water policies evolve as one would expect, society is prepared for the consequences. And that would seem to be what CALSIM II is about.

9.3 Future Model Development and Use

From the list of perceived weaknesses above, there are clearly many opportunities for further refinement of CALSIM II. Rather than attempt to meet all needs using only one model, namely CALSIM II, it seems preferable to improve its adaptability to various levels of detail through its ability to link to other models when additional detail in a particular region or for a particular feature is desired. For example, the monthly time step used by CALSIM II is sufficient for many studies. Yet some seasonal (multi-month) decision making is needed in CALSIM II to reflect decisions made by the SWP and CVP as to what Table A and other allocations to honor in full. On the other hand, it is clear that many water quality and ecosystem management decisions would profit from more detailed weekly or daily time steps. However, such shorted time-step models will need the guidance of a longer time-step model. As discussed earlier, models with shorter time scales can require increased spatial resolution, both of which lead to increased model complexity and a strong argument for model modularity.

Additional potential applications of CALSIM II include operational planning using gaming, or the involvement of potential decision makers during the simulation runs via a well developed graphical user interface, and to improve the capability of modeling water quality, energy production, conjunctive groundwater and surface water interactions and use, to mention a few.

There will always be a need to perform alternative ‘what if’ policy analyses where a relatively fast model that also provides some capability for uncertainty analyses is required. Perhaps CALSIM II will never be able to serve this need, and if so another more simplified modeling approach could be developed to fill that need. This simpler screening tool would be calibrated to produce results comparable to those of CALSIM II or observed data. Is this possible? We can not be certain but feel the idea should be seriously considered.

Acknowledgments

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Caveat

Just as all models are approximations of reality, so may all advice be an approximation of what it should be. We hope what we have written in this report is correct and useful, but encourage CALSIM model managers and California's water community to take our assessments and suggestions for what they are, arrived at based on our own experiences and some limited exposure to those who know much more about CALSIM and CALSIM II than we do.

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1. CALSIM Compared to Other Modeling Approaches

Management of complex systems such as coordination of the California State Water Project (SWP) and the Federal Central Valley Project (CVP) requires effective decision support tools for simulating and analyzing system components in a fully integrated manner. The classic definition of a decision support system (DSS) provided by Sprague and Carlson (1982) is *"an interactive computer-based support system that helps decision makers utilize data and models to solve unstructured problems."*

A DSS integrates the following interactive subsystems: (i) dialog generation and management subsystem (DGMS) for managing the interface between the user and the system; (ii) data base management subsystem (DBMS); and (iii) model base management subsystem (MBMS).

CALSIM II is a DSS developed as a joint venture between the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Bureau) to (i) provide a significant modernization and upgrading of the previous models DWRSIM and PROSIM employed by these organizations, (ii) develop a comprehensive modeling system that simultaneously addresses the current and future needs of both the SWP and CVP; and (iii) develop a generalized modeling system that could be applied in any river basin system, in contrast with the previous models that were less generalized and more specifically designed for the SWP and CVP. In this respect, CALSIM II represents a state-of-the-art modeling system that is similar in general concept, while differing in specific details, to other river basin modeling systems such as AQUATOOL (Valencia Polytechnic University, Spain), ARSP (Acres Reservoir Simulation Program) (Boss International, 2003), IRAS (Interactive River-Aquifer Simulation) (Loucks, et al. 1996), MIKE BASIN (Danish Hydrologic Institute, 2002), MODSIM (Labadie and Larson, 2000), OASIS (Randall, et al., 1997), RAISON (Young, et al. 2000), ResSim (U.S. Army Corps of Engineers, Hydrologic Engineering Center), Ribasim (River BAsin SIMulation Model) (Delft Hydraulics, Netherlands), REALM (REsource ALlocation Model) (James, 2003), RiverWare (Zagona, et al. 1998), WaterWare (Jamieson and Fedra, 1996), and WEAP (Water Evaluation and Planning System, 2003) (Hansen, 1994). All of these can be categorized as decision support systems since all three subsystems of a DSS are embodied within them.

A distinguishing feature of several of these modeling systems is the use of optimization on a period by period basis (not fully dynamic) to "simulate" the allocation of water under various prioritization schemes, such as water rights, without the presumption of perfect foreknowledge of future hydrology and other uncertain information. This is a valid approach since use of optimization overcomes the disadvantage of employing numerous, unwieldy prescriptive rules governing water allocation. Systems employing optimization in this manner include: ARSP, MODSIM, OASIS, REALM, RiverWare, and WEAP and are therefore more akin to CALSIM II. ARSP, MODSIM, REALM and Ribasim are further distinguished by use of specialized minimum cost network flow optimization algorithms, although of these only MODSIM includes iterative structures using an imbedded scripting language for including non-network "side constraints" in the optimization. The other modeling systems are essentially limited to a pure network structure that does not allow inclusion of all the complex, non-network type constraints necessary to model the complex CVP-SWP system.

It may be useful to compare this use of optimization with some other uses that have appeared in the modeling literature. One use of optimization is purely for computational convenience; in this case optimization is employed as a numerical method for obtaining the solution of a series of simultaneous (often linear) equations. This approach, which was used in the first generation of computational economic models about forty years ago, exploited the fact that some existing computational algorithms for solving optimization problems were faster than those for solving large systems of simultaneous equations. A second use of optimization applies when the solution of the system of equations characterizing a water balance has multiple possible solutions; this is essentially the case described above, where optimization is being used primarily to identify a unique solution for a system of equations. Both of these uses of optimization are primarily descriptive rather than prescriptive (also referred to as positive vs. normative) in intent: the goal is to model how a system, characterized by a set of equations, operates. To the extent that the real–world managers of the system do optimize some objective function, the aim is to mimic their behavior by setting up and solving a similar optimization. But, the goal is to model what they actually do, not to advise them what they ought to do. The third use of optimization adopts an explicitly prescriptive goal and sets out to ascertain what managers ought to do if they wished to optimize some objective function (e.g. maximize economic efficiency). While this is certainly a legitimate analytical exercise, it should be kept conceptually distinct from the use of optimization in a purely descriptive context.

1.1 Advantages of Optimization-Driven Simulation

For large, complex, integrated systems, simulation models that optimize operation and allocation of water within each time-step by operational priorities have become the major simulation approach. Models of similar approach include ACRES (Acres Engineering), AQUATOOL (Spain), MODSIM (Colorado State U.), OASIS (Hydrologics, Inc.), WASP (Australia), and WEAP (Tellus Institute). Priority-based simulation models with optimization engines have become widespread in part because:

- The models are simpler to develop, comprehend, and modify.
- Their software is easier to upgrade, since the data set describing the system and its operating policies is substantially separate from the software code.
- Data are easier to update and modify, since changes require little or no software changes.
- Priority-based operations are a common basis for water rights and operating policies.
- Priority-based operations are relatively easy to explain.

The major exception to this technological trend in simulation modeling is to use more traditional procedural operating rules in simulation models with a graphical user interface for primarily flood control operations (HEC-RESSIM) or for exploratory study of large systems or detailed management of relatively small systems (Stella-type models).

Similar to several of these systems, CALSIM II allows specification of objectives and constraints in strategic planning and operations without the need for reprogramming of complex models. The CALSIM II authors developed the English-like WRESL (Water Resources Engineering Simulation Language) as an intuitive means of defining the objective function and constraints for a mixed-integer linear programming model, similar to the OCL (Operational Control Language) used in OASIS and the Policy Editor employed in RiverWare. In MODSIM, the optimization model is formulated directly through the graphical user interface with no need for a modeling language, but with supplemental features of the optimization defined through the PERL scripting language. WRESL allows planners and operators to specify targets, objectives, guidelines, constraints, and their associated priorities, in ways familiar to them. WRESL provides simple text file output that is converted to FORTRAN 90 code by a parser-interpreter program, whereas PERL is fully embedded in the network optimization code. Both modeling systems are data centered, meaning that model operation is controlled solely by user specification of input data rather than hidden rules or hard-wired data structures.

CALSIM II, OASIS, RiverWare and MODSIM are similar in that all use a high level language with syntax and logical operators; are written to simple text files which are subsequently parsed and interpreted; use rule-based or IF-THEN-ELSE conditional structures; are designed to be easy for planners and operators to use without the need for reprogramming; allow adaptive and conditional rules which are dependent on current system state variable information; include constructs for assigning targets, guidelines and constraints, along with their associated priorities; and include a goal seeking capability. CALSIM employs a mixed integer linear programming solver for repeated period by period solution that is less efficient computationally than the network solver employed in MODSIM, ARSP, REALM and Ribasim.

Unfortunately, unlike these aforementioned modeling systems, CALSIM lacks a comprehensive graphical user interface for constructing and editing the river basin system topology. CALSIM II would be greatly enhanced if, similar to RiverWare, IRAS, and MODSIM, objects representing features of the basin such as reservoirs, canals, and river reaches, could be created on the palette of a graphical user interface by simply clicking and dragging various icons for the objects to the display. The objects are instances of various classes that share certain common characteristics, and each object contains its own physical process methods and associated data. We believe that complaints concerning the complexity of using CALSIM II would be greatly reduced with development of such an object-oriented graphical user interface.

2. Comparative Strengths and Weaknesses

2.1 Some Prominent Strengths

CALSIM II has important strengths as a general inter-regional operations planning model, particularly compared with available alternatives and its predecessors. The primary strengths include:

- Coordination of Federal and State Interests A unique aspect of CALSIM II is the high degree of cooperation between Federal (i.e., U.S. Bureau of Reclamation) and State (i.e., California Department of Water Resources) interests in its development. This kind of cooperation is rare, and in fact this may be the only such example of such coordination for a system of this scale and complexity. Although it is clear that DWR staff have taken the greatest degree of responsibility in the planning, development, coding, testing and application of CALSIM II, it is also clear that USBR staff have also played an important role. CALSIM II can provide a showcase for other states as to what can be accomplished with Federal and State cooperation for river basin management.

- Consensus model. CALSIM II is the official joint modeling environment of the State and USBR. This includes a common schematic, hydrologic representation of the system, common set of facility capacities, and common representation of system operating policies. This saves a lot of unproductive bickering and helps all parties improve representations, rather than compete over representations.

- Common effort. The joint development of CALSIM II by USBR and DWR has provided more focused and effective use of resources and expertise than previous development of agency-specific models. CALSIM II development has also involved other agencies and consulting expertise more than pervious models of this system.

- Data-driven model. CALSIM II is a rather data-driven simulation model with an optimization engine. This modeling approach provides:

    a. much greater flexibility than its predecessors and traditional water resources simulation approaches.
    b. a promising framework for improving transparency, data, and model documentation, compared to other approaches.

- Public domain. The model and data are substantially in the public domain, facilitating transparency and adaptability for California's decentralized water system. Ongoing software development efforts will improve CALSIM in this regard.

- Steady improvements. Data improvements have been steadily pursued following the adoption of CALSIM II, although deficiencies remain widespread.

- Improved Delta water quality representation. Although problems appear to remain, the model developers have made substantial gains in representing Delta water quality operating criteria and performance.

- Better groundwater representation. Efforts to better include groundwater and non-CVP-SWP project operations are good efforts in the right direction, and merit continuation and expansion.

- Benchmark Studies. The development of documented benchmark studies seems to have resulted in significant model improvements and aided in the development of comparative model applications. Such exercises should be continued and improved.

- <u>Long-term vision</u>. The vision of a more transparent and publicly available model that can be employed by those outside the major agencies is excellent. This is a major change in direction, and achieving this vision will require adjustments over time. Often, these adjustments will be externally driven. Externally-driven improvements are a price of success and evidence of success for modeling policy that is open and public.

Few, if any, modeling organizations in the country have consistently done as good a job on model development and application for such a large, complex, and controversial system as the modeling group which developed CALSIM II. They are to be commended for their work to take California water modeling beyond past "closed shop" practices in favor of the development and dissemination of modeling capabilities that are more relevant to California's current water management problems. Most areas and suggestions for improvement noted below are meant to aid the model developers in moving further and faster in the direction they are already heading.

2.2 Some Prominent Weaknesses

The strengths and weaknesses of CALSIM II are not only technical (software, data, and methods), but also are institutional regarding how this model has been developed and employed. The administrative setting and objectives of model development and application are important, and difficult to manage. Alas, the management/policy problems of a system change frequently, while data and modeling capability change more slowly, and effective administrative structures change very slowly, if at all.

- <u>Inadequate data development and management</u> are principal shortcomings of CALSIM II. There has not been a sufficiently systematic, transparent, and accessible approach to the development and use of hydrologic, water demand, capacity, and operational data for CALSIM II. This problem extends beyond inadequate documentation and has led to controversy, confusion, and inefficiency in application of CALSIM II.
    a. Inadequate data management steepens the unavoidably difficult learning curve inherent for a complex system. Data have mostly been considered a "back room" activity of a few experienced experts. Retirement, promotion, or departure of these experts has left many gaps in knowledge and created difficulties for re-developing data for newer policy and planning problems.
    b. The administration of data development is fragmented, disintegrated, and lacks a coherent technical or administrative framework. Data required by CALSIM II are developed by several administrative units, without systematic technical vision or quality control for modeling purposes. Within DWR, different groups develop hydrologic and water demand data under different Deputy Directors, without effective coordination. This division must be overcome for a coherent data and analytical framework to be developed and implemented.
    c. In many cases it appears that water use and other hydrologic data inputs to CALSIM II are based on data collection and analyses that took place during the 1960s when DWRSIM and PROSIM were being constructed. It is important to ensure that data used for CALSIM II are up-to-date and consistent with the best current information

- The expertise and insights of many in local agencies, system operators, and consulting firms have not been prominent in the development of CALSIM II. For such a system with many hundreds of local experts, this is somewhat unavoidable, especially early in model development. Periodic re-examinations of how each area in CALSIM II is represented, in consultation with local agency and consulting experts, might overcome these technical shortcomings, and create and maintain a broader technical, user, and credibility base for CALSIM II. Active involvement of local agencies in CALSIM II development and applications would be much easier with better data management, and would be rewarded with a broader base of CALSIM II expertise and enhanced model credibility.

- Compared to the current CALSIM II, any central operations planning model for California water management should be:
    a. Expanded in geographic scope to include major non-CVP-SWP areas, especially the Tulare Basin, the Colorado River, and southern California. Operations and demands in these regions seem increasingly important for CVP and SWP operations, and are important for the integrated operations of California's major local and regional water management agencies.
    b. Expanded in management scope to include local management options such as water conservation, reuse, water transfers, groundwater and conjunctive use management, etc. These additional water management options are important for local, regional, and statewide water policy, planning, and management efforts and can have significant effects on CVP and SWP water demands.
    c. Made regionally modular, so smaller regional models can be run independently and tested locally, with boundary conditions consistent with the larger model.
    d. Made modular in terms of hydrologic, water management, and water demand processes, allowing better development, comparison, and updating of hydrologic and water demand process models. Agricultural, urban, environmental, and other water demands should be represented more directly, and explicitly. Groundwater should be represented and operated more explicitly. Land use based local hydrology and water demand approaches might be implemented in such standardized modules.
    e. Subject to a systematic model and data testing regime and continuous quality improvement program. As the problems of California water change, different and greater demands will be placed on analytical capability, requiring an essentially continuous testing, re-testing, and improvement of data and models. This might parallel a continuous review of local representations and data involving local agency and consulting experts.
    f. Financed on a broader base, by more than the CVP and SWP projects. Increasing use of CALSIM II is being made by local, regional, State, and Federal agencies interested in developing bilateral or multi-lateral water transfers or projects, which incidentally involve the CVP and SWP. To develop inter-regional modeling capability needed to integrate these activities at local, regional, and inter-regional scales, more sustained funding and involvement from local and regional agencies is needed. In effect, local and regional agencies have been "free riders" on CALSIM

II's analytical capabilities, and it is not necessarily a good bargain for them. Everyone should benefit from broader technical and financial participation.

g. Capable of analyzing a wide range of scenarios. More capability is needed to examine various long-term scenarios with respect to hydrologic, water demand, and operational uncertainties in the future. There also needs to be a better capacity to accommodate other approaches to representing hydrologic uncertainty and variability besides simply simulating 70-plus years of record.

- Input data and its development. Important aspects of CALSIM II rest upon the representations of other models of Delta hydrodynamics and water quality, water demands, and groundwater. The credibility of CALSIM II also rests on testing these models that send important data/representations to CALSIM II, and documenting them adequately. These models include:
  a. CU Model and SIMETAW: The consumptive use model and the newer SIMETAW model, used to develop hydrologic inputs and estimate return flows, also require testing and more explicit documentation. The underlying data for these models also need more systematic, standardized, and transparent treatment.
  b. DSM2: Representation of the Sacramento-San Joaquin Delta will always be important and prone to controversy, given the prominent importance of Delta flows and water quality for the operation and planning of California's water system. The difficulties of representing the Delta in operations and planning models are compounded by the tidal nature of the Delta, which usually implies a need for shorter time-steps. Representation of Delta water quality constraints currently falls heavily on an ANN method within CALSIM II. This ANN is calibrated (trained) based on a hydrodynamics model, DSM2. Thus, controversies regarding Delta representation in CALSIM II are likely to lead to questions of the adequacy of DSM2. The transparency and testing procedures valuable for establishing the credibility and limitations of a Central Valley operations model would also seem to apply to DSM2, or any other Delta hydrodynamics-water quality model. Tests of methods used to represent small-time step phenomena with larger time-steps (e.g., "partial month standards") should be tested in a forum that would give the approach credibility and where its limits could be developed, discussed, and documented.
  c. CVPM/CALAG/LCPSIM/IWR-MAIN: Representations of water demands in CALSIM II rely heavily on other models, particularly CVPM and eventually CALAG for agricultural water demands and LCPSIM and eventually IWR-MAIN for urban water demands. Thus, these models also will attract attention, and will probably require the same types of testing, transparency, and documentation suggested for DSM2 and CALSIM II. Many water contractors of the CVP and SWP also have internal water sources (groundwater, water conservation, and water reuse) and side contracts with other agencies to supply water that can increase or decrease (at different times) their water demands from the CVP and SWP contracts and from the demands estimated from CALAG and IWR-MAIN types of models.
  d. IGSM /CVGSM: Water users in California rely on groundwater as a water source and as the major source of over-year drought storage. Groundwater is also being increasingly used and looked-towards as a source of storage as part of conjunctive use schemes, and water transfer and market schemes. Thus, representation of

groundwater in the system is important, and probably should be expanded considerably. The representation of groundwater quantities, storage, and recharge and pumping capability will also attract attention from interested and critical parties. Thus, the IGSM/CVGSM modeling efforts of DWR and USBR should include the same types of transparency, documentation, and testing suggested for CALSIM II.

e. Agricultural demands: _Agricultural demands in the model are estimated by an external modeling system (CU model). Staff noted that the estimation methods being used are include out of date information on agricultural cropping patterns and irrigation technology, both of which result in inaccurate estimates of agricultural water demands. This estimation process needs to be revised and updated to include current information on an ongoing basis. The methodology needs to be improved to include economic factors in the estimation of cropping decisions and water demands. In many case, the preferred spatial scale for the economic modeling of agricultural water demand is going to be the individual irrigation district rather than very broad areas containing multiple quite heterogeneous districts.

- CALSIM II is currently awkward to apply for broader State and CVP-SWP policy questions. Practically, the time needed to complete analyses is too long and CALSIM II does not explicitly represent many of the management options which policy makers are interested in investigating, evaluating, and orchestrating.

- More CALSIM II modelers are needed. Many water managers and policy makers across California look to CALSIM II for many purposes, and there is near-universal consensus that the application of CALSIM II is currently limited by a dearth of knowledgeable modelers. Current training by DWR and USBR on CALSIM software is useful, but clearly insufficient. To be a functioning and credible CALSIM II modeler one must understand both CALSIM software and the operational complexities of the system (which probably no one can know in its entirety). Improved model and data documentation is also essential here.

- Stakeholders and policy makers are poorly guided in how to interpret CALSIM II results. Not only must CALSIM II become more responsive to current planning and policy concerns and management options, but current policy makers must receive some education in the benefits and limits of such modeling for their purposes. This is a very difficult problem that will often involve the role assigned to modeling and model results within larger politically-driven policy making processes.

- Non-interpretation of model results is not helpful. Several recent DWR reports based on CALSIM II results have been considerable improvements over past practices in terms of presenting model results, discussion of the model, and examination of model performance in a historical context. However, often the studies have not contained the kind of written discussion and interpretation of results that would demonstrate that the authors have thought about the results and drawn conclusions in a realistic and self-critical manner. This detracts from the perceived credibility of the work and makes the study less informative for readers (most of who surely do not have the modeling background of the authors).

- Some needs exist to improve CALSIM software. These are well-known to the model developers and include:
    a. Elimination of the need for the FORTRAN compiler,
    b. A public-domain mixed integer-linear programming (MIP) solver,
    c. A graphical user interface, including ties to databases and GIS display if possible,
    d. Post-processing tools for users to help new users and broader application and scrutiny of CALSIM II results,
    d. Version control software and system (also a problem for model administration),
    e. Better data and database management software and protocols (this has great data management and administration implications),
    f. An ability to more systematically set objective function weights,
    g. More automated input and output data checking is needed to improve productivity in model application and quality control of modeling output. This would also facilitate use of CALSIM II by a broader range of modelers,
    h. Ability to access and employ sensitivity analysis information coming from the MIP solver to identify possible multiple optima and identify binding constraints and slacks,
    i. A debug version of the code where water can be added or subtracted at any location and time (at a great penalty) to quickly identify locations and times of model infeasibilities. (Prof. J. Lund has had great success with this approach to correcting infeasibilities in the CALVIN model of California for a network flow algorithm.),
    j. Time-step issues should be explored and evaluated comparatively. There are major drawbacks to shortening time-steps system-wide (run-time, data development, interpretability of results, etc.), but short time-step components within the model or other approaches might adequately represent short-period aspects of the system for many purposes.

There will be some who argue that CALSIM II is and should remain a model of only the CVP and SWP system. While this would be simpler administratively and financially, it seems technically and politically untenable. California's water system is being asked to operate in an increasingly integrated manner across local and regional scales, with multiple local water demands, supplies, and aquifers being coordinated with the operations of major aqueduct and storage infrastructure. Any model of the CVP and SWP systems must be responsive to this operational integration, either implicitly through better parameterization of local supplies and demands, or explicitly by widening the geographic and functional scope of the model.

3. Limitations, Uncertainties, and Impediments

3.1 Removal of Unnecessary Ties to DWRSIM and PROSIM

Much of the spatial detail employed in CALSIM II is a carryover from the previous DWRSIM model. This is particularly evident in the coarse delineation of watersheds and sub-areas, which may no longer be relevant for future applications of CALSIM II. It is recommended that all unnecessary ties to the previous DWRSIM and PROSIM models be removed in further development of CALSIM II.

3.2 Relative vs. Absolute Predictions

As noted in the Executive Summary, we are skeptical of the usefulness of the distinction between comparative and absolute predictions. To declare that CALSIM II is intended for comparative predictions and should not be used for absolute predictions is not a helpful or desirable strategy. Rather than embracing this limited view of what CALSIM II can be expected to accomplish, we recommend that model developers recognize the requirement for CALSIM II to provide absolute values. To satisfy this purpose, additional calibration of the model will be required to ensure that it provides a reasonably reliable depiction of how the California water system operates. In addition, data on model accuracy and the outcome of the calibration runs should be made available so that users can gauge the likely errors involved in using the model for their own particular purposes. Some methods for doing this and performing sensitivity and uncertainty analyses are contained in Appendix H.

Model uses should realize that model calibration and validation exercises can illustrate only how well the model can reproduce historical decisions and system behavior. Our ability to predict future policy decisions and the emergency responses to water shortages is clearly limited, thus decreasing the absolute precision of any model's predicted values of various system performance measures. Thus it is useful to distinguish between the ability of the model to reproduce correctly the physical operations of the water systems in California (which should be good), its ability to reproduce and anticipate decisions by the agricultural sector that determine the quantities of water the consume, and its ability to mimic historical and current water operation decisions by the CVP, SWP and other water management agencies.

In general, it appears that the developers of CALSIM II do not have a clear idea of how to define the scope of CALSIM II use and many of the applications are evolving in a reactionary manner. Model developers should identify clearly the desired uses for CALSIM II and then determine acceptable approaches for satisfying those desires. Developers should seek to improve data accuracy and overcome unrealistic assumptions to improve confidence in model results.

3.3 Hydropower

CALSIM II is currently greatly lacking in hydropower computations, which is an important of the federal CVP system. This should include risk-based power capacity evaluation, and possible incorporate the ISM (indexed sequential hydrologic modeling) method that the Bureau has used for many years in hydropower capacity analysis. Also, hydropower should not simply be an after-the-fact calculation, but explicitly included in the system objectives.

3.4 Daily operations

A great challenge awaits the developers as they attempt to adapt CALSIM II to daily operations. These challenges are primarily related to the impacts of routing on distribution of flows and scheduling of reservoir releases. Under the current period-by-period optimization structure over daily time increments, without appropriate consideration of routing there is the danger that the model will allow diversion of upstream flows to lower priority users, resulting in injury to higher priority downstream users in the following days where travel times exceed 1 day. The proper inclusion of routing in the daily operations requires some kind of look-ahead capability in CALSIM II, which is currently lacking. In addition, scheduling of reservoir releases on a daily basis creates difficult timing issues in order to minimize unnecessary downstream spills or shortages caused by routing and attenuation of upstream reservoir releases. Another complexity in moving into daily operations is that reservoir discharges now become head-dependent, whereas this can usually be ignored on a monthly time scale. This means that the maximum reservoir release in any day will be dependent on the head, and should be based on the average head over the day, which introduces the potential for time consuming iterative processes to deal with nonlinear relationships in discharge-head curves for any reservoir.

3.5 Groundwater model

Groundwater has only limited representation in CALSIM II. This resource is modeled as a series of inter-connected lumped-parameter basins. Groundwater pumping, recharge from irrigation, stream-aquifer interaction and inter-basin flow are calculated dynamically by the model.

The purpose of the multi-cell groundwater model is to better represent groundwater levels in the vicinity of the streams to better estimate stream gains and losses to aquifers.

In the Sacramento Valley floor, groundwater is explicitly modeled in CALSIM II using a multiple-cell approach based on DSA boundaries. For the Sacramento Valley, there are a total of 14 groundwater cells.

Currently no multi-cell model has been developed for the San Joaquin Valley. Instead stream-aquifer interaction is estimated from historical stream gage data. These flows are fixed and are not dynamically varied according to stream flows or groundwater elevation.

The approach to modeling groundwater in CALSIM II, a lumped-parameter tank model seems to be a reasonable approach. However, few details of this implementation were provided to the review panel, that it is not possible to assess its accuracy or reliability. Details of the calibration and verification activities performed to date should be carried out and reported for the groundwater tank model. The effect of using large size tanks should be assessed and the level of uncertainty in computed results reported. In addition, the effect of these uncertainties on CALSIM II calculations should also be assessed. The San Joaquin valley aquifers are not well represented in the tank model, but it is in the CVGSWM. The San Joaquin valley groundwater should also be modeled in CALSIM II.

Groundwater availability from aquifers is poorly represented in the model. This results from the fact that aquifers in the northern part of the state (Sacramento Valley) have not been investigated regarding storage and recharge characteristics. Thus, in the model, upper bounds on potential pumping from aquifers are undefined. This does not represent reality, since, if CALSIM II is used for statewide planning, it would allow pumping of vast quantities of water for export to southern parts of the state, something which agency staff claim is unrealistic.

Realistic upper bounds to pumping from any of the aquifers represented in the model need to be developed and implemented.

In addition, historical groundwater pumping is used to estimate local groundwater sources in the model. However, the information on the historical pumping is very limited, causing these pumping rates to be very uncertain. Better pumping information is needed and an analysis of the effect of this uncertainty on model results needs to be conducted.

In general, the level of representation of groundwater in CALSIM II is not reasonable from the point of view of the reviewers. This is due to several factors, perhaps the most important being the lack of information presented to the reviewers for their assessment. Another factor is the lack of data collected and analyzed by the State of California to properly account for groundwater resources in the Central Valley. These data are critical to an understanding of the availability of water in the state and the operation of the major water systems that supply water to agriculture and small municipalities in the Central Valley. Assumptions of unlimited groundwater resources in the Sacramento Valley are unfounded and unbelievable. Efforts should be taken to make reasonable estimates of these resources.

There are other approaches that provide reasonably accurate estimates of river-aquifer interactions and groundwater basin response, while not sacrificing computer time. The response function approach is a good example, whereby the CVGSM model is used to develop kernel functions describing this response. A similar approach is described in Fredericks, et al. (1998). These kernels may require readjustment as head conditions change in the basin, but they provide a more accurate prediction tool and are easily incorporated in the MIP model since they apply a linear superposition assumption and retain the linearity of the constraints in the model. A dynamically linked CALSIM-CVGSM configuration is not necessary for reasonably accurate solutions. If computer run time for CALSIM II is considered excessive now, it could only considerably worsen if this type of linkage is incorporated.

Soil moisture is not dealt with in a realistic manner and needs to be improved in applications where the model output might be sensitive to these assumptions.

3.6 Dynamic Variation of Priority Weights

A severe restriction in CALSIM II is the inability to dynamically vary the weights used to prioritize flow allocation in the system. It should not only be possible to dynamically vary these weights, but this variation should be conditional on the current system state, however that state (or states) is defined. In addition to dynamic variation of weights, more explanation is needed of the reservoir operating rules and how these rules are incorporated into CALSIM II. The description of operating rules used in the system is not very clear. For example, what kinds of hedging or shortage rules are used to mitigate the effects of drought?

3.7 Expanding Scope of CALSIM II

CALSIM II is a considerable advance on earlier models in that it fully incorporates both the State Water Project run by the Department of Water Resources and the Central Valley Project operated by the Bureau of Reclamation. However to be able to examine the full range of Californian water issues, it would be desirable that all components of the linked system should be incorporated in the model including the Friant system, the larger Tulare Basin, and southern California and its links to the Colorado River. Also because of the very important linkage between surface water and groundwater use, improvements should be made in this area particularly with regard to how that linkage affects demand for surface water and how access to groundwater reduces the economic impact of surface water restrictions.

When expanding the geographical scope of the model to include non CVP-SWP areas, as well as Southern California, a hierarchical, decomposition approach would allow development of separate models for these areas that can then be linked together through iterative processes. Otherwise, the CALSIM II model can become extremely unwieldy. Again, integration can still be achieved through appropriate iterative interaction between the regional models. In the same vein, it is also unnecessary to explicitly integrate water quality and detailed water demand/consumptive use models into the model structure. Iterative schemes involving successive estimation of water quality and other parameters can produce comparable accuracy at reduced computer run times, while reducing the complexity of the model.

The replacement of DSM2 with a neural network is consistent with reinforcement or machine learning methods which are increasingly being used to replace complex, computationally time consuming models employed in decision support systems. The complex models are only used to provide the data sets used for training the neural network. Current research at Colorado State University and elsewhere is using neural networks for groundwater surface water interaction and return flow computation to replace computationally expensive groundwater models.

3.8 Key Model Outputs

In the past, the primary purpose behind the development of CALSIM II and its predecessors has been the examination of the reliability of water supplied to the State Water and the Central Valley Projects. However it is clear that there is now a demand for a model that will provide a wider range of outputs including:

- Water supply reliability for all water users
- Demand for water by existing users
- Outflows to Delta
- Use of groundwater and the rate of depletion of aquifers
- Water quality in the Delta and in the San Joaquin River
- Indicators of ecological health in particular with regard to key fish species
- The value of hydroelectric generation.

Although the modules in the CALSIM II package currently address many of these areas, the recognition that all these outputs are important may necessitate some further model development and a greater degree of testing and calibration of these parameters.

3.9 Modeling Allocation, Accounting and Operating Rules

CALSIM II uses a system of weights and constraints to define the water allocation process and the operating rules for storage reservoirs. Unfortunately these do not accurately reflect how operators of the state and federal water projects behave in managing their complex systems. Ideally, CALSIM should both reflect how the operators behave and be accepted by them as a useful tool when considering their management alternatives. The failure to achieve this limits the usefulness of CALSIM to investigate the specific operating or accounting rules that are of interest to those operators. For example, CALSIM II was not used to test changes to the accounting and allocation rules that have recently been proposed by the Department of Water Resources and the US Bureau of Reclamation because the rules that were changed do not exist in CALSIM II.

4. Options for Improving CALSIM

4.1 Optimization Model and Run Times

Many of the complaints regarding using of CALSIM II relate to long run times, which is not conducive to sensitivity or uncertainty analyses. Since CALSIM II employs a mixed integer linear programming (MIP) solver, the usual sensitivity information available in linear programming solvers, such as dual variables and right-hand-side ranging, are not available. The problem is that small changes in right-hand-side constants or objective coefficients (i.e., weights on water allocation priorities) can produce large abrupt changes in model solutions. In this case, dual variables do not provide useful information for MIP problems. Sensitivity analysis can only be conducted through trial and error processes involving incremental adjustment of important weights, coefficients, and uncertain data inputs with subsequent repetitive execution of the model. In light of this, it is crucial that the MIP solver employed in CALSIM II is upgraded. Significant advances have been made in MIP solvers, as described by Bixby, et al. (2000), which are not reflected in the current XA solver utilized in CALSIM II. There have been many recent improvements to the branch and bound method which should be incorporated, and the LP solver itself can be improved with better sparse matrix analysis. As planned by the CALSIM II developers, removal of the need for use of the FORTRAN 90 compiler will also improve run times when changes in optimization model structure are required.

4.2 Confidence in the model

The usefulness of a computer model in water resource management is only as good as the confidence that the stakeholders have in the accuracy and reliability of the model and the trust that they have in the modelers. There are several factors that affect that confidence and a number of ways that confidence can be improved.

- **Documentation**

Producing documentation of models requires considerable resources to do properly and ongoing resources to maintain especially when model development is continuing. Typically documentation of any water resource model is poorly done. However, where there are external model users, as is the case with CALSIM II, it is important. The survey conducted by Ferreira et al (2003) indicated that many users of the model thought that documentation of CALSIM II was poor.

- **Seminars**

In the Murray-Darling Basin, seminars with key users and interest groups in which the operation of the model is described and discussed have proved to be useful in increasing confidence in models. The practicality of this approach will depend on the number and location of the prospective participants and the resources available to support the process.

- **Data**

A model can only be as good as the data that is used to develop and calibrate it. The agreement over an acceptable set of hydrologic data that occurred during the development of CALSIM II is a considerable advance. However, there appears to be a need to improve the collection and use of data on water diversions and return flows. Because of the close links between the surface water use and groundwater use there also is a need to have better information on the use of groundwater.

The models used to calculate the Local Water Supplies in the Depletion Study Areas depend on estimates of surface water use, crop evapotranspiration rates and water use efficiencies developed using data from the 1970's. Confidence would be improved if more recent data were available to check these estimates.

- **Calibration**

A very good way to improve confidence in a model is to calibrate it against historical data to ensure that the model output is able to reproduce the observed data. Calibration is the process of using the model to reproduce the historical behavior of the system and then fine-tuning the model so that the match between modeled and observed values improves. The calibration of the model assists in detecting errors in the model and the input data. It also enables a comparison to be made between the way that the operators actually manage the system and the way that the model assumes that the system is managed.

A further consequence of the calibration process is that the statistics of the match between modeled and observed values can be used as a reasonable estimate of the absolute accuracy of the model output.

It is legitimate in a calibration/validation run to incorporate changes to infrastructure, institutional or operational rules as they occurred especially if these changes are specified as input parameters to the model. This was done to a limited extent in the CALSIM II validation run with three regulatory periods modeled related to decisions made by the State Water Resources Control Board. It is also legitimate to incorporate growth in demand especially if that growth is described in a manner that is consistent with the way that demand is specified in the production run. Demand north of the Delta was specified in the validation run by inputting the historical crop areas.

A Calibration/Validation report should be very useful in demonstrating the accuracy of the model. However there are a number of elements in the CALSIM II validation run and the validation report which reduce that confidence including:

- State Water Project (SWP) demands south of the Delta were set at historical deliveries in years with no restriction and at the contractor's request level in restricted years. Neither of these pieces of information is available to a production run which calculates demand based on crop areas. Therefore the validation run does not provide reliable information on how well the model can represent these demands.
- The validation run omitted Article 21 deliveries. Although this omission will not affect the delivery of 'Table A' volumes south of the Delta, it will affect flow in the Delta and Delta water quality. Also, in the example model run presented in the paper by Draper A.J. et al (2003) which was supplied as part of the review, changes to Article 21 deliveries constituted the largest impact resulting from a change to the allowable pumping capacity at Banks between March and December. This suggests that the modeling of these demands is important.
- The DWR (2003) report produces estimates of SWP and Central Valley Project (CVP) deliveries south of the Delta but then adjusts them for changes in storage before presenting comparisons of those results with observed deliveries. This process merely checks that the model is preserving a water balance and does not present a legitimate validation of model deliveries.
- The report provides statistics on long term average deliveries and flows but no statistics on the fit for individual years. Additional analysis of the output would assist stakeholders to assess whether the estimate of water supply reliability and in particular the modeled volumes of water available in the most restricted years are accurate.
- In some instances, such as the examination of water quality in the Delta, the ability to accurately model monthly flows and deliveries will be important. The validation report contains no information that would enable the ability to model monthly flows to be assessed.
- A key model output is the water quality in the Delta. It would assist the validation of the model if a comparison of parameters such as the location of the X2 boundary was provided.

The users of CALSIM should recognize that models are a summary of what one believes to be true and important about a system. Validation is then an exercise to test how good that summary and understanding really is.

Appendix I contains brief descriptions of calibration modeling in the Murray-Darling Basin in Australia and in the State of Texas.

4.3 Assessment of the reliability of "delivered" water

An important recent application of CALSIM II which has drawn widespread attention is the "State Water Project Delivery Reliability Report. While this is an important step forward in the use of CALSIM for policy purposes, it highlights a number of issues, both conceptual and empirical, that need to be resolved in order to provide a more adequate assessment of the reliability of water supply in California.

First, it illustrates the need for sound calibration of CALSIM. The question being asked is not a comparative one – What are the consequences of changing some aspect of the system from X to Y? – but rather an absolute one – How does the system function at present? How often can users expect a shortage in deliveries of Z%?

Second, it highlights the fact any water system model such as CALSIM requires a blend of hydrology and behavioral analysis. To conduct a water balance, the model needs to know what deliveries are required by the customers of the given project, and what are the diversions by other user groups who extract water from the same surface or groundwater sources. These are fundamentally questions of economic and institutional behavior, not matters of hydrology. Therefore they cannot be dealt with by hydrologists alone. Like its predecessors, CALSIM tends to treat these as black boxes. The diversions by water users outside the CVP-SWP are taken as exogenously given, based on an assumed "level of development" and simplistic assumptions about the patterns of water use associated with that level of development. The deliveries required by the water users who are served by CVP-SWP are generally taken as given. For reasons explained below, both of these treatments are simplistic and unsatisfactory.

In CALSIM modeling exercises the level of development plays two different roles depending upon the context. In a simulation context, the level of development is used to represent hydrologic variability and uncertainty; in a calibration/validation context, it is used to reflect the actual historical demand for water withdrawals. These are very different purposes and it is important to keep them distinct. In most applications of CALSIM prior to the recent reliability study, the main focus was simulation and the representation of hydrologic variability. The chief purpose served by using 73 years of adjusted streamflow records was to represent the variability and uncertainty in the streamflow that one can expect to observe in any single year. Therefore, the calendar date of the record has no substantive significance, the (adjusted) streamflows for 1952 or 1982 are not being used to represented what happened historically in 1952 or 1982, but rather as an indication of the variation in streamflow that could be expected to occur next year, or any other year. In this context of simulating hydrologic variability, it makes good sense to apply the *same* level of development (i.e. the same pattern of water use) to every year in the sequence, rather than a series of different levels of development that vary with calendar time, because the streamflows represent alternative hydrologies that can occur in any given year.[1] The situation is different when one is conducting a calibration or validation

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[1] This could be modified to allow for the fact that local weather conditions have a significant impact on irrigation (and urban) demands – e.g., farmers plant fewer acres of crops in a drought year. In that case, one could have different levels of water demand and extraction in different year *types;* but, these would all be keyed to the same overall level of economic development (e.g. the California economy in the 1990s). CALSIM II does not presently

exercise. In that case, one wants to represent the historical demands in 1952 or 1982 in order to compare what the model predicts with what actually happened. Therefore, in a calibration or validation exercise one wants the level of development to change each year in order to reflect the demand that occurred historically.

Both simulation and calibration/validation raise some other important technical issues. In the context of simulation, there are several different ways to generate a hydrologic sequence that is calibrated to a fixed level of development. One can use all 73 years for which data are available. One could use a subset of those years chosen either according to some deterministic rule or randomly. The subset could be oriented, for example, towards the extremes of the 73 sequence of annual records. However, the drawback of any approach based on sampling from the observed historical record is that it *understates* the full variability in streamflow that could be experienced in the future. The 73 years of record are drawings from a probability distribution the extremes of which extend beyond the minimum and maximum flows observed in the historical record. Relying on this record, therefore, understates the true minimum and maximum flows that might be encountered. In a reliability assessment exercise, one might want to take some steps to minimize the potential understatement of streamflow uncertainty. This could be accomplished by fitting a (parametric) probability model to the historical streamflow record and then sampling from the tails of the fitted distribution (Stedinger, 1981). The use of statistical models of streamflow variability could be considered in future applications of CALSIM to assess delivery reliability.

The assessment of delivery reliability requires that particular attention be given to the definition and measurement of the water users' demands. In this context, the user's demands play two roles: they affect the definition of "deliveries" and they influence the assessment of "reliability". With respect to deliveries, CALSIM II considers water to be delivered whenever it has the water irrespective of the ability of a contractor to use the water or to store it; The reality is that, if the contractor does not have a demand for the full quantity of water and is not able to store the excess, that amount will not be delivered. Therefore, the calculation of deliveries would be flawed. Furthermore, reliability cannot be assessed without reference to demand. Stating that a water supply system can deliver 100 acre feet in a wet year but only 70 acre feet in a dry year is useful only if one knows what the demands will be in wet and dry years. The implications are quite different if the user needs 105 acre feet per year than if he or she needs 65 acre feet per year. Thus, the users' demands should serve as the norm against which reliability is assessed. Instead, the recent reliability report uses the so-called 'Table A' water amounts as the norm for assessing deliveries to SWP contractors. This does not seem to be a satisfactory approach because there is no presumption that the Table A amounts, negotiated in 1960, measure the actual demands of SWP contractors in any particular year. The actual demands of the individual contractors will be influenced by how much storage they have, what access they have to other surface water or groundwater, and the demands of the farmers they serve to plant crops and apply water. Without accounting for these factors, it is difficult to generate a meaningful assessment of supply reliability.

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consider the impact of annual weather conditions on demands. In order to model water demands accurately in a year, the climate conditions would be linked to the flow conditions to provide an input set for a particular year.

The assessment of reliability should ideally go beyond a comparison with quantities demanded to incorporate the notion of a loss function. If a user has a demand for 100 acre feet and can only receive 90 acre feet in one scenario and 80 acre feet in another, while the shortfall is twice as large in the second scenario the actual *consequences* of the shortfall to the user, in terms of lost profit or higher cost, might be more than twice as large. To assess the economic value of reliability, or the economic cost of a lack of reliability, one needs to be able translate shortages into monetary losses. To accomplish this, the warning time provided and the delivery shortfalls from CALSIM would need to be processed through an economic model of the value of water to different SWP contractors.

Because water users face difference demands and have access to different sources of supply, when assessing reliability it is unhelpful to aggregate all contractors and simply present the results in terms of total annual project deliveries, as was done in the report. Precisely because of the potential non-linearity of the loss function, a given aggregate shortfall can have different consequences when distributed differently among the individual contractors. A similar observation applies to the temporal distribution of delivery shortfalls across the year. It is unhelpful to aggregate supply system deliveries into an annual total, as done in the report. For a user to be able to obtain 100% of his or her demands in the period from March to May but only 60% in the next three-month period from June to August has different consequences than being able to obtain 80% in each of the six months. Furthermore, for both agricultural users and many urban users, major decisions affecting water use have to be made in the spring. They are based on the expectation around March about the amount of water that will subsequently be available for delivery during the summer months. What matters to these users when assessing supply reliability is the amount of water they can expect around March to be delivered over the summer, rather than the ultimate total delivery.

For both reliability assessment and also model calibration/validation, it is important to avoid excessive aggregation when describing shortfalls between demand and supply, or deviations between model predictions and actual outcomes. In regression analysis, it is the convention to measure the goodness of fit of a regression equation not by the average deviation but rather by the sum of the squared deviations. In ordinary least squares regression, by definition the average deviation is always zero (that is to say, the average of the predicted values of the dependent variable always equals the average of the actual values) regardless of how well or badly the regression equation fits the data. The average deviation thus provides *no* information regarding the goodness of fit; by contrast, the sum of squared deviations or the sum of the absolute values of the deviations are sensitive measures of goodness of fit. Although the calibration of CALSIM is not an exercise in least squares regression, the same general principle applies. To judge whether the model is doing a good job, the goodness of fit should be measured by reference to the disaggregate results and not simply by the overall average deviation.

Additional comments on the 2003 CALSIM II Validation Report are contained in Appendix F.

5. Managing CALSIM Development and Applications

The costs of not continuously and substantially improving our analytical capabilities are political (in terms of continued controversy and diminished agency credibility), economic (as inferior system performance for agricultural and urban water users), environmental (in terms of inferior environmental system performance), and financial (lawyers and policy consultants are more expensive than engineers and scientists).

CALSIM II is a substantial improvement over its predecessor models, DWRSIM and PROSIM, with a great deal more flexibility, transparency, and potential than these earlier models. The modeling team for CALSIM has identified an exciting and relevant vision of how modeling should be done for this complex and difficult system in the coming years. However, implementation of this vision in a coherent technical manner that leads to both technical and stakeholder credibility will be a difficult process, requiring financial and institutional support if this kind of capability is to be developed and sustained.

To accomplish these objectives CALSIM II developers need to be in an institutional position where they can see the model more as “outsiders” view it. This would allow them to be more responsive in supporting the credibility of their work and the relevancy of their tools and results to the broad range of current water management problems. As such CALSIM II should no longer be solely responsible to CVP-SWP managers, but should be responsible to a broader range of technical managers from additional interests, reflecting its current and prospective uses.

It would be imprudent to manage a state’s finances, a business, or a retirement plan without quantification – quantification in such matters is necessarily imperfect, but necessary nonetheless. While shortcomings have been identified in CALSIM II, it would be similarly irresponsible to manage California’s water budget without carefully-interpreted quantification. Progressive and continuous improvement in our quantitative understanding of California’s water system provides a common basis for improving its performance for all interests.

One possible means of maintaining control of the quality of particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and persons from other stakeholder organizations if they are interested and want to participate. This consortium would be responsible for maintaining a toolbox of ‘acceptable’ models for ‘official’ use by the agencies and contractors.

IMC responsibilities and authority could include:

- Prioritize, coordinate, and provide consistency, technical guidance and oversight for all modeling applications,
- Approve model selection and insure that each requested application is carried out using the most appropriate model(s) and input data,
- Provide or otherwise insure documentation of the modeling process itself as well as the modeling results,

- Insure that the results are expressed and made available in a way such that others can understand and benefit from that modeling application, as applicable.
- Implement peer reviews of models and their applications as deemed appropriate.

To help meet their responsibilities the IMC will need to establish, publish and implement some procedures for insuring the quality of the entire model development and application process. They will need to identify among all the models that might be used, which are the most appropriate to address each of these separate groups of model applications. They must identify various models, i.e., establish a model toolbox, from which clients can choose the one that best meets their needs (or perhaps argue that another model should be added to the toolbox). The IMC will also need to maintain model documentation and provide for peer reviews of any model, its documentation, and/or its use in a project.

Further suggestions and discussion on the creation and operation of a possible IMC for model development and application, as well as for managing peer reviews of both the models and their applications, are contained in Appendix E.

6. Recommendations for Future Use, Development, and Application of CALSIM II

The most concise recommendation we might make would be to fix the shortcomings beginning with what are considered the most serious, and proceeding to those that are less serious, taking into account the time and other resources needed to address each weakness. However, we believe it is more useful to suggest ideas on how to systematically address both present shortcomings and those likely to emerge as stakeholders' quantitative understanding of California's water system and its problems continue to evolve.

6.1 Model development and support consortium

As discussed in the previous section and in Appendix E, it might be useful to explore creation of a broader interagency modeling consortium for developing operations planning models for California. The joint DWR-USBR development strategy used for CALSIM II has shown some notable successes, and should be expanded to include additional parties and sources of expertise. Such a consortium might include staffs from several agencies (DWR and USBR, as well as potential members from MWD, KCWA, CCWD, and other agencies), NGOs, some consultants, and universities. Such a model development forum would:

a. Bring a wider range of expertise to bear on model development problems.
b. Facilitate having more agencies involved in supporting model development with expertise and financial resources.
c. Better enable model developers to see the model as "outsiders" see it.
d. Potentially improve contracting for model development and testing.

e. Take model development and testing outside of the explicit agency framework; a broader consortium should be more conducive to self-critical and transparent technical practices.
f. Provide a common training ground for agency, NGO, and consulting staffs to become effective modelers, broadening the talent base for technical work in California.
g. Reduce impediments to model development and testing arising from current State budgetary and personnel hiring problems.

Many of the questions, concerns, and problems mentioned in the user community interviews could be addressed well in such a distributed model development, testing, and support framework. It would still be necessary for each stakeholder group and agency to maintain its own modeling staff, but these would be partially shared in an interagency modeling consortium.

The governance and finance of such a consortium would be difficult and would probably require a steering committee or governing board, but any resulting model(s) would have broader credibility and a broader and deeper technical base.

In the immediate term, a users' group should be formed and the formal listing of model development activities should be posted on the web, including short descriptions of each development activity and contact information.

6.2 Quality Control Program

The DWR and USBR modeling team (or a broader model development consortium) need an explicit quality control program. Such a program should include a variety of activities:

a. periodic external reviews on the broad modeling program
b. specialized external reviews of model products and applications
c. a standing (or sitting) external technical advisory body
d. software engineering and maintenance
e. a regime of model testing
f. model and data documentation
g. data development and management
h. user group activities
i. local agency and interest involvement
j. model, data, and documentation accessibility (including web site use).
k.

Such a quality control program would benefit from deep consultation with stakeholders and the broad community of water technical people, perhaps via the California Water and Environment Modeling Forum (www.cwemf.org).

6.3 A Training Program

DWR, USBR, and assorted agencies and consultants should establish a more formal common regimen to train new CALSIM II users in both CALSIM software and the complexities of actual system operation. All these groups currently rely on a relatively small pool of perhaps a dozen knowledgeable CALSIM II users and all proclaim a need for many more capable users. A training regimen consisting of current CALSIM II training classes, supplemented by additional training in software application and system operation and apprenticeships or rotations through operations and model development shops would be useful to all concerned. The entire water community would benefit from having such expertise being widespread. Having widespread CALSIM II modeling expertise also makes explaining CALSIM II and its results easier. This might be an appropriate activity for a model development consortium.

6.4 Extend Improvements in Modeling Practice to Supporting Models

CALSIM II is at the center of a web of additional models used by DWR, USBR, and other agencies to prepare inputs for CALSIM II and post-process outputs from CALSIM II.

Delta controversies and difficulties of representation seem endemic to problems of modeling Central Valley operations. The technical basis for representations of Delta operations and water quality performance requires a similar level of transparency and testing to avoid this becoming a "weak link" in the Valley-wide operations planning model. Since so much is based on the DSM2 Delta model, documentation of fairly strenuous tests of the DSM2 model are highly desirable. This would provide a firm foundation for the use of ANN or other approaches for summarizing DSM2 behavior in an operations model. Similar documentation, testing, and development are desirable for the other models mentioned above which provide data for CALSIM II (CVGSM/IGSM, CVPM/CALAG, IWR-MAIN, LCPSIM, CU model, and SIMETAW).

6.5 Hydrologic Data and Data Development

An effort should be made to step back and perhaps re-define a more systematic and solid basis for developing hydrology for water management models of California's inter-tied water system. Currently, several efforts exist to develop surface or groundwater hydrologies for parts of the Central Valley (sponsored by DWR-USBR, USACE-Sacramento District, USEPA, USGS, CALFED, local agencies, etc.). An effort should be made to broaden the range of hydrologic expertise involved in hydrology data development for management modeling of California's inter-tied water system, and establish a consistent and high, but reasonable, standard of documentation and testing for developed data and any underlying hydrologic models. Establishing such a standard of documentation and testing would make existing hydrologic studies more accessible and useful for future studies and encourage the comparison and further development of existing representations of the system's hydrology.

6.7 Performance-Based Optimization

Performance-based optimization should be added to CALSIM's capabilities; it would not be difficult in terms of software or data, and would add much greater ability to explore and seek improvements in management within a complex system. The multi-period optimization approach being developed (CAM) is an operations-oriented first step in this direction, but could be expanded without great difficulty.

For large-scale water resource systems of great complexity and many options for system management, it is often difficult to find “optimal” operations with simulation modeling. There are simply many myriads of decision options and combinations of options, which theoretically each require a simulation model run – which would be prohibitive in terms of analysis cost and time. In such situations, performance-based optimization models, such as those seeking maximum economic performance, can offer useful insights as to where to look for improving system operations and management. Metropolitan Water District of Southern California (MWD) and San Diego County Water Authority (SDCWA) employ performance-based optimization modeling of parts of California’s water system to gain strategic insights for planning and management. An economic-engineering optimization model has been developed for California and, despite significant limitations, shows several insights for California (CALVIN), suitable for identifying promising operational and management strategies worthy of more detailed analysis (Jenkins et al. 2001; Draper et al. 2003; Jenkins et al. 2004). The CALSIM II modeling approach could easily be adapted to provide greater functionality to this type of performance optimization. Having performance-based optimization capability together with a compatible simulation model for more detailed analysis and trade-off evaluation could greatly improve the capability of California’s water community to explore and develop promising and creative options for improving operations, facilities, and overall system management.

6.8 Modular and Layered Versions of CALSIM II

Speedier versions of CALSIM II are needed for operations planning and integrated water planning studies. Such versions would be regional modules of CALSIM II (for regional studies) or explicitly aggregated system-wide models from the most detailed CALSIM II schematic for system-wide or statewide studies. Both approaches would simplify the model for particular purposes, yet be tied to a common detailed schematic and detailed hydrologic, operations, and water demand data sets.

Geographically modular or aggregated system-wide versions would allow additional local and regional water management options to be represented for particular operations and policy planning purposes and allow users to more quickly explore and develop operating policies. The final runs from such integrated or exploratory studies could then be evaluated using a more detailed and complete version of CALSIM II.

Modular regional models might represent regions with relatively few inter-ties, such as: Sacramento Valley, Delta and eastside streams, San Joaquin Valley, San Francisco Bay Area, Tulare Basin, and Southern California (DWR’s South Coast and Colorado River hydrologic regions). (We have had good success with the CALVIN model of California with 5 modular regional models, which combine to form a system-wide model. These geographic sub-models greatly improved quality control in model development, work flow and data checking, and identification of problems in the model.)

6.9 Model Calibration and Testing

Many approaches exist for model calibration and testing (Modeling Forum 2000). Calibrating a planning model oriented to operations in an uncertain and distant future is always challenging. For a model that serves many uses (including policy-urgent uses unforeseen by developers), use-specific testing will often be impossible within a responsive time frame and budget. Such unavoidable situations call for more thorough, general, and well-documented model calibration and testing than would otherwise be needed.

For the model to have technical credibility, stakeholder credibility, and to serve the kind of training and reference function needed for the water management community, a systematic and coherent means of setting parameter values in the model and documenting these values is needed. Similarly, a systematic self-critical means of testing is needed for a model to establish and retain credibility, and have defined limitations, for a range of applications.

A potentially excellent resource for model testing is comparisons of seasonal operations planning CALSIM II model runs with recent years' seasonal operations, as done by actual operators. Similarly, system operators could scrutinize historical simulations, such as those in the recent November report, for systematic differences from operating practice. Such comparison with operator policies and philosophy could also be performed with SWP or CVP delivery reliability estimates. Such comparative analyses would both help define the likely (and unavoidable) differences between actual and modeled operations and water deliveries and identify potential opportunities to narrow such differences.

Credibility arises, in part, from demonstration that problems and limitations are systematically identified and addressed or considered in model development and in making and interpreting model runs. This can be accomplished by use of documentation, metadata, written guidance, and protocols and logs for identifying model problems and recording model improvements.

Given present and anticipated uses of CALSIM II, the model should be calibrated, tested, and documented for "absolute" or non-comparative uses. This is what many applications require today and will be increasingly desired and required in the future. Maintaining the traditional "comparative-only" use of CALSIM II is undesirable if the model is to be useful for the CVP and SWP systems, the operations of water contractors, or for statewide planning purposes.

6.10 Documentation of Model Improvements

Along with better documentation of model versions, logs of data and model improvements and "bug fixes" should be maintained. Explicit protocols and records for identifying and correcting modeling errors and problems would enhance the credibility of the modeling effort with technical people and policy makers. Such protocols also provide an internal aid to staff and staff development in modeling. I understand that this kind of record-keeping is done, but the precise form of, nature, and extent of this record-keeping is unclear. It would be useful and reassuring to stakeholders and policy makers to know that this kind of record-keeping of the software and data was being done.

6.11 Better Model Integration in Decision-Processes and Stakeholder Education

Greater aid should be given to interested parties and decision-makers who must work with the unavoidable limitations of any model. If possible, a document should be prepared for stakeholders and interested parties outlining the model, summarizing the model's primary limitations, and providing guidelines for interpreting model results. Those developing policy-making forums and processes should thoughtfully incorporate computer models in these processes in ways that do not assume model omniscience, or otherwise place too great or exclusive a reliance on model results.

Models and model results will never be perfect. If models are to be important for planning and policy-making, they be must be presented and used in ways that enlighten policy-makers more than they add confusion and controversy to already difficult situations, if possible.

7. References

Bixby, R., M. Fenelon, E. Rothberg, and R. Wunderling, (2000), "MIP: Theory and Practice – Closing the Bap," in, *System Modelling and Optimization: Methods, Theory and Applications*, M. J. D. Powell and S. Scholtes (eds.), pgs. 19-49, Kluwer Academic Publishers.

Carnegie Mellon University, (1994), The Capability Maturity Model: Guidelines for Improving the Software Process, Addison Wesley, Boston

Draper, A.J., A. Munevar, S.K. Arora, E. Reyes, N.L. Parker, F.I. Chung and L.E. Peterson, (2003), 'CalSim: A Generalized Model for Reservoir System Analysis', Paper supplied to November 2003 CALSIM II Review.

Draper, A.J., M.W. Jenkins, K.W. Kirby, J.R. Lund, and R.E. Howitt, (2003), "Economic-Engineering Optimization for California Water Management," *Journal of Water Resources Planning and Management*, ASCE, Vol. 129, No. 3, pp. 155-164, May

Disco, C. and J. van den Ende (2003), "Strong, Invincible Arguments?: Tidal models as management instruments in twentieth-century Dutch coastal engineering," *Technology and Culture*, Vol. 44, July, pp. 502-535.

DWR (2003), 'CALSIM II Simulation of Historical SWP/CVP Operations', California Department of Water Resources Technical Memorandum Report November 2003.

DWR (2002), 'The State Water Project Delivery Reliability Report 2002', California Department of Water Resources Bay-Delta Office Report 2002.

Ferreira, I.C., S.K. Tanaka, S.P. Hollinshead and J.R. Lund (2003), 'CALSIM II in California's Water Community: Musing on a Model', Draft Report to November 2003 CALSIM II Review, 18 September 2003.

Fredericks, J., J. Labadie, and J. Altenhofen, (1998), "Decision Support System for Conjunctive Stream-Aquifer Management," *Journal of Water Resources Planning and Management*, ASCE, 124(2)

Hansen, E., (1994), "WEAP – A System for Tackling Water Resource Problems," in *Water Management Europe: An Annual Review of the European Water and Wastewater Industry*, Stockholm Environment Institute, Stockholm, Sweden

James, B., (2003), "REALM: Simulation Software for Water Supply Systems," Department of Natural Resources and Environment, Victoria, and Victoria University of Technology, Victoria, Australia,

Jamieson, D. and K. Fedra, (1996), "The WaterWare Decision-Support System for River Basin Planning. 1. Conceptual Design," *Journal of Hydrology*, 177(3-4), 163-175

Jenkins, M.W., A.J. Draper, J.R. Lund, R.E. Howitt, S. Tanaka, R. Ritzema, G. Marques, S.M. Msangi, B.D. Newlin, B.J. Van Lienden, M.D. Davis, and K.B. Ward, (2001), "Improving California Water Management: Optimizing Value and Flexibility," Center for Environmental and Water Resources Engineering Report No. 01-1, Dept. of Civil and Environmental Engineering, University of California, Davis, CA, http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/.

Jenkins, M.W., J.R. Lund, R.E. Howitt, A.J. Draper, S.M. Msangi, S.K. Tanaka, R.S. Ritzema, and G.F. Marques, (2000), "Optimization of California's Water System: Results and Insights," *Journal of Water Resources Planning and Management*, ASCE, in press.

Johnson, S.A., J.R. Stedinger and K. Staschus, (1991), Heuristic Operating Policies for Reservoir System Simulation, Water Resources Research, 27(5), 673-685

Modeling Forum (2000), "Protocols for Water and Environmental Modeling," California Water and Environment Modeling Forum, http://www.cwemf.org

Labadie, J. and R. Larson, (2000), "MODSIM: Decision Support System for River Basin Management: Documentation and User Manual," Colorado State University and U.S. Bureau of Reclamation, Ft. Collins, CO, May

Loucks, D.P., M. Taylor, and P. French, (1996), "IRAS – Interactive River-Aquifer Simulation Model, Program Description and Operating Manual, Cornell University, Ithaca, NY

Randall, D., C. Cleland, C. Kuehne, G. Link, and D. Sheer, (1997), "A Water Supply Planning Simulation Model using a Mixed Integer Linear Programming Engine, Journal of Water Resources Planning and Management, ASCE, 123(2).

Stedinger, J.R., 1981, Chapter 6 in Loucks, Stedinger and Haith, Water Resource Systems Planning and Analysis, Prentice-Hall, Englewood Cliffs, NJ, 560 pp., 1981.

Young, W., D. Lam, V. Ressel, and I. Wong, (2000), "Development of an Environmental Flows Decision Support System," *Environmental Modelling and Software*, 257-267

Zagona, E., T. Fulp, H. M. Goranflo, and R. Shane, (1998), "RiverWare: A General River and Reservoir Modeling Environment," *Proceedings of the First Federal Interagency Hydrologic Modeling Conference*, Las Vegas, NV, pp. 113-120.

A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California

Appendices

Appendix A: CALSIM II Science Review

Dates: Nov 13-14th
Location: Bay-Delta Room, CBDA Offices
650 Capitol Mall, 5th Floor
Sacramento, CA

Day 1: The Management Context, Model and Application Details

9:00 Welcome – Kim Taylor
- Overview of the CALFED Bay Delta Program -
- Introduction of the Panel

9:15 Water issues in California – Francis Chung
- General Hydrology
- SWP/CVP
- Operational challenges
- Sacramento-San Joaquin Delta – Ron Ott (5 min.)

9:35 Panel Q&A

9:45 Planning Models – Andy Draper
- CALSIM software
- CALSIM II application overview
- Interaction with other models

10:10 Panel Q&A

10:20 Break

10:30 Summary of CALSIM Applications
- DPLA/CalFed/US Bureau of Reclamation: Integrated Storage Investigations – Steve Roberts
- Bay Delta Office (DWR): SWP Delivery Reliability Report - Kathy Kelly
- USBR: Multi-layered modeling to simulate CVPIA (b)(2) water and Environmental Water Account Operations – Nancy Parker
- Operations Control Office (DWR): Oroville Relicensing, SWP Allocation decision procedure – Curtis Creel
- Department of Planning and Local Assistance (DWR): California Water Plan Update – Kamyar Guivetchi/Ken Kirby

12:15 Panel Q&A

12:30 Lunch

1:15 Summary of User and Stakeholder Interviews
  1:15 Interview Summary and Findings – UC Davis
  1:35 Panel Q&A
  1:50 Public Comment

2:15 CalSim II Details

- Development philosophy – Francis Chung
- Operation priorities, constraints, common assumptions – Erik Reyes
- Hydrology development – Andy Draper
- Delta water quality constraints – Ryan Wilbur

3:15 CalSim Evaluation

- Historical Operations Study / Sensitivity Analysis – Sushil Arora

3:30 Panel Q&A

3:45 Break

4:00 Future Directions

- Data Structure / Version Control / Multi-Period Prescriptive Optimization – Ryan Wilbur
- Daily Time Step - Dan Easton
- CalSim II – CVGSM Integration – Tariq Kadir
- Water Quality / Upstream Models – Nancy Parker

5:00 Panel organizational meeting (additional information needs, questions of specific staff, discussion plan)

Day 2—Panel Deliberations and Preliminary Report

8:30 Panel Q&A with specific DWR and USBR staff on request

9:30 Panel *in camera* discussions

11:00 Panel presentation of draft main findings—Pete Loucks

12:00 Wrap up and next steps - Kim Taylor

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Appendix B: Briefing Material for CALSIM II Peer Review

California Water
Averting a California Water Crisis (3 pages)
California Water Today, Bulletin 160-0, Chapter 2 (20 pages)
Water Supplies, California Water Plan Update, Bulletin 160-98, Chapter 3 (11pages)
Urban, Agricultural and Environmental Water Use, California Water Plan Update, Bulletin 160-98, Chapter 4 (17 pages)
California's Major Water Projects (map) (1 page)

CVP and SWP
State Water Project Operations (6 pages)
Central Valley Project Operations (16 pages)

CalSim and CalSim II Overview
CalSim: A Generalized Model for Reservoir System Analysis (19 pages)

CalSim Software Details
CalSim water resources simulation model: Users guide (18 pages)
CalSim water resources simulation model: Wresl language reference (11 pages)

CalSim II Details
Network Representation (1 page)
Sacramento-San Joaquin Delta Operations (9 pages)
Coordinated Operating Agreement (3 pages)
Reservoir Rule Curves (2 pages)
CalSim ANN Implementation (8 pages)
CVPIA (b)(2) Management and Operations (6 pages).[ii]
EWA Management and Operations (8 pages)
Multi-Cell Groundwater Model (2 pages)
SWP and CVP Delivery Allocation Logic (3 pages)

Hydrology Development
Surface Water Hydrology Development for CalSim II (8 pages)

Supporting Computer Models
Model Interaction (1 page)
CALAG (2 pages)
CU Model (2 pages)
DSM2 (2 pages)
IGSM2 – CVGSM (4 pages)
LCPSIM (5 pages)

CalSim II Evaluation
Planned Sensitivity Analysis (7 pages)
CalSim II Simulation of Historical SWP-CVP Operations - Extracts (61 pages)

CalSim II Applications
CalSim II Project Applications Summary (not completed)
SWP Delivery Reliability Report – Extracts (25 pages)
North of Delta Offstream Storage Investigations (3 pages)
In-Delta Storage Investigations (3 pages)
California Water Plan Update 2003 (3 pages)
*CalSim II and SWP Operations Control Office (1 page).*iii

Future Model Development

(a) CalSim Software
CalSimMulti-period Prescriptive Optimization (not completed)
CalSim Daily Time Step Model (not completed)
CalSim Water Quality Module (not completed)
Data Structure / Version Control (not completed)
CalSim Graphical User Interface (not completed)

(b) CalSim II Applications
CalSim II – CVGSM Integration (not completed)
CalSim II Geographical Expansion (not completed)
Global Climate Change (not completed)
Refined Spatial Resolution (not completed)
Expansion of Land Use Based Demands (not completed)
CalSim II – CALVIN Integration (not completed)
Revision of Urban Water Demands (not completed)

(c) Supporting Models
Replacement of Consumptive Use Model (not completed)

Appendix C: CALSIM II Review Process and Timeline

Establishing the Peer Review Panel

Dr. Pete Loucks (Cornell University and South Florida Water Management District) has accepted the CALFED Science Program's invitation to chair the panel. Other members are being currently being contacted by the Science Program staff

Organization of Briefing Material

Science Program and key agency staff, in consultation with the review panel chair, are identifying and organizing briefing material for panel members. Target date for completion is Sept 1, 2003. (This was extended to December 8, 2003)

Public Meeting of Review Panel

Target: 2-day session in November, 2003 in Sacramento area

Review workshop structure will include:

- Presentation overviews of California hydrology, water management, current issues, and the development of CALSIM II
- Presentations on the range of different current and potential applications of CALSIM for planning, operations, and supply reliability projects
- A summary of an independent interview project by Dr. Jay Lund of users and stakeholders explaining the major questions people are trying to answer with CALSIM II and other models
- Public comment to the panel
- Detail discussion of the model, including assumptions used in different applications, verification studies, and sensitivity analyses
- Opportunity for panel members to ask follow up questions of CALSIM developers and users
- An in camera session for panelists to discuss and begin compiling review comments
- A public presentation of the panel's draft findings

Panel Chair Provides Final Report to CALFED Lead Scientist

The panelists will be asked to finalize their review comments within 3 weeks of the public meeting and to transmit those directly to the Lead Scientist. The Science Program will transmit the completed review to CBDA and the CALFED community.

Appendix D: Panelists CALSIM II Review, Nov. 13-14, 2003

Name	Affiliation	Position	Address/Phone/E-mail
Andy Close	Murray Darling Basin Commission	Lead Modeler and System Manager	GPO Box 409 Canberra ACT 2601, AUSTRALIA (02)62790102 andy.close@mdbc.gov.au
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John Labadie	Colorado State University	Professor	B211 Engineering, Fort Collins, CO 80523 (970)491-6898 John.Labadie@colostate.edu
Pete Loucks	Cornell University	Professor	"Civil and Environmental Engineering, 311 Hollister Hall, Ithaca, NY 14853 " (607) 255-4896 DPL3@cornell.edu
Jay Lund	UC Davis	Professor	Civil and Environmental Engineering 3109 Engineering III, Davis, CA 95616" (530)752-5671 jrlund@ucdavis.edu
Daene McKinney	University of Texas at Austin	Professor	Civil and Environmental Engineering Campus Mail Code: C1786, Austin, TX 78712 (512)471-8772 daene_mckinney@mail.utexas.edu
Jery Stedinger	Cornell University	Professor	Civil and Environmental Engineering, Hollister Hall, Ithaca, NY 14853 (607) 255 2351 JRS5@Cornell.edu

Appendix E: Managing Model Development, Application, Documentation and Communication.

One possible means of maintaining control of the quality of particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and persons from other stakeholder organizations, including NGOs and universities, if they are interested and want to participate. This consortium would be responsible for maintaining a toolbox of 'acceptable' models for 'official' use by the agencies and contractors.

IMC responsibilities and authority could include:

- Prioritize, coordinate, and provide consistency, technical guidance and oversight for all modeling applications,
- Approve model selection and insure that each requested application is carried out using the most appropriate model(s) and input data,
- Provide or otherwise insure documentation of the modeling process itself as well as the modeling results,
- Insure that the results are expressed and made available in a way such that others can understand and benefit from that modeling application, as applicable.
- Implement peer reviews of models and their applications as deemed appropriate.

To help meet their responsibilities the IMC will need to establish, publish and implement some procedures for insuring the quality of the entire model development and application process. They will need to identify among all the models that might be used, which are the most appropriate to address each of these separate groups of model applications. They must identify various models, i.e., establish a model toolbox, from which clients can choose the one that best meets their needs (or perhaps argue that another model should be added to the toolbox). The IMC will also need to maintain model documentation and provide for peer reviews of any model, its documentation, and/or its use in a project.

CMM Level 3 Performance Expectations

Firms that develop professional software are typically required to meet certain software standards. One such standard is defined in a book from Carnegie Mellon University. These so called Capability Maturity Model (CMM 1994) standards have various levels. For example, the South Florida Water Management District, that develops hydrologic models used as inputs to major investment decisions, strives to meet Level 3 standards. To meet such standards in software development and peer review, one needs to show that

- Modeling related problems are anticipated and prevented

- Model development and application groups work together as an integrated product team.
- Model use training is planned and provided as is needed.
- New modeling methodologies are identified and evaluated for possible implementation on a qualitative basis.
- Data are collected and used in all defined processes.
- Data are systematically shared across various projects.
- Both the models and their applications are evaluated and judged satisfactory by independent reviewers.

It seems to this panel that CALFED could without too much difficulty meet such standards if it chose to. Clearly planning for, conducting, and documenting these activities will require additional time and money. The expectation is that in the long run, such documentation and review will save time and money by redirecting misguided initiatives, identifying alternative approaches, or providing valuable technical support for a potentially controversial decision.

Model Toolbox

The IMC in collaboration with all agencies involved in water resources planning could be responsible for creating and maintaining a collection of models that agencies can use to meet their needs. As shown in Figure 1, this collection of models might be called the model toolbox. The criteria to be used as a basis for deciding whether a proposed model should or should not be included in the toolbox will depend in part on an assessment of the attributes of that model compared to alternative models and the suitability of the model to meet the needs of the project. Associated with the model toolbox is a library of completed model application documents and data bases for use by anyone who could benefit from them.

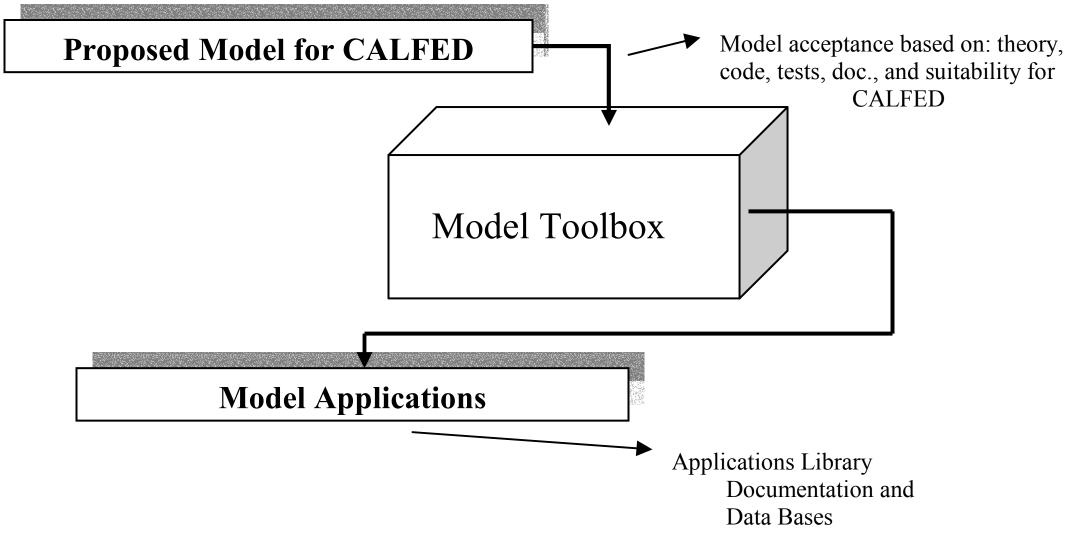


Figure 1. Model Toolbox consisting of approved models for use and Applications Library consisting of documentation and model data bases.

Everyone would agree that all modeling applications should be performed with the ‘best’ models available. But ‘best’ does not mean that all models used should be the most detailed, complex, realistic and thus usually the most expensive models available. The decision regarding the ‘best’ or most appropriate model should be based on the particular issues or questions being addressed, on the quantity and quality of the available input data, and on the time, personnel, and money available to perform the modeling application. The central question to be answered before initiating any modeling application is just what model output information (and precision) is needed to meet the needs of the decision making process. Expressed in other words, just how sensitive will the decision be to the type, amount and precision of the model output?

IMC in consultation with the other agencies could provide guidance on the adequacy of a particular version of CALSIM II or other associated model requested by each client with respect to the theory upon which it is based, its data requirements, its spatial and temporal resolutions, its documentation and status with respect to peer reviews, its capabilities, and its limitations. Similar considerations must be given to the proposed input data. To provide these services to each client requesting services from the IMC would require IMC to be staffed with personnel acquainted with the models in the toolbox, as well as be able to perform or review the simulations requested by various agencies.

There will likely be requests to use models not yet included in the model toolbox. IMC together with others from the DWR and/or USBR will need to judge the merits of such requests and if deemed beneficial, consider including such models in the toolbox. Undoubtedly the extent and quality of the documentation, testing, and peer review of various models in the toolbox will vary. However, a model’s inclusion in the toolbox should signify that the model has been judged to be the best available for meeting the goals for which it was designed and is applicable to conditions in California.

Information Flows and Documentation

The IMC will probably be devoting a substantial amount of time giving guidance to clients and, when applicable, to the public. They will need to be working with the clients who are requesting model applications, and in situations where they are not doing this work, they will need to be reviewing and approving the work of the agencies or contractors who are performing the modeling services. IMC would provide technical assistance as well as oversight and coordination among all CALSIM II modeling activities.

Requests for modeling are easy to make, and time and money are required to carry them out. Requests sent to this proposed IMC should reflect some thought by those requesting such model runs as to just why the model application is desired, and just how the results are to be used. We would propose that requests include such items as:

- Reason for modeling,

- Type of modeling (e.g., event based or continuous),
- Particular model preference if any, and why, and possible alternatives,
- Model output information (data) needed and why and when it is needed,
    - What questions are the model results going to answer?
    - What issues are being studied?
    - What decisions are to be made, or at least to be informed, based on these model results?
    - When are the model results needed?
    - What formats are desired for presenting the model results?
- Location or site being modeled and the spatial and temporal scales desired,
- Particular input data assumptions, boundary conditions and other regional assumptions required,
- Source of input data, and format required or desired for the output data,
- Model calibration and verification needs and preferred procedures if any,
- Money and time available for modeling,
- Extent (duration) of the simulations to be performed,
- Desired performance measures, other than variables being simulated, if any,
- Alternative scenarios to be modeled (i.e., number of simulation runs needed),
- Other analyses or model applications that may or will need the output from this model application,
- Sensitivity and uncertainty analyses needed, and for which decision variables and why,
- Client contact person,
- Requirements for intermediate reviews of results or needs for periodic review of modeling application process logs and documents, and
- Other particular requirements or needs.

The use of a model nearly always takes place within a broader context. The model itself can also be part of a larger whole, such as a network of models in which some are using the outputs of other models. These conditions may impose constraints on the simulation modeling project. All these considerations need to be specified in the modeling application request.

Along with the proposal, there should also be a simple order-of-magnitude estimate of the expected values of all relevant decision variables based on simple mass-balance analytical solution methods that can be used without requiring a computer. These estimated values should be used to validate (check the reasonableness of) selected portions of the model runs. If there are any serious discrepancies, it may signify a major problem in the model output.

Is all this paperwork useful? It is to the extent it leads to a more effective and efficient use of personnel, money and time. Preparing a formal modeling application request requires some serious thought as to just why this is necessary and just what information is needed to further the project or analysis. It involves defining the objectives that are to be accomplished. Writing this down in some detail helps reduce the differences in perception that can exist between those who need information and those who are going to provide that information (IMC or a contractor). The problem as stated is often not the problem as understood, by either the client or the model user. In addition, problem perceptions and modeling objectives can change over the duration of a project. One should ask and answer the question of whether or not modeling in general is the right way to obtain the needed information. What are the alternatives to modeling?

The objective of any modeling project should be clearly understood with respect to the domain and the problem area, the reason for using a particular model, the questions to be answered by the model, the model assumptions and limitations, and the scenarios to be modeled. Throughout the project these objective components should be checked to see if any have changed and if they are being met.

If IMC is to serve as a central point to coordinate CALSIM II-related modeling activities, and to provide modeling services, it needs to have the authority to do so. This authority extends to giving advice on issues related to model and input data selection, and for reviewing, approving and prioritizing requests for services. Should contractors be involved in particular model applications, IMC must be authorized to specify the technical terms to be met and oversee the work done by the contractor. Finally IMC will need the financial and human resources needed to do this in a timely manner.

Modeling Application Documentation

One common problem of model studies once they are underway occurs when one wishes to go back over a series of simulation results to see what was changed or why a particular simulation was made or what was learned. It is also commonly difficult if not impossible for third parties to continue from the point at which any previous modeling project was terminated, especially if some time has passed. These problems are caused by a lack of information on how the study was carried out. What was the pattern of thought that took place? Which actions and activities were carried out? Who carried out what work and why? What choices were made? How reliable are the end results? These questions should be answerable if a model journal is kept. Just like computer programming documentation, modeling project documentation is often neglected under the pressure of time and perhaps because writing it is not as interesting as running the models themselves.

The paper trail of what has happened, what assumptions have been made, how calibration and verification were carried out, what results were obtained, why changes, if any, were made, what sensitivity analysis procedures were used and their results, and so on, could be contained in a modeling application documentation (MAD). Once the model application is completed, a copy of the MAD should be given to the requesting agency, as applicable and a copy should remain in IMC. These reports, or at least a summary of them, should be available for downloading from the web. Should further model applications be requested and approved, the requester as well as the IMC can refer to this previously prepared documentation to better understand what was done previously that pertains to the current request.

Model Calibration

Once a model is tested satisfactorily, it can be calibrated. Calibration of models such as CALSIM II are difficult because there are no historical observations of future scenarios to compare with model results. Historical runs, such as have been made, can provide some basis for calibration. In general the smaller the deviation between the calculated model results and the field observations, the better the model. This is true to a certain extent, as the deviations in a perfect model are only due to measurement errors. In practice, however, a good fit is by no means a guarantee of a good model.

The deviations between the model results and the field observations can be due to a number of factors. These factors include possible software errors, inappropriate modeling assumptions such as the (conscious) simplification of complex structures, neglecting certain processes, errors in the mathematical description or in the numerical method applied, inappropriate parameter values, errors in input data and boundary conditions, and measurement errors in the field observations.

To determine whether or not a calibrated model is a ‘good’ predictor, it should be validated or verified. Calibrated models should be able to reproduce field observations not used in calibration. Validation can be carried out for calibrated models if an independent data set has been kept aside for this purpose. If all available data are used in the calibration process in order to arrive at the best possible results, validation will not be possible. A decision to leave out validation may be a justifiable one especially when data are limited.

Philosophically it is impossible to know if a simulation model of a complex system is ‘correct’. There is no way to prove it. Experimenting with a model, such as by carrying out multiple validation tests, can increase confidence in that model. After a sufficient number of successful tests, one might be willing to state that the model is ‘good enough’, based on the modeling project requirements. The model can then be regarded as having been validated, at least for the ranges of input data and field observations used in the validation.

If model predictions are to be made for situations or conditions for which the model has been validated, there may be some confidence in the reliability of those predictions. Yet one cannot be certain. Much less confidence can be placed on model predictions for conditions outside the range for which the model was validated.

While a model should not be used for extrapolations as commonly applied in predictions and in scenario analyses, this is often exactly the reason for the modeling project. What is likely to happen given events we have not yet experienced? A model’s answer to this question should also include the uncertainties attached to these predictions. Depending on the type of model selected and used, one might end up predicting an incorrect future with great accuracy, or predicting the correct future with great uncertainty’. We don’t yet know how to predict the correct future with great accuracy – so we do ‘what ifs’. One can then argue about what scenarios – the ifs – are the most reasonable or probable, or about the impacts from improbable scenarios that you want to avoid should such scenarios occur.

Use the model

Once the model has been judged 'good enough,' the model may be used to obtain the information desired. Close communication between the client and the modeler during the modeling application process is essential to avoid any unnecessary misunderstandings about what information is wanted and the assumptions on which that information is to be based.

Before the end of this model-use step one should determine whether all the necessary simulations have been performed and whether they have been performed well. Questions to ask include

- did the model fulfill its purpose?
- are the results valid?
- are the quality requirements met?
- was the discretization of space and time chosen well?
- was the choice of the model restrictions correct?
- was the correct model and/or model program chosen?
- was the numerical approach appropriate?
- was the implementation performed correctly?
- what are the sensitive parameters (and other factors)?
- was an uncertainty analysis performed?

If any of the answers to these questions is no, then the situation should be corrected. If it cannot, the reason(s) for why it cannot be corrected should be documented in the model application document (MAD).

Interpret model results

Interpreting the information resulting from models is a crucial step in the modeling application process, especially in situations in which the client may only be interested in those results and not the way they were obtained. The model results can be compared to those of other similar studies. Are the results consistent? IMC must make that judgment. Any unanticipated results should be discussed and explained. The results should be judged with respect to the modeling project objectives.

The results of any modeling project typically include large files of time-series data. Only the most dedicated of clients will want to read those files. Thus these data must be presented in a more concise form. Statistical summaries should explicitly include any restrictions and uncertainties in the results. They should identify any gaps in the domain knowledge, thus generating new research questions or identifying the need for more field observations and measurements.

Report model results

Once the modeling application is completed, the organization doing the modeling will be responsible for preparing a report. The contents of this report should conform to the agreement made between modeling organization and the client prior to the initiation of the modeling application (see above). Although the results of a model are very rarely used as the sole basis for policy decisions, those requesting model applications may have a responsibility to translate their model results into policy recommendations. Policymakers, managers, and indeed the participating stakeholders typically want simple and clear unambiguous answers to complex questions. Much of the scientifically justified discussion, say regarding the uncertainties associated with some of the data, included in the main body of a report are not included in the executive summary of that report. This executive summary is often the only part read by those responsible for making decisions. Therefore, the conclusions of the model study must not only be scientifically correct, but also concisely formulated, without jargon, and fully understandable by managers and policymakers. When preparing or reviewing contractor model results reports, the IMC should consider this need.

These model application and model results reports should include sufficient detail to allow others to reproduce the model study (including its results) and/or to proceed from the point where this study ended. The report therefore requires a clear indication of the validity, usability and any restrictions of the model results.

Data Management

CALSIM II and its associated or linked models will require data. They will also produce data. Many of these data will have spatial and temporal dimensions. This information must be documented (meta data), preserved, and made accessible to IMC customers, coordination agencies and others. IMC should participate in data management strategic development, storage, documentation and dissemination. It should work with data base managers of various agencies to help them satisfy the IMC's data management requirements.

The availability of quality assured data is a critical dependency that must be met to facilitate timely completion of model development, implementation and application. To mitigate the impact of the availability of data on the timeline for the major model completion deadlines, the following issues should be addressed. :

- Updating land use / land cover data at regular and timely intervals.
- Developing and maintaining a common modeling database. This data base should include infrastructure design and operating policy data as well as water quality, ecological, land use, economic and of course hydrological data. Many of these data sets will have spatial as well as temporal dimensions. Each data set should have an associated metadata file.
- Pre-processed and post-processed datasets from previous model runs should be archived along with its metadata file in a central location for ease of access and availability.
- Measures to insure the consistency and quality of the input data.
- Measures to insure adequate communication among model developers, users and stakeholders. This includes measures to assist in developing documentation appropriate for each type of stakeholder.

Support of IMC activities

Common failures of IMC type organizations are typically due to:

- Insufficient staff to enable cross-training. This may lead to the dependency on one person or a very small group of employees for each sub module or the overall effort.
- Inadequate funding to institute good project management discipline.
- Inadequate funding to contract for technical writers and software engineers.
- Inadequate funding to contract for peer reviews.

Risk assessments

A risk assessment of CALSIM II and its associated models and data should be completed. The timely availability of quality assured data for example, is a risk. Project risk management includes the processes concerned with identifying, analyzing, and responding to uncertainties. Risk management attempts to minimize the results of adverse events. As a guide, the template, such as shown at the end of this Appendix, may be used to facilitate the assessment of risks.

Problem Management

Given the high visibility and criticality of the CALSIM II modeling effort an issue or problem management process should be developed within IMC. Issue/problem management includes the process for identifying, communicating, and resolving issues and problems.

The purpose of this procedure is to ensure that:

- Issues are identified, reported, managed, and resolved in a timely and effective manner. Responsibility is assigned to an owner for reporting, managing and resolving each issue
- All affected stakeholders are aware of the status of the issues
- Escalation of unresolved issues take place according to a defined procedure

In order to ensure that project issues and problems are appropriately managed various issue/problem management steps should be identified and followed to track the actions taken to resolve the issue or problem throughout the life of a modeling project.

B. Managing Peer Reviews

One means of quality control involves peer reviews of the models, their associated software, and their applications. One possible means of facilitating the peer review processes and for maintaining control on the particular versions of CALSIM II and accompanying models used for SWP-CVP planning and management decisions is another reason to create an interagency modeling consortium (IMC) consisting of DWR, USBR, and other stakeholder organization personnel if they are interested and want to participate. As suggested above, this consortium could be responsible for maintaining a toolbox of ‘acceptable’ peer-reviewed models for use by the agencies and contractors. The peer reviews should be of the theory underlying each model, the model's software, the documentation of that software, the model's functions and capabilities including those pertaining to model data input and output, model calibration and verification, sensitivity analyses, uncertainty analyses, user control (GUIs), spatial and temporal resolutions, limiting assumptions, and on the model (as opposed to code) documentation.

Just having evidence of published articles about a particular model in peer reviewed journals is not a substitute for a peer review of the model software and its applicability or suitability for certain types of analyses for SWP-CVP. Peer reviews of all models, their software, and their use should be accomplished by experts both within and outside of the originating agencies. 'Inside' agency (or internal) reviews may uncover some needed changes and identify other issues or problems that external reviewers could be asked to specifically examine and address. Internal reviews can make the external review process more effective, less costly and less time consuming.

Peer reviews are considered a key process area for Level 3 and higher of the Capability Maturity Model guidelines for improving the software process (Carnegie Mellon University, 1994). The purpose of peer review evaluations is to find defects in the model formulation and software and in its use, i.e., model application. Peer reviewers can also identify possible ways of correcting those defects, if any. If there are no defects, or after all known defects have been corrected, both the developers and users of any model and its software can have a stronger basis for believing that their product and its output are reliable.

Peer reviews serve the same function as accountants. Once a firm's financial records have been peer reviewed by accountants (assuming they are qualified, objective and honest) the board of directors as well as the stockholders will have more assurance of the liabilities and net worth of their firm, and just how well it is being managed. In this case it is the assurance of the quality of the models, their software, and on their use in project evaluations, that actual and potential users of the model results depend upon.

The types of problems and issues for which a model, its software, and its documentation are designed to address are called the model's 'application niche'. Peer review of model development should include the evaluation of the intended application niche along with consideration of other aspects of model performance. Users of any model should be aware of the types of analyses for which the model is best suited and those for which the model is not well suited. This, along with the results of a peer review of any model application, should help the potential model user, or the user of the model results, better understand the limitations of the scientific basis of the model and just how much confidence can be placed on the model output.

Peer review triggers

Clearly judgment will have to be exercised as to just when and in what detail a peer review needs to be implemented. However the triggers on when a decision about a peer review needs to be made can be defined.

As shown in Figure 2, decisions regarding peer review are needed when models are proposed for the tool box and when model applications are completed. Should IMC decide a peer review is warranted when either of those events takes place, they will have to decide on the type of review and its level of detail. They will also need to identify the individuals to be asked to carry out that peer review.

Peer reviews are going to take time and cost money. They will also require IMC time to prepare the documentation needed for the peer reviewers and to read and act on reports prepared by the peer reviewers. This will apply if the peer review is internal or external.

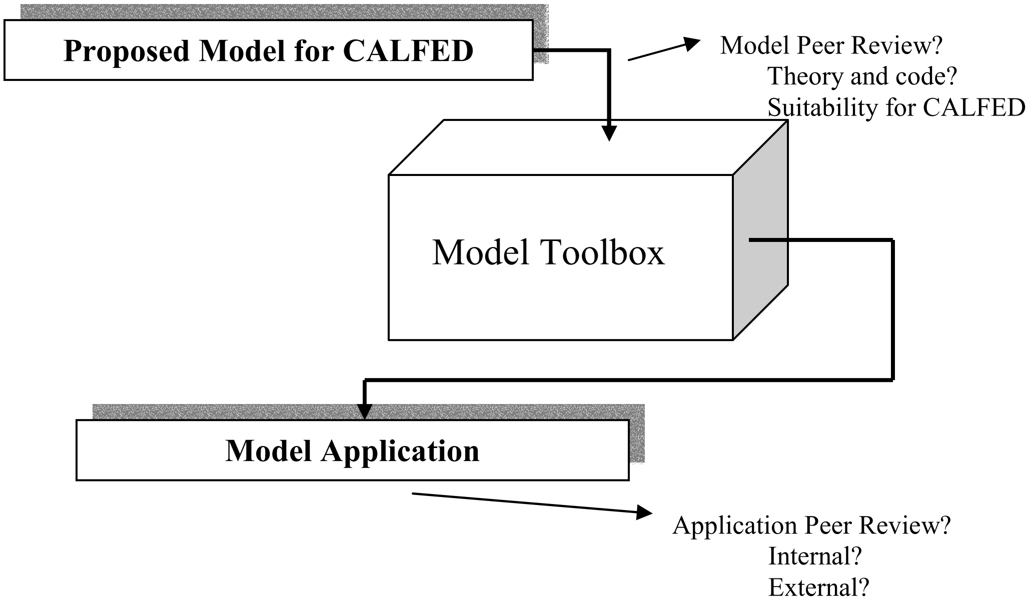


Figure 2. Schematic showing events where a peer review decision can be made.

The particular models and their associated software and documentation to be peer reviewed should be identified by the individuals or departments or agencies. This can include model process descriptions, software source code, documents, test results, and other supporting materials, as needed, for an adequate peer review of the entire model and its software. These products to be reviewed should be identified in writing and a written history of the review of different versions of each item should be maintained.

Events that take place in the progression of model development and use and subsequent modifications that warrant a peer review should be identified and specified in a written document. (This fits in to the model development and use documentation that should be maintained for Level 3 or higher CMM) When these events take place a peer review process should be considered, and if warranted, implemented. Depending on the event, the review can be solely internal, or it can involve an independent external review team as well.

Model application reviews should include an evaluation of the intended model application niche, and its applicability to current needs. Peer review may be appropriate for existing models when new information becomes available that could negate some or all of the conclusions of previous reviews or suggest a change in the currently specified application niche. Peer review of a model's applicability to a particular study should be planned well in advance of when model results are needed. The results of application reviews can influence the decisions made based on the model outputs. Once a peer review has been conducted for a particular model and its input data, peer reviews of subsequent applications of a model with similar inputs might be unnecessary. However, any time the model results may be controversial, or end up in litigation, another peer review may be justified.

Peer Review Process

The extent and process of performing and responding to peer reviews can vary in any organization. The ones discussed in this section attempt to follow the processes recommended by the Capability Maturity Model Level 3 guidelines.

Project peer review process should be specified in writing. A first step in this process should be to identify the particular modeling products and processes that will undergo peer review. This includes the models (i.e. the processes being modeled and the assumptions built into the models for describing these processes), their supporting software, the documentation of the model and its software, as well as all the written guidelines on how the models are to be used.

A second step is to perform an internal peer review prior to a model's use for project evaluation. It should be peer reviewed for accuracy, its suitability for use, and for identifying any possible errors in its logic, its coding, or in its documentation. Following an internal review, an external peer review can be performed.

Following the successful conclusion of internal and external peer reviews of a model and its documentation, the model can be applied to evaluate alternative projects. After the model has been applied to a particular project, the modeling process and its results should be peer reviewed to insure that the model has been applied properly, that the input data were appropriate, and that the conclusions drawn were valid.

Peer review teams should be selected, along with a peer review team leader. The particular personnel on the team will depend on the particular model and its software and documentation being reviewed. CALFED should have a list of qualified peer reviewers representing all applicable disciplines, both internal and external, that it can call upon to perform these reviews. The peer reviews are to be of the models and their use, not of the people who developed or used them. The reviews are to be used to evaluate the quality of modeling products and processes, not of the personnel involved.

Establishing and carrying out ongoing peer review processes costs money. Adequate funding must be made available to

1. identify and recruit a peer review team and team leader
2. prepare and distribute the peer review materials to the peer review team
3. support the time required for the team to review the materials prior to a team meeting
4. support the team meeting and to participate in it as appropriate (e.g., answering questions, conducting model experiments and sensitivity analyses, etc.)
5. reproduce and distribute the team report and to take actions as needed
6. monitor the modifications or changes being made to the model, its software, and its documentation, or redoing the model application, as needed.
7. prepare and distribute to model developers and potential users a report on the results of the peer review and the actions taken.

The particular peer review process may depend on just what is being peer reviewed and the resources and time available to perform the review. In general, however, the steps of a peer review could include the following:

1. DWR or CALFED should identify and establish a pool of possible reviewers representing various disciplines, with sufficient redundancy to allow for scheduling conflicts when ever some subset of those reviewers are needed. This includes both internal as well as external reviewers. What ever administrative work is need to establish this pool should be completed prior to when these reviewers will be needed.

2. At particular milestones in any new model development or in model application an internal peer review process could be initiated, to examine the modeling assumptions, the software that implements those assumptions in the case of model development or the data being used for model inputs in the case of model applications, and the documentation being prepared to describe the processes, to document the software code, and to document the tests that were run to test the code, or to document the results of the model application. If deemed appropriate, an external peer review could also be performed. If an external review is to take place, the particular reviewers need to be selected, notified, sent supporting documents, and be scheduled for one or more meetings, as needed. They should be issued contracts specifying the requirements (the checklist of items to be reviewed) and products expected.

3. Recommendations made by the peer review team need to be addressed and the actions taken along with the rationale for those actions should be documented.

4. The peer review team should review the actions taken and the results obtained from these actions. If not judged acceptable new recommendations should be made and submitted. A final report should be prepared by the peer review team when all recommendations have been successfully implemented or addressed, or if no further actions based on review team's recommendations will be taken by the model developers or users.

The time and effort required for various levels of review should also be assessed and provided to the review team so that they can carry out the level of review requested of them. Otherwise the reviews may be superficial and while appearing to be peer reviewed, a model and its associated products may in fact be inadequately reviewed. Peer review teams have the responsibility to specify in writing the scope and limitations of their reviews.

As was the case for this peer review panel, the materials to be sent to the review team to allow them to prepare for their meeting should include the statement of review objectives and the level of detail desired, the applicable requirements and standards upon which to judge the adequacy of the products being reviewed, and of course the material that is to be reviewed. There should be a list of questions for the reviewers to address. Each review team member should be assigned and given responsibility for answering specific questions and for completing specific aspects of the overall review. All team members should be given specific review standards or requirements, including the expected completion dates. Checklists should be provided the review team that are applicable to the specific type of product being reviewed and the level of detail to be examined. These checklists will contain the criteria for judging the product, such as compliance with any standards and procedures, completeness, correctness, rules of construction, and maintainability.

Peer Review Issues and Questions

Each model development or application review will dictate its own special set of questions to be addressed. Some of these questions could relate to:

- Model Purpose and Objective
    - Use of model related to decisions being considered.
    - Model application niche, and why.
    - Model strengths and weaknesses –is it the best model?
- Model Processes and Limitations
    - Model processes, spatial and temporal scales, grid resolution.
    - Model variables and level of aggregation.
- Model Theoretical Basis
    - Model algorithms, numerical or analytical methods,
    - Model process formulation
    - Modeling approach in comparison with other models
    - Any shortcomings in relation to application niche
- Model Parameter Estimation
    - Methods used
    - Data available for parameter estimation
    - Parameter estimate reliabilities
    - Boundary conditions and appropriateness.
- Model Input Data Quantity/Quality
    - Data used in design of model
    - Data adequacy (quantity, quality, resolution) for model purpose and application
    - Data necessary for application of model
    - Key data gaps in model application
    - Additional data needs and why
- Model Key Assumptions
    - Basis for major assumptions

    - Sensitivity of model outputs to key assumptions
    - Sensitivity of potential decisions to key assumptions
    - Ease in modifying key assumptions
- Model Performance Measures
    - Criteria for assessing model performance
    - Correspondence of model output with measured observed data
    - Any model bias throughout range of model predictions
    - Variability and uncertainty analyses and representations in model results
    - What determines model's variability and uncertainty.
    - Model performance relative to others in application niche
- Model Documentation and User's Guide
    - Clarity of documentation, comprehensiveness of user's guide
    - Model applicability and limitations
    - Input data requirements for calibration, verification, model runs
    - Post modeling analyses, display and interpretation of results
    - Model code documentation
    - Model application documentation examples for prospective users.
- Review Retrospective
    - How well model and its application meet objectives and needs of project
    - Possible changes in the model to improve model performance
    - Robustness of model solutions to small changes in uncertain parameters, etc.
    - Ease of including uncertainty analyses associated with uncertain input data.
    - Key research needs for model improvement.

Peer Review Completion Reports

Procedures need to be established to track and confirm actions based on suggested changes or modifications in the material being reviewed. Once these actions are taken and completed, and documented, the peer review process for that particular product is completed. Peer review completion reports should contain data on what was reviewed and the results of the review. These data should include a description of the products that were reviewed, the level of detail of the review, any review limitations or qualifications, the number and backgrounds of the reviewers, the time spent preparing for and during review team meetings, the defects found and recommendations made, and the actions taken to address these recommendations.

Overall Peer Review Evaluations

The IMC or initiating agency should document the planning for and scheduling of peer reviews. The products to be reviewed and the level of detail to be examined also need to be specified. The procedures to be followed for selecting peer review team members, and the team leader, should also be determined and documented. Procedures for training potential reviewers, if such training is needed, should be identified and implemented, as required.

Periodically the IMC or applicable agency should assess just how well the plan described in the preceding paragraph is being carried out, and just how beneficial these peer reviews are to the overall modeling effort. Measures should be identified and used to determine the status of the peer review activities. These measures could include the number of completed peer reviews performed compared to the number expected to be performed, the overall effort expended on peer reviews compared to that expected, and the number and extent of peer review recommendations requiring actions.

At a minimum these periodic reviews should verify that

1. The planned peer reviews and/or audits are conducted.
2. The peer review leaders are adequately trained for their roles.
3. The reviewers are properly trained or experienced in their roles.
4. The processes for preparing for and conducting peer reviews, and for following up on reviewer's recommendations are adequate and are being followed.
5. The reporting of peer review results is complete, accurate, timely and is being made available to model users.

Risk Management Template

Risk Definition Name	Enter a short name that uniquely defines the risk
Risk #	Enter a unique number assigned to the risk. Range starts with 1 and continues.
Date Risk Identified	Enter the date the risk was identified
Risk Identification Source	Enter the source of the risk identification. In example, meeting name, group, or person.
Risk Owner	Enter the name of the person who will be responsible for ensuring the risk is approved, managed, periodically assessed, communicated, and tracked through closed or transfer.
Risk Detailed Description	Enter a detailed description of the risk so that a reader clearly understands the risk.
Probable Impact of Risk on Project (H, M, L)	Enter the impact on the project. o High = the risk will most likely occur and the impact could prevent the project from achieving its purpose. o Medium = there is a 50/50 change the risk would occur and the impact is serious but the project could still achieve its purpose if appropriately managed. o Low = there is a low probability that the risk would occur and minimal impact to the project's purpose.
Probable Impact of Risk on Project Costs	Enter the impact on the project in dollars. Determine what the potential cost to the project would be if the risk occurs.
Probable Impact of Risk on Project Schedule	Enter the schedule impact on the project. Determine how the schedule would be potentially impacted if the risk occurs.
Probable Impact of Risk on Project Results	Enter the impact on the project. Determine how the overall project purpose and results will be potentially impacted if the risk occurs.
Detailed Plan to Mitigate or Transfer Risk	Enter the detailed plan to mitigate the risk or a statement that the risk will be accepted. Mitigation could include ways to minimize, avoid, or transfer the risk to another party or group. Risk transfer would include evidence of agreement by the accepting party.
Detailed Project Action Items Required to Mitigate or Transfer Risk	Enter the detailed action items required to mitigate the risk. These items will be summarized and assigned within the project Action Log, along with an action item owner, and target completion date.
Detailed Project Plan Tasks Required to Mitigate Risk	Enter the detailed project plan task required to mitigate the risk. These items will be summarized and contained within the MS Project Schedule along with the effort, duration, schedule, and assigned resources.
Comments	Enter any permanent comments that cannot be included in the above items.
Referenced Documents	Enter any documents that a reader should consider in understanding, analyzing, mitigating, or accepting this risk.
Date Risk Closed	Enter the date this risk was closed. This would include when all action items or project tasks were completed, or the risk was transferred to another party or group.

Appendix F: Analysis of the November 2003 CALSIM II Validation Report

The following comments come from an analysis of the model results presented in the validation report *'CALSIM II Simulation of Historical SWP/CVP Operations'*, DWR (2003). The observations relate to the formulation of the model at November 2003. Changes might be made to that formulation which could resolve these issues.

Overestimation of Project Deliveries

The validation run suggests that the modeled demands included in CALSIM II overestimate the actual demands. CVP demands south of the Delta are assumed to be always equal to the contract entitlement whereas the observed deliveries in unrestricted years are consistently less than this amount. The modeled North of Delta deliveries are also consistently higher than observed. The modeled and observed CVP deliveries from the validation report are listed in Table 1.

Table 1. Comparison of modelled and observed CVP deliveries (1975-1998)

Project	Simulated Delivery (Taf/yr)	Historical Delivery (taf/yr)	Difference (taf/yr)	% Difference
CVP North of Delta	1960	1750	210	12
CVP South of Delta	2650	2490	160	6.4

Because the SWP south of delta demands were set to historical deliveries in many years, comparison with the historical deliveries in the validation report is of limited validity. However the fact that the historical SWP deliveries over the last ten years have averaged only 2385 taf/year while the modeled 'year 2001 development' SWP Delta deliveries reported in the 2002 State Water Project Delivery Reliability Report average 3090 taf/year, suggests that modeled SWP deliveries may also be too high.

Allocations to Project Contractors

Seasonal allocations to SWP and CVP contractors are made on the basis of water in storage, forecast inflows, projected carryover storage requirements and in-Basin and Delta regulatory requirements. The allocation processes used by the operators and those used by CALSIM II, are not identical. An examination of the way that CALSIM II has restricted project deliveries during the dry period of 1987-1992 (Figures 10, 16, 17 and 24 of the validation report) suggests that CALSIM II has allocated less water in the early years of the dry sequence than occurred in practice and consequently had more water available in 1991 and 1992 when the most severe restrictions were experienced. The carryover storage rules adopted can have a significant impact on the expected frequency and severity of water supply restrictions. The model rules need to be examined to ensure that the accurately reflect the way the system will be managed in the future.

San Luis Reservoir Operation

The rules used by the system operators for transferring water from headwater storages to the San Luis Reservoir can have a significant impact on:
- the pattern of flow in the Delta,
- the operation of accounting rules between the SWP and the CVP and
- opportunities for SWP wheeling of CVP water and possibly the availability of Article 21 water to SWP contractors.

A comparison of the modeled and observed storage behavior of the SWP component of San Luis (Figure 15) reveals that the model consistently underestimates the volume in storage. A comparison of the CVP component of the storage (Figure 23) indicates that the actual storage is filled earlier in the season and that the actual storage is also slightly higher than the modeled.

Users of CALSIM II output need to be confident that the rules adopted by the model for determining these transfers reflect the way this component of the system will be operated in the future.

Appendix G: Some Principles for Strategic Water Analysis for the California Water Plan Bulletin 160-03 (from the stakeholder review Draft, Sept. 30, 2003)

Strategy:

1) A frequently amended strategic document will lay out DWR's strategic analysis framework and identify the technical objectives, roles, and responsibilities of major DWR data collection efforts and analytical tools and their interactions and their responsible managers.

Transparency:

2) All data and models should be in the public domain and available on the web.
3) All data and models should have significant documentation.
4) Known limitations should be documented.

Longer-term viability:

5) Modularity: Major analytical tools will be designed and implemented to fit modularly and explicitly within the larger strategic analysis framework.
6) Adaptive data management framework: Major data efforts will fall within a larger data management framework, including protocols for data documentation and updating, and documentation of limitations.
7) A frequently-updated document will outline short-term and long-term efforts, budgets, and responsibilities for continuous improvement of analytical tools and data, with policy for continued user, local agency, and stakeholder involvement.

Coverage:

8) Spatial coverage for the basic data and analytical framework will be statewide.
9) Local and regional water management and resources will be explicitly represented.

Accountability and Quality Control:

10) In developing analytical tools, systematic efforts should be made to involve local agencies and stakeholders.
11) Major analytical products will undergo external review by a) external unaffiliated experts and b) local agencies whose systems are included in the model. User groups will exist for all major analytical products.
12) DWR's strategic analysis framework will undergo periodic internal and external review.

Appendix H: Model Sensitivity and Uncertainty Analysis

(This is a draft of a book chapter by DPL/JRS that may be useful for CALSIM II developers)

The usefulness of any model is in part dependent on the accuracy and reliability of its output data. Yet, because all models are imperfect abstractions of reality, and because precise input data are rarely if ever available, all output values are subject to imprecision. The input data and modeling uncertainties are not independent of each other. They can interact in various ways. The end result is imprecision and uncertainty associated with model output. This chapter focuses on ways of identifying, quantifying, and communicating the uncertainties in model outputs.

1. Introduction

Models are the primary way we have to estimate the multiple affects of alternative water resource system design and operating policies. Models predict the values of various system performance indicators. Model outputs are based on model structure, hydrologic and other time-series inputs and a host of parameters whose values describe the system being simulated. Even if these assumptions and input data reflect, or are at least representative of, conditions believed to be true, we know they will be wrong. Our models are always simplifications of the real systems we are studying. Furthermore, we simply cannot forecast the future with precision. So we know the model outputs of future conditions are uncertain estimates, at best.

Some prediction uncertainties can be reduced by additional research and data collection and analysis. Before undertaking expensive studies to gather and analyze additional data it is reasonable to ask what improvement in estimates of system performance or what reduction in the uncertainty associated with those estimates would result if all data and model uncertainties could be reduced. Such information helps determine how much one would be willing to ‘pay’ to reduce prediction uncertainty. If prediction uncertainty on average is costing a lot, it may pay to invest in additional data collection, more studies, or in better models all aimed at reducing that prediction uncertainty. If that uncertainty has no, or only a very modest, impact on the likely decision that is to be made, one should find other issues to worry about.

If it appears that reducing prediction uncertainty is worthwhile, then one should consider how best to do it. If doing this involves obtaining additional information, then it is clear that the value of this additional information, however measured, should exceed the cost of obtaining it. The value of such information will be the increase in system performance, or the reduction in its variance, that one can expect from obtaining such information. If additional information is to be obtained, it should be that information which reduces the uncertainties considered important, not the unimportant ones.

This chapter reviews some methods for identifying and communicating model prediction uncertainty. The discussion begins with a review of the causes of risk and uncertainty in model output. It then examines ways of measuring or quantifying uncertainty and model output sensitivity to model input imprecision, concentrating on methods that seem most relevant or practical for large-scale regional simulation modeling. It builds on some of the statistical methods reviewed in Chapter III and the modeling of risk and uncertainty in Chapter VI.

2. Issues, concerns, and terminology

Outcomes or events that cannot be predicted with certainty are often called risky or uncertain. Some individuals draw a special and interesting distinction between risk and uncertainty. In particular, the term risk is often reserved to describe situations for which probabilities are available to describe the likelihood of various events or outcomes. If probabilities of various events or outcomes cannot be quantified, or if the events themselves are unpredictable, some would say the problem is then one of uncertainty, and not of risk. In this chapter what is not certain is considered uncertain, and uncertainty is often described by a probability distribution. When the ranges of possible events are known and their probabilities are measurable, risk is called objective risk. If the probabilities are based solely on human judgment, the risk is called subjective risk.

Such distinctions between objective and subjective risk, and between risk and uncertainty, rarely serve any useful purpose to those developing and using models. Likewise the distinctions are often unimportant to those who should be aware of the risks or uncertainties associated with system performance indicator values.

Uncertainty in information is inherent in future-oriented planning efforts. Uncertainty stems from inadequate information and incorrect assumptions, as well as from the variability of natural processes. Water managers often need to identify both the uncertainty as well as the sensitivity of, or changes in, system performance indicator values due to the any changes in possible input data and parameter values from what were predicted. They need to reduce this level of uncertainty to the extent practicable. Finally, they need to communicate the residual uncertainties clearly so that decisions can be made with this knowledge and understanding.

Sensitivity analysis can be distinguished from uncertainty analysis. Sensitivity analysis procedures explore and quantify the impact of possible errors in input data on predicted model outputs and system performance indices. Simple sensitivity analysis procedures can be used to illustrate either graphically or numerically the consequences of alternative assumptions about the future. Uncertainty analyses employing probabilistic descriptions of model inputs can be used to derive probability distributions of model outputs and system performance indices. Figure 1 illustrates the impact of both input data sensitivity and input data uncertainty on model output uncertainty.

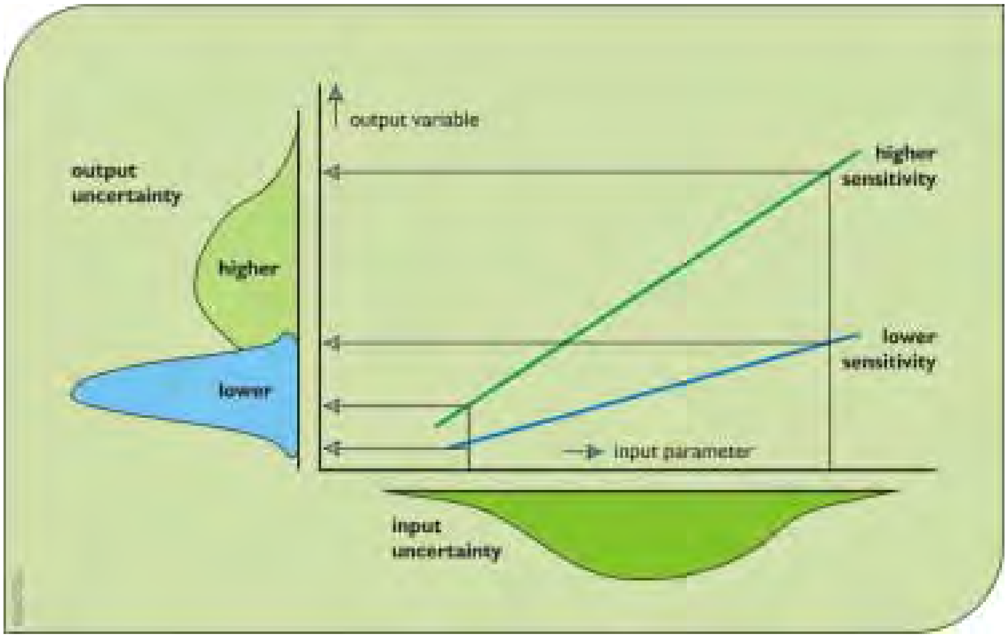


Figure 1. Schematic diagram showing relationship among model input parameter uncertainty and sensitivity to model output variable uncertainty (Lal, 1995).

It is worthwhile to explore the transformation of uncertainties in model inputs and parameters into uncertainty in model outputs when conditions differ from those reflected by the model inputs. Historical records of system characteristics are typically used as a basis for model inputs. Yet conditions in the future may change. There may be changes in the frequency and amounts of precipitation, changes in land cover and topography, and changes in the design and operation of control structures, all resulting in changes of water stages and flows, and their qualities, and consequently changes in the impacted ecosystems.

If asked how the system would operate with inputs similar to those in the historical database, the model should be able to interpolate within the available knowledge base to provide a fairly precise estimate. Still that estimate will not be perfect. This is because our ability to reproduce current and recent operations is not perfect, though it should be fairly good. If asked to predict system performance for situations very different from those in the historical knowledge base, or when the historical data are not considered representative of what might happen in the future, say due to climate change, such predictions become much less precise. There are two reasons why. First, our description of the characteristics of those different situations or conditions may be imprecise. Second, our knowledge base may not be sufficient for calibrating model parameters in ways that would enable us to reliably predict how the system will operate under conditions unlike those that have been experienced historically. The more conditions of interest are unlike those in the historical knowledge base, the less confidence we have that the model is providing a reliable description of systems operation. Figure 2 illustrates this issue.

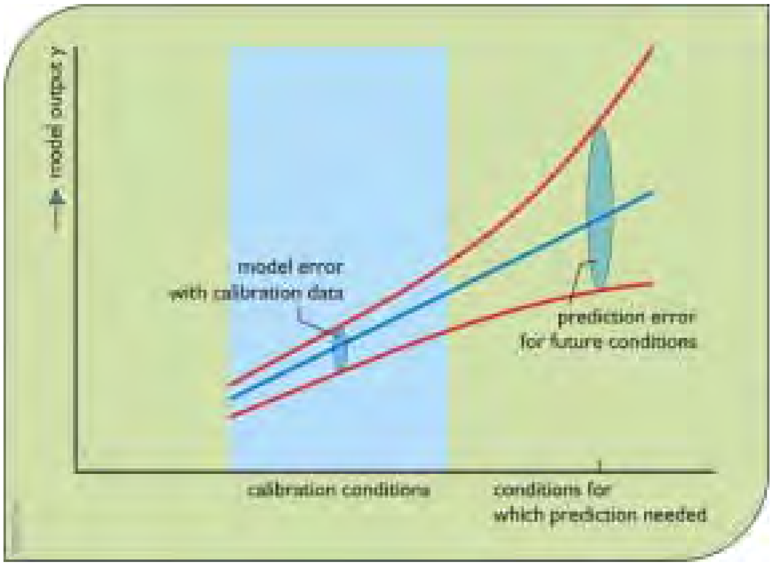


Figure 2. The precision of model predictions is affected by the difference between the conditions or scenarios of interest and the conditions or scenarios for which the model was calibrated.

Clearly a sensitivity analysis needs to consider how well a model can replicate current operations, and how similar the target conditions or scenarios are to those described in the historical record. The greater the required extrapolation from what has been observed, the greater will be the importance of parameter and model uncertainties.

The relative and absolute importance of different parameters will depend on the system performance indicators of interest. Seepage rates may have a very large local effect, but a small global effect. Changes in system-wide evapotranspiration rates will likely impact system-wide flows. The precision of model projections and the relative importance of errors in different parameters will depend upon the:

(1) precision with which the model can reproduce observed conditions,
(2) difference between the conditions predicted and the historical experience included in the knowledge base, and the
(3) system performance characteristics of interest.

Errors and approximations in input data measurement, parameter values, model structure and model solution algorithms, are all sources of uncertainty. While there are reasonable ways of quantifying and reducing these errors and the resulting range of uncertainty of various system performance indicator values they are impossible to eliminate. Decisions will still have to be made in the face of a risky and uncertain future. Decisions can be modified as new data and knowledge are obtained in a process of adaptive management.

There is also uncertainty with respect to human behavior and reaction related to particular outcomes and their likelihoods, i.e., to their risks and uncertainties. As important as risks and uncertainties associated with human reactions are to particular outcomes, they are not usually part of the models themselves. Social uncertainty may often be the most significant component of the total uncertainty associated with just how a water resource system will perform. For this reason we should seek designs and operating policies that are flexible and adaptable.

When uncertainties associated with system operation under a new operating regime are large, one should anticipate the need to make changes and improvements as experience is gained and new information accumulates. When predictions are highly unreliable, responsible managers should favor actions that are robust (e.g., good under a wide range of situations), gain information through research and experimentation, monitor results to provide feedback for the next decision, update assessments and modify policies in the light of new information, and avoid irreversible actions and commitments.

3. Variability and uncertainty in model output

Differences between model output and observed values can result from either natural variability, say caused by unpredictable rainfall, evapotranspiration, water consumption, and the like, and/or by both known and unknown errors in the input data, the model parameters, or the model itself. The later is sometimes called knowledge uncertainty but it isn't always due to a lack of knowledge. Models are always simplifications of reality and hence 'imprecision' can result. Sometimes imprecision occurs because of a lack of knowledge, such as just how a particular species will react to various environmental and other habitat conditions. Other times known errors are introduced simply for practical reasons.

Imperfect representation of processes in a model constitutes model structural uncertainty. Imperfect knowledge of the values of parameters associated with these processes constitutes model parameter uncertainty. Natural variability includes both temporal variability and spatial variability, to which model input values may be subject.

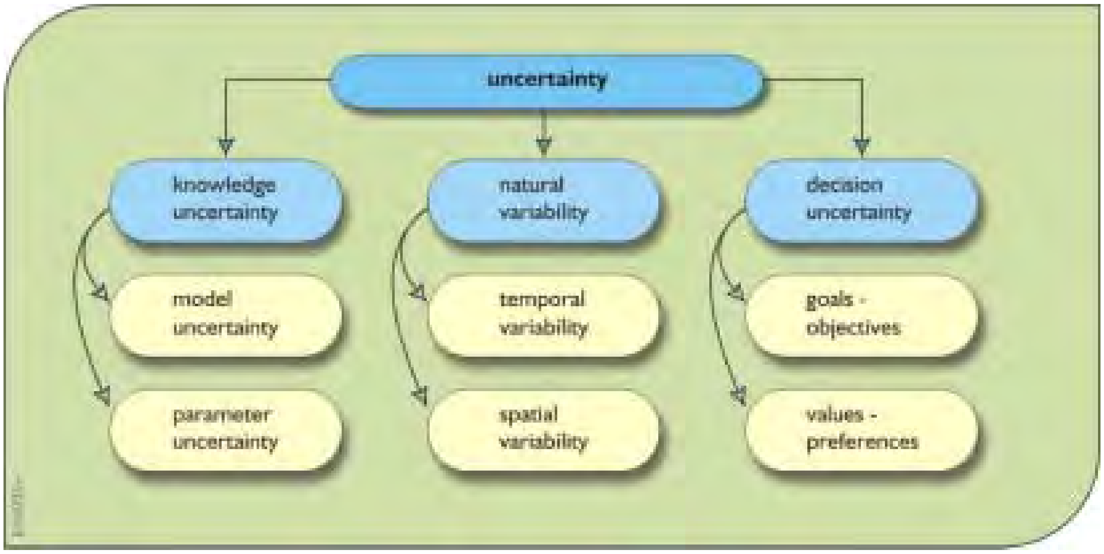


Figure 3. One way of classifying types of uncertainty.

Figure 3 illustrates these different types of uncertainty. For example, the rainfall measured at a weather station within a particular model grid cell may be used as an input value for that cell, but the rainfall may actually vary at different points within that cell and its mean value will vary across the landscape. Knowledge uncertainty can be reduced through further measurement and/or research. Natural variability is a property of the natural system, and is usually not reducible at the scale being used. Decision uncertainty is simply an acknowledgement that we cannot predict ahead of time just what decisions individuals and organizations will make, or even just what particular set of goals or objectives will be considered and the relative importance of each.

Rather than contrasting 'knowledge' uncertainty vs. natural variability vs. decision uncertainty, one can classify uncertainty in another way based on specific sources of uncertainty, such as those listed below, and address ways of identifying and dealing with each source of uncertainty.

Informational Uncertainties:

- imprecision in specifying the boundary and initial conditions that impact the output variable values
- imprecision in measuring observed output variable values

Model Uncertainties:

- uncertain model structure and parameter values
- variability of observed input and output values over a region smaller than the spatial scale of the model
- variability of observed model input and output values within a time smaller than the temporal scale of the model. (e.g., rainfall and depths and flows within a day)
- errors in linking models of different spatial and temporal scales

Numerical Errors:

- errors in the model solution algorithm

3.1 Natural variability

The main source of hydrologic model output value variability is the natural variability in hydrological and meteorological input series. Periods of normal precipitation and temperature can be interrupted by periods of extended drought and intense meteorological events such as hurricanes and tornadoes. There is no reason to think such events will not continue to occur and become even more frequent and extreme. Research has demonstrated that climate has been variable in the past and concerns about anthropogenic activities that may increase that variability increase each year. Sensitivity analysis can help assess the affect of errors in predictions if those predictions are based only on past records of historical time-series data describing precipitation, temperature and other exogenous forces across and on the border of the regions being studied.

Time series input data are often actual, or at least based on, historical data. The time-series values typically describe historical conditions including droughts and wet periods. What is distinctive about natural uncertainty, as opposed to errors and uncertainty due to modeling limitations, is that natural variability in meteorological forces cannot be reduced by improving the model's structure, increasing the resolution of the simulation, or by better calibration of model parameters.

Errors result if meteorological values are not measured or recorded accurately, or if mistakes are made in the generation of computer data files. Furthermore, there is no assurance the statistical properties of historical data will accurately represent the statistical properties of future data. Actual future precipitation and temperature scenarios will be different from those in the past, and this difference in many cases may have a larger affect than the uncertainty due to incorrect parameter values. However, the affects of uncertainties in the parameter values used in stochastic generation models are often much more significant than the affects of using different stochastic generation models (Stedinger and Taylor, 1982).

While variability of model output is a direct result of variability of model input (e.g., hydrologic and meteorological data), the extent of the variability, and the lower and upper limits of that variability, may also be affected by errors in the inputs, the values of parameters, initial boundary conditions, model structure, processes and solution algorithms.

Figure 4 illustrates the distinction between the variability of a system performance indicator due to input data variability, and the extended range of variability due to the total uncertainty associated with any combination of the causes listed in the previous section. This extended range is what is of interest to water resource planners and managers.

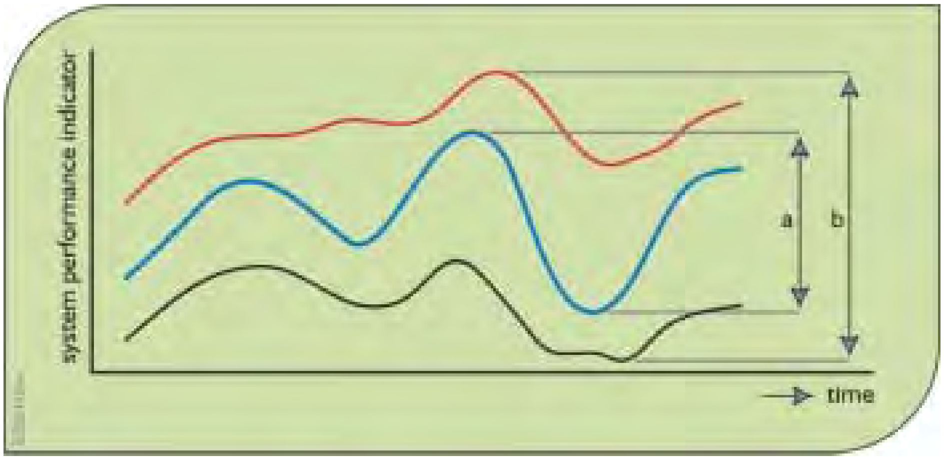


Figure 4. Time-series of model output or system performance showing variability over time. Range "a" results from the natural variability of input data over time. The extended range "b" results from the variability of natural input data as well as from imprecision in input data measurement, parameter value estimation, model structure and errors in model solution algorithms. The extent of this range will depend on the confidence level associated with that range.

What can occur in practice is a time-series of system performance indicator values that can range anywhere within or even outside the extended range, assuming the confidence level of that extended range is less than 100%. The confidence one can have that some future value of a time series will be within a given range is dependent on two factors. The first is the number of measurements used to compute the confidence limits. The second is on the assumption that those measurements are representative of - come from the same statistical or stochastic process yielding - future measurements. Figure 5 illustrates this point. Note that the time series may even contain values outside the range "b" defined in Figure 4 if the confidence level of that range is less than 100%. Confidence intervals associated with less than 100% certainty will not include every possible value that might occur.

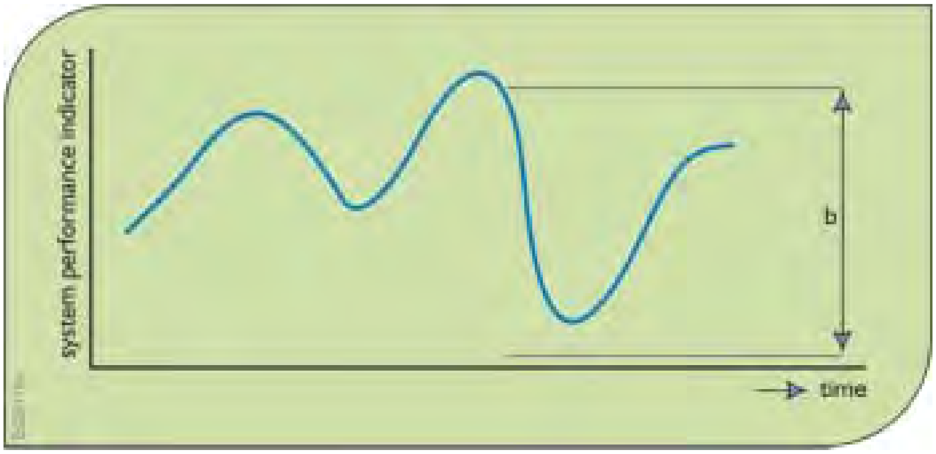


Figure 5. Typical time series of model output or system performance indicator values that are the result of input data variability and possible imprecision in input data measurement, parameter value estimation, model structure and errors in model solution algorithms.

3.2 Knowledge uncertainty

Referring to Figure 3, knowledge uncertainty includes model structure and parameter value uncertainties. First we consider parameter value uncertainty including boundary condition uncertainty, and then model and solution algorithm uncertainty.

3.2.1 Parameter value uncertainty

A possible source of uncertainty in model output results from uncertain estimates of various model parameter values. If the model calibration procedure were repeated using different data sets, different parameter values would result. Those values would yield different simulated system behavior, and thus different predictions. We can call this parameter uncertainty in the predictions because it is caused by imprecise parameter values. If such parameter value imprecision were eliminated, then the prediction would always be the same and so the parameter value uncertainty in the predictions would be zero. But this does not mean that predictions would be perfectly accurate.

In addition to parameter value imprecision, uncertainty in model output can result from imprecise specification of boundary conditions. These boundary conditions can be either fixed or variable. However, because they are not being computed based on the state of the system, their values can be uncertain. These uncertainties can affect the model output, especially in the vicinity of the boundary, in each time step of the simulation.

3.2.2 Model structural and computational errors

Uncertainty in model output can also result from errors in the model structure compared to the real system, and approximations made by numerical methods employed in the simulation. No matter how good our parameter value estimates, our models are not perfect and there is a residual model error. Increasing model complexity to more closely represent the complexity of the real system may not only add to the cost of data collection, but also introduce even more parameters, and thus even more potential sources of error in model output. It is not an easy task to judge the appropriate level of model complexity, and to estimate the resulting levels of uncertainty associated with various assumptions regarding model structure and solution methods. Kuczera (1988) provides an example of a conceptual hydrologic modeling exercise with daily time steps where model uncertainty dominated parameter value uncertainty.

3.3 Decision uncertainty

Uncertainty in model predictions can result from unanticipated changes in what is being modeled. These can include changes in nature, human goals, interests, activities, demands, and impacts. An example of this is the deviation from standard or published operating policies by operators of infrastructure such as canal gates, pumps, and reservoirs in the field, as compared to what is specified in documents and incorporated into the water systems models. Comparing field data with model data for model calibration may yield incorrect calibrations if operating policies actually implemented in the field differ significantly from those built into the models. What do operators do in times of stress? And can anyone identify a place where deviations from published policies do not occur?

What humans will want to achieve in the future may not be the same as what they want today. Predictions of what people will want in the future are clearly sources of uncertainty. A perfect example of this is in the very flat Greater Everglades region of south Florida in the US. Fifty years ago folks wanted the swampy region protected from floods and drained for agricultural and urban development. Today many want just the opposite at least where there are no human settlements. They want to return to a more natural hydrologic system with more wetlands and unobstructed flows, but now for ecological restoration objectives that were not a major concern or much appreciated some half a century ago. Once the mosquitoes return and if the sea level continues to rise, future populations who live there may want more flood control and drainage again. Who knows? Complex changing social and economic processes influence human activities and their demands for water resources and environmental amenities over time. Some of these processes reflect changes in local concerns, interests and activities, but population migration and many economic activities and social attitudes can also reflect changing national and international trends.

Sensitivity scenarios that include human activities can help define the affects of those activities within an area. It is important that careful attention go into the development of these alternative scenarios so that they realistically capture the forces or stresses that the system may face. The history of systems studies are full of examples where the issues studied were rapidly overwhelmed by much larger social forces resulting from, for example, the relocation of major economic activities, an oil embargo, changes in national demand for natural resources, economic recession, sea-level rise, an act of terrorism, or even war. One thing is sure; the future will be different than the past, and no one is certain just how.

3.3.1 Surprises

Water resource managers may also want to consider how vulnerable a system is to undesirable environmental surprises. What havoc might an introduced species like the zebra mussel invading the Great Lakes of North America have in a particular watershed? Might some introduced disease suddenly threaten key plant or animal species? Might management plans have to be restructured to address the survival of some species such as salmon in the Rhine River in Europe or in the Columbia River in North America? Such uncertainties are hard to anticipate when by their nature they are truly surprises. But surprises should be expected. Hence system flexibility and adaptability should be sought to deal with changing management demands, objectives, and constraints.

4. Sensitivity and uncertainty analyses

An uncertainty analysis is not the same as a sensitivity analysis. An uncertainty analysis attempts to describe the entire set of possible outcomes, together with their associated probabilities of occurrence. A sensitivity analysis attempts to determine the relative change in model output values given modest changes in model input values. A sensitivity analysis thus measures the change in the model output in a localized region of the space of inputs. However, one can often use the same set of model runs for both uncertainty analyses and sensitivity analyses. It is possible to carry out a sensitivity analysis of the model around a current solution and then use it as part of a first order uncertainty analysis.

This discussion begins by focusing on some methods of uncertainty analysis. Then various ways of performing and displaying sensitivity analyses are reviewed.

4.1 Uncertainty Analyses

Recall that uncertainty involves the notion of randomness. If a value of a performance indicator or performance measure, or in fact any variable, like the phosphorus concentration or the depth of water at a particular location varies and this variation over space and time cannot be predicted with certainty, it is called a random variable. One cannot say with certainty what the value of a random variable will be but only the likelihood or probability that it will be within some specified range of values. The probabilities of observing particular ranges of values of a random variable are described or defined by a probability distribution. There are many types of distributions and each can be expressed in several ways as presented in Chapter III.

Suppose the random variable is *X*. If the observed values of this random variable can be only discrete values, the probability distribution of *X* can be expressed as a histogram, as shown in Figure 6a. The sum of the probabilities for all possible outcomes must equal 1. If the random variable is a continuous variable that can assume any real value over a range of values, the probability distribution of *X* can be expressed as a continuous distribution as shown in Figure 6b. The shaded area under the density function for the continuous distribution is 1. The area between two values of the continuous random variable, such as between u and v in Figure 6c, represents the probability that the observed value *x* of the random variable value *X* will be within that range of values.

The probability distribution, $P_X(x)$ shown in Figure 6 (a) is called a probability mass function. The probability distributions shown in Figure 6 (b and c) are called a probability density functions (pdf) and are denoted by $f_X(x)$. The subscript *X* of P_X and f_X represents the random variable, and the variable *x* is some value of that random variable *X*.

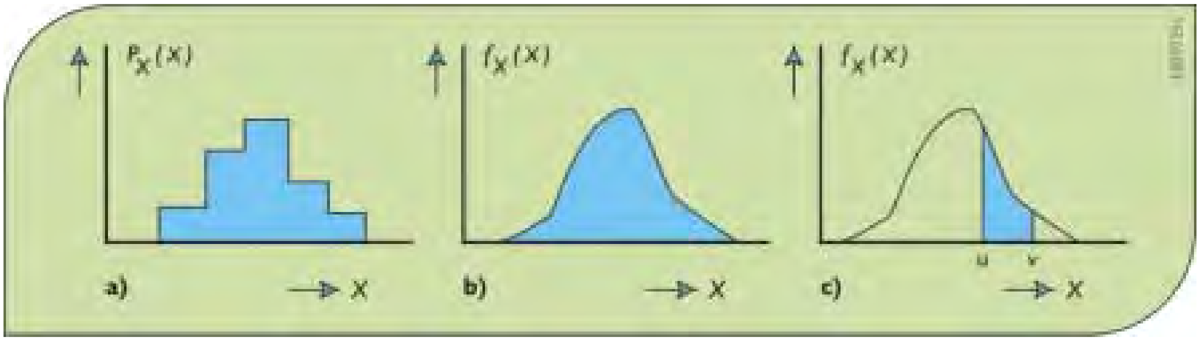


Figure 6. Probability distributions for a discrete or continuous random variable *X*. The area under the distributions (shaded areas in a and b) is 1, and the shaded area in c is the probability that the observed value x of the random variable *X* will be between u and v.

Uncertainty analyses involve identifying characteristics of various probability distributions of model input and output variables, and subsequently functions of those random output variables that are performance indicators or measures. Often targets associated with these indicators or measures are themselves uncertain.

A complete uncertainty analysis would involve a comprehensive identification of all sources of uncertainty that contribute to the joint probability distributions of each input or output variable. Assume such analyses were performed for two alternative project plans, *A* and *B*, and that the resulting probability density distributions for a specified performance measure were as shown in Figure 7. Figure 7 also identifies the costs of these two projects. The introduction of two performance criteria, cost and probability of exceeding a performance measure target (e.g., a pollutant concentration standard) introduces a conflict where a tradeoff must be made.

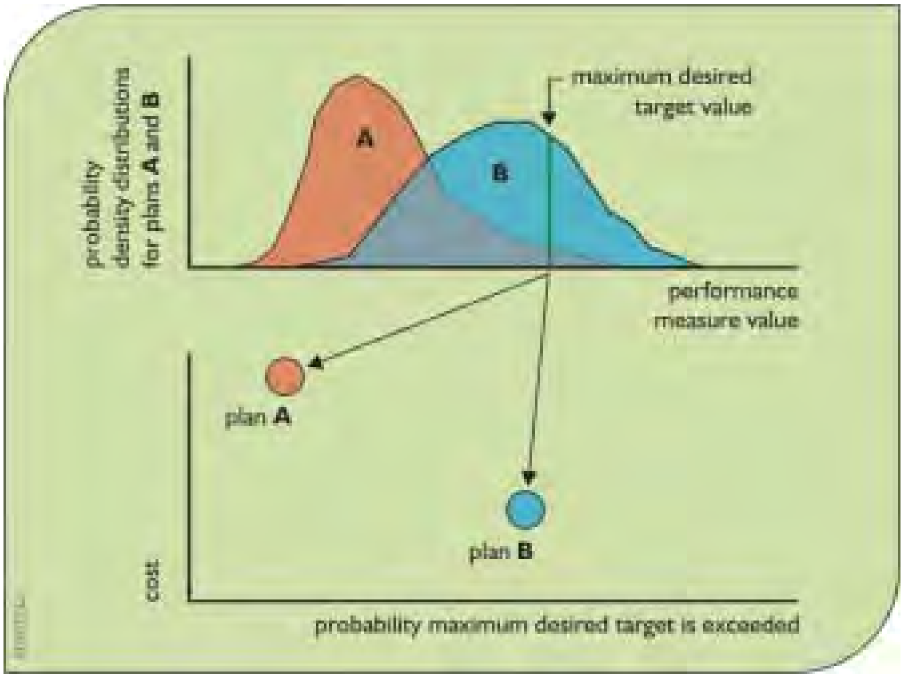


Figure 7. Tradeoffs involving cost and the probability that a maximum desired target value will be exceeded. In this illustration we want the lowest cost (*B* is best) and the lowest probability of exceedance (*A* is best).

4.1.1 Model and model parameter uncertainties

Consider a situation as shown in Figure 8, in which for a specific set of model inputs, the model outputs differ from the observed values, and for those model inputs, the observed values are always the same. Here nothing randomly occurs. The model parameter values or model structure needs to be changed. This is typically done in a model calibration process.

Given specific inputs, the outputs of deterministic models are always going to be the same each time those inputs are simulated. If for specified inputs to any simulation model the predicted output does not agree with the observed value, as shown in Figure 8, this could result from imprecision in the measurement of observed data. It could also result from imprecision in the model parameter values, the model structure, or the algorithm used to solve the model.

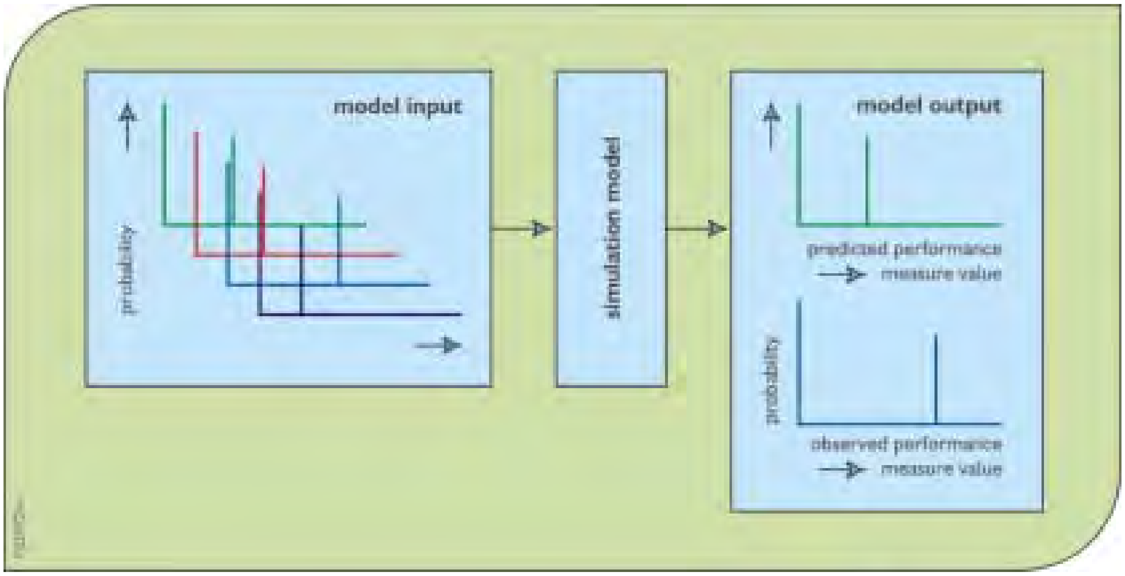


Figure 8. A deterministic system and a simulation model of that system needing calibration or modification in its structure. There is no randomness, only parameter value or model structure errors to be identified and corrected.

Next consider the same deterministic simulation model but now assume at least some of the inputs are random, i.e., not predictable, as may be case when random outputs of one model are used as inputs into another model. Random inputs will yield random outputs. The model input and output values can be described by probability distributions. If the uncertainty in the output is due only to the uncertainty in the input, the situation is similar to that shown in Figure 8. If the distribution of performance measure output values does not fit or is not identical to the distribution of observed performance measure values, then calibration of model parameter values or modification of model structure may be needed.

If a model calibration or 'identification' exercise finds the 'best' values of the parameters to be outside reasonable ranges of values based on scientific knowledge, then the model structure or algorithm might be in error. Assuming the algorithms used to solve the models are correct and observed measurements of system performance vary for the same model inputs, as shown in Figure 9, it can be assumed that the model structure does not capture all the processes that are taking place that impact the value of the performance measures. This is often the case when relatively simple and low-resolution models are used to estimate the hydrological and ecological impacts of water and land management policies. However, even large and complex models can fail to include or adequately describe important phenomena.

In the presence of informational uncertainties there may be considerable uncertainty about the values of the "best" parameters during calibration. This problem becomes even more pronounced with increases in model complexity.

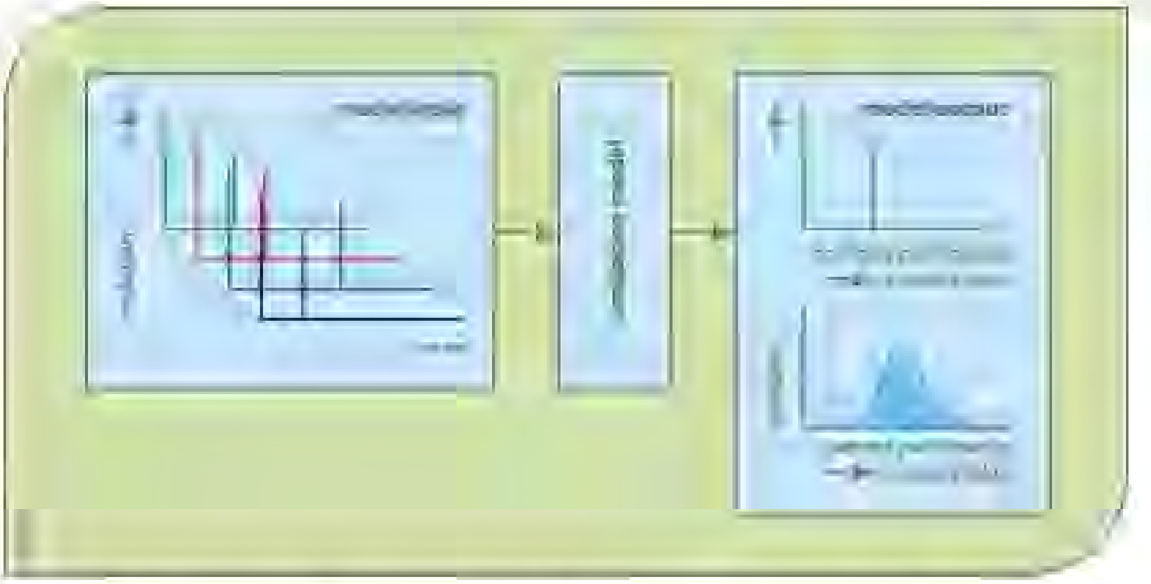


Figure A deterministic simulation model of a 'random or stochastic' system. To produce the variability in the model output that is observed in the real system, even given the same input values, the model's parameter values may need to vary over distributions of values and/or the model structure may need modification along with additional model inputs.

An example: Consider the prediction of a pollutant concentration at some site downstream of a pollutant discharge site. Given a streamflow Q (in units of 1000 m^3/day), the distance between the discharge site and the monitoring site, $\overline{X}$ (m), the pollutant decay rate constant k (day^{-1}), and the pollutant discharge W (Kg/day), we can use the following simplified model to predict the concentration of the pollutant C (g/m^3 = mg/l) at the downstream monitoring site:

$$C = (W/Q)\ \exp\{-k(X/U)\}$$

In the above equation assume the velocity U (m/day) is a known function of the streamflow Q.

In this case the observed value of the pollutant concentration C may differ from the computed value of C even for the same inputs of W, Q, k, X, and U. Furthermore, this difference varies in different time periods. This apparent variability, as illustrated in Figure 9, can be simulated using the same model but by assuming a distribution of values for the decay rate constant k. Alternatively the model structure can be modified to include the impact of streamflow temperature T on the prediction of C.

$$C = (W/Q)\ \exp\{-k\theta^{T-2}(X/U)\}$$

Now there are two model parameters, the decay rate constant k and the dimensionless temperature correction factor □and an additional model input, the streamflow temperature, T. It could be that the variation in streamflow temperature was the sole cause of the first equation's 'uncertainty' and that the assumed parameter distribution of k was simply the result of the distribution of streamflow temperatures on the term $k\theta^{T-20}$.

If the output were still random given constant values of all the inputs, then another source of uncertainty exists. This uncertainty might be due to additional random loadings of the pollutant, possibly from non-point sources. Once again the model could be modified to include these additional loadings if they are knowable. Assuming these additional loadings are not known, a new random parameter could be added to the input variable W or to the right hand side of the equations above that would attempt to capture the impact on C of these additional loadings. A potential problem, however, might be the likely correlation between those additional loadings and the streamflow Q.

While adding model detail removed some 'uncertainty' in the above example, increasing model complexity will not always eliminate or reduce uncertainty in model output. Adding complexity is generally not a good idea when the increased complexity is based on processes whose parameters are difficult to measure, the right equations are not known at the scale of application, or the amount of data for calibration is small compared to the number of parameters.

Even if more detailed models requiring more input data and more parameter values were to be developed, the likelihood of capturing all the processes occurring in a complex system is small. Hence those involved will have to make decisions taking this uncertainty into account. Imprecision will always exist due to less than a complete understanding of the system and the hydrologic processes being modeled. A number of studies have addressed model simplification, but only in some simple cases have statisticians been able to identify just how one might minimize modeling related errors in model output values.

The problem of determining the "optimal" level of modeling detail is particularly important when simulating the hydrologic events at many sites over large areas. Perhaps the best approach for these simulations is to establish confidence levels for alternative sets of models and then statistically compare simulation results. But even this is not a trivial or costless task. Increases in the temporal or spatial resolution typically require considerable data collection and/or processing, model recalibrations, and possibly the solution of stability problems resulting from the numerical methods used in the models. Obtaining and implementing alternative hydrologic simulation models will typically involve considerable investments of money and time for data preparation and model calibration.

What is needed is a way to predict the variability evident in the system shown in Figure 9. Instead of a fixed output vector for each fixed input vector, a distribution of outputs are needed for each performance measure based on fixed inputs (Figure 9) or a distribution of inputs (Figure 10.). Furthermore the model output distribution for each performance measure should 'match' as well as possible the observed distribution of that performance measure.

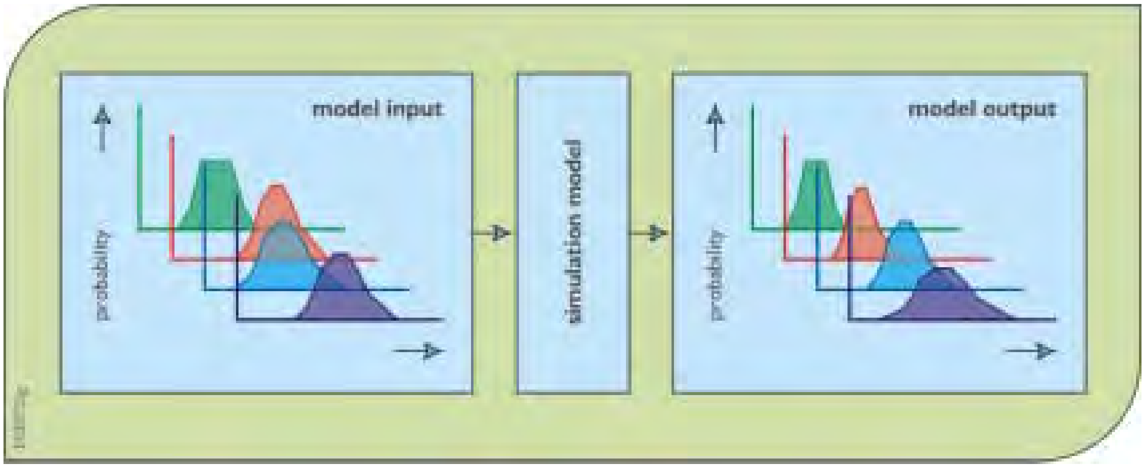


Figure 10. Simulating variable inputs to obtain probability distributions of predicted performance indices that match the probability distributions of observed performance values.

4.1.2 What uncertainty analysis can provide

An uncertainty analysis takes a set of randomly chosen input values (that can include parameter values), passes them through a model (or transfer function) to obtain the distributions (or statistical measures of the distributions) of the resulting outputs. As illustrated in Figure 11, the output distributions can be used to

- Describe the range of potential outputs of the system at some probability level.
- Estimate the probability that the output will exceed a specific threshold or performance measure target value.

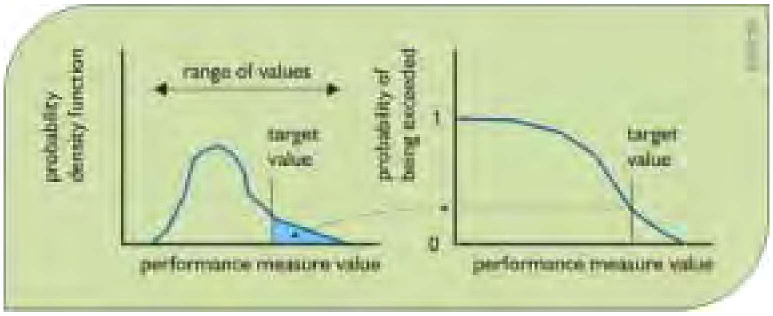


Figure 11. The distribution of performance measures defines range of potential values and the likelihood that a specified target value will be exceeded. The shaded area under the density function on the left represents the probability that the target value will be exceeded. This probability is shown in the probability of exceedance plot on the right.

Common uses for uncertainty analyses are to make general inferences, such as the following:

- Estimating the mean and standard deviation of the outputs.
- Estimating the probability the performance measure will exceed a specific threshold.
- Putting a reliability level on a function of the outputs, e.g., the range of function values that is likely to occur with some probability.
- Describing the likelihood of different potential outputs of the system.

Implicit in any uncertainty analysis are the assumptions that statistical distributions for the input values are correct and that the model is a sufficiently realistic description of the processes taking place in the system. Neither of these assumptions is likely to be entirely correct.

4.2 Sensitivity analyses

"Sensitivity analysis" is aimed at describing how much model output values are affected by changes in model input values. It is the investigation of the importance of imprecision or uncertainty in model inputs in a decision making or modeling process. The exact character of sensitivity analysis depends upon the particular context and the questions of concern. Sensitivity studies can provide a general assessment of model precision when used to assess system performance for alternative scenarios, as well as detailed information addressing the relative significance of errors in various parameters. As a result, sensitivity results should be of interest to the general public, federal and state management agencies, local watershed planners and managers, model users, and model developers.

Clearly, upper level management and the public may be interested in more general statements of model precision, and should be provided such information along with model predictions. On the other hand, detailed studies addressing the significance and interactions among individual parameters would likely be meaningful to model developers and some model users. They can use such data to interpret model results and to identify where efforts to improve models and their input values should be directed.

Initial sensitivity analysis studies could focus on two products:
(1) detailed results to guide research and assist model development efforts, and
(2) calculation of general descriptions of uncertainty associated with model predictions so that policy decisions can reflect both the modeling efforts best prediction of system performance and the precision of such predictions.

In the first case, knowing the relative uncertainty in model projections due to possible errors in different sets of parameters and input data should assist in efforts to improve the precision of model projections. This knowledge should also contribute to a better understanding of the relationships between model assumptions, parameters, data and model predictions.

For the second case, knowing the relative precision associated with model predictions should have a significant effect on policy development. For example, the analysis may show that, given data inadequacies, there are very large error bands associated with some model variables. When such large uncertainties exist, predictions should be used with appropriate skepticism.

Incremental strategies should be explored along with monitoring so that greater experience can accumulate to resolve some of those uncertainties.

Sensitivity analysis features are available in many linear and nonlinear programming (optimization) packages. They identify the changes in the values of the objective function and unknown decision variables given a change in the model input values, and a change in levels set for various constraints (Chapter V). Thus sensitivity analysis addresses the change in "optimal" system performance associated with changes in various parameter values, and also how "optimal" decisions would change with changes in resource constraint levels, or target output requirements. This kind of sensitivity analysis provides estimates of how much another unit of resource would be worth, or what "cost" a proposed change in a constraint places on the optimal solution. This information is of value to those making design decisions.

Various techniques have been developed to determine how sensitive model outputs are to changes in model inputs. Most approaches examine the affects of changes in a single parameter value or input variable assuming no changes in all the other inputs. Sensitivity analyses can be extended to examine the combined effects of multiple sources of error, as well.

Changes in particular model input values can affect model output values in different ways. It is generally true that only a relatively few input variables dominate or substantially influence the values of a particular output variable or performance indicator at a particular location and time. If the range of uncertainty of only some of the output data is of interest, then undoubtedly only those input data that significantly impact on the values of those output data need be included in the sensitivity analysis.

If input data estimates are based on repeated measurements, a frequency distribution can be estimated that characterizes natural variability. The shorter the record of measurements, the greater will be the uncertainty regarding the long-term statistical characteristics of that variability. If obtaining a sufficient number of replicate measurements is not possible, subjective estimates of input data ranges and probability distributions are often made. Using a mixture of subjective estimates and actual measurements does not affect the application of various sensitivity analysis methods that can use these sets or distributions of input values, but it may affect the conclusions that can be drawn from the results of these analyses.

It would be nice to have available accurate and easy-to-use analytical methods for relating errors in input data to errors in model outputs, and to errors in system performance indicator values that are derived from model output. Such analytical methods do not exist for complex simulation models. However methods based on simplifying assumptions and approximations can be used to yield useful sensitivity information. Some of these are reviewed in the remainder of this chapter.

4.2.1 Sensitivity coefficients

One measure of sensitivity is the sensitivity coefficient. This is the derivative of a model output variable with respect to an input variable or parameter. A number of sensitivity analysis methods use these coefficients. First-order and approximate first-order sensitivity analyses are two such methods that will be discussed later. The difficulty of

1. obtaining the derivatives for many models,
2. needing to assume mathematical (usually linear) relationships when obtaining estimates of derivatives by making small changes of input data values near their nominal or most likely values, and
3. having large variances associated with most hydrologic process models have motivated the replacement of analytical methods by numerical and statistical approaches to sensitivity analysis.

Implicit in any sensitivity analysis are the assumptions that statistical distributions for the input values are correct and that the model is a sufficiently realistic description of the processes taking place in the system. Neither of these assumptions is likely to be entirely correct.

The importance of the assumption that the statistical distributions for the input values are correct is easy to check by using different distributions for the input parameters. If the outputs vary significantly, then the output is sensitive to the specification of the input distributions and hence they should be defined with care. A relatively simple deterministic sensitivity analysis can be of value here (Benaman, 2002). A sensitivity coefficient can be used to measure the magnitude of change in an output variable Q per unit change in the magnitude of an input parameter value P from its base value P_o. Let SI_{PQ} be the sensitivity index for an output variable Q with respect to a change ΔP in the value of the input variable P from its base value P_o. Noting that the value of the output $Q(P)$ is a function of P, the sensitivity index could be defined as

$$SI_{PQ} = [\ Q(P_o + \Delta P) - \ Q(P_o - \Delta P)\ ] / 2\ \Delta P \qquad (1)$$

Other sensitivity indices could be defined (McCuen 1973). Letting the index i represent a decrease and j represent an increase in the parameter value from its base value P_o, the sensitivity index SI_{PQ} for parameter P and output variable Q is could be defined as

$$SI_{PQ} = \{\ |\ (Q_o - Q_i) / (P_o - P_i\ )\ | + \ |\ (Q_o - Q_j) / (P_o - P_j\ )\ |\ \} / 2 \qquad (2)$$

or

$$SI_{PQ} = \max\ \{\ |\ (Q_o - Q_i) / (P_o - P_i\ )\ |\ ,\ |\ (Q_o - Q_j) / (P_o - P_j\ )\ |\ \} \qquad (3)$$

A dimensionless expression of sensitivity is the elasticity index, EI_{PQ}, that measures the relative change in output Q for a relative change in input P could be defined as

$$EI_{PQ} = [P_o / Q(P_o)]\ SI_{PQ} \qquad (4)$$

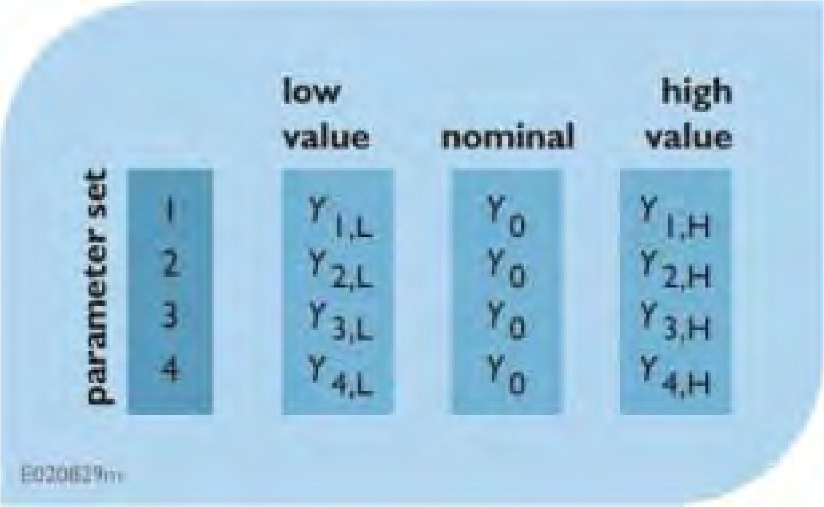
4.2.2 A simple deterministic sensitivity analysis procedure

This deterministic sensitivity analysis approach is very similar those most often employed in the engineering economics literature. It is based on the idea of varying one uncertain parameter value, or set of parameter values, at a time. The ideas are applied to a water quality example to illustrate their use.

The output variable of interest can be any performance measure or indicator. Thus one does not know if more or less of a given variable is better or worse. Perhaps too much and/or too little is undesirable. The key idea is that, whether employing physical measures or economic metrics of performance, various parameters (or sets of associated parameters) are assigned high and low values. Such ranges may reflect either the differences between the minimum and maximum values for each parameter, the 5 and 95 percentiles of a parameters distribution, or points corresponding to some other criteria. The system model is then run with the various alternatives, one at a time, to evaluate the impact of those errors in various sets of parameter values on the output variable.

Table 1 illustrates the character of the results that one would obtain. Here Y_0 is the nominal value of the model output when all parameters assume the estimated best values, and $Y_{i,L}$ and $Y_{i,H}$ are the values obtained by increasing or decreasing the values of the i^th^ set of parameters.

Table 1. Sensitivity of model output *Y* to possible errors in four parameter sets containing a single parameter or a group of parameters that vary together.



parameter set	low value	nominal	high value
1	$Y_{1,L}$	Y_0	$Y_{1,H}$
2	$Y_{2,L}$	Y_0	$Y_{2,H}$
3	$Y_{3,L}$	Y_0	$Y_{3,H}$
4	$Y_{4,L}$	Y_0	$Y_{4,H}$

A simple water quality example is employed to illustrate this deterministic approach to sensitivity analysis. The analysis techniques illustrated here are just as applicable to complex models. The primary difference is that more work would be required to evaluate the various alternatives with a more complex model, and the model responses might be more complicated.

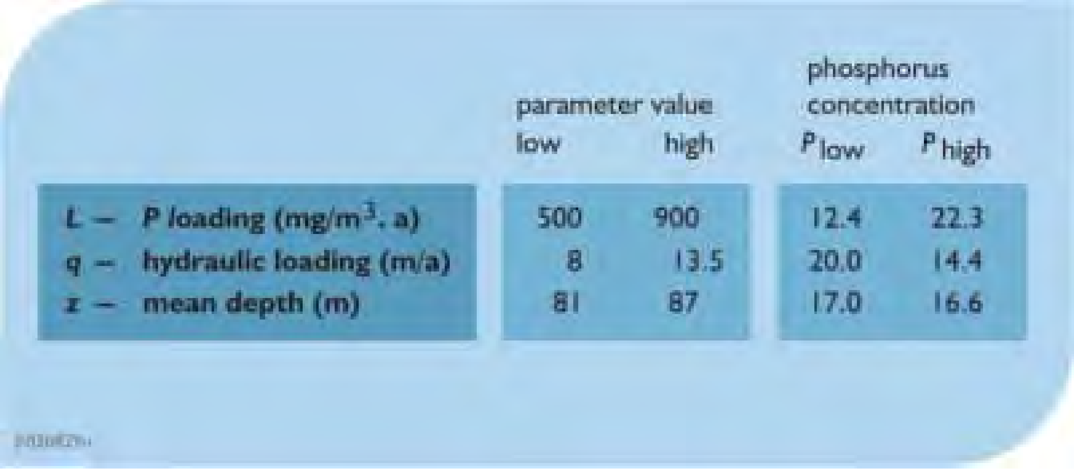
The simple water quality model is provided by Vollenweider's empirical relationship for the average phosphorus concentration in lakes (Vollenweider, 1976). He found that the phosphorus concentration, P (mg/m^3), is a function of the annual phosphorus loading rate, L (mg/m^2•a), the annual hydraulic loading, q (m/a or more exactly m^3/m^2•a), and the mean water depth, z (m).

$$P = (L/q) / [1 + (z/q)^{0.5}] \qquad (5)$$

L/q and P have the same units; the denominator is an empirical factor that compensates for nutrient recycling and elimination within the aquatic lake environment.

Data for Lake Ontario in North America would suggest that reasonable values of the parameters are L = 680 mg/m^3; q = 10.6 m/a; and z = 84 m, yielding P = 16.8 mg/m^3. Values of phosphorus concentrations less than 10 mg/m^3 are considered oligotrophic, whereas values greater than 20 mg/m^3 generally correspond to eutrophic conditions. Reasonable ranges reflecting possible errors in the three parameters yield the values in Table 2.

Table 2. Sensitivity of estimates of phosphorus concentration (mg/m^3) to model parameter values. The two right most values in each row correspond to the Low and High values of the parameter, respectively



	parameter value		phosphorus concentration	
	low	high	P_{low}	P_{high}
L – P loading (mg/m^3. a)	500	900	12.4	22.3
q – hydraulic loading (m/a)	8	13.5	20.0	14.4
z – mean depth (m)	81	87	17.0	16.6

One may want to display these results so they can be readily visualized and understood. A tornado diagram (Eschenbach, 1992) would show the lower and upper values of P obtained from variation of each parameter, with the parameter with the widest limits displayed on top, and the parameter having smallest limits on the bottom. Tornado diagrams (Figure 12) are easy to construct and can include a large number of parameters without becoming crowded.

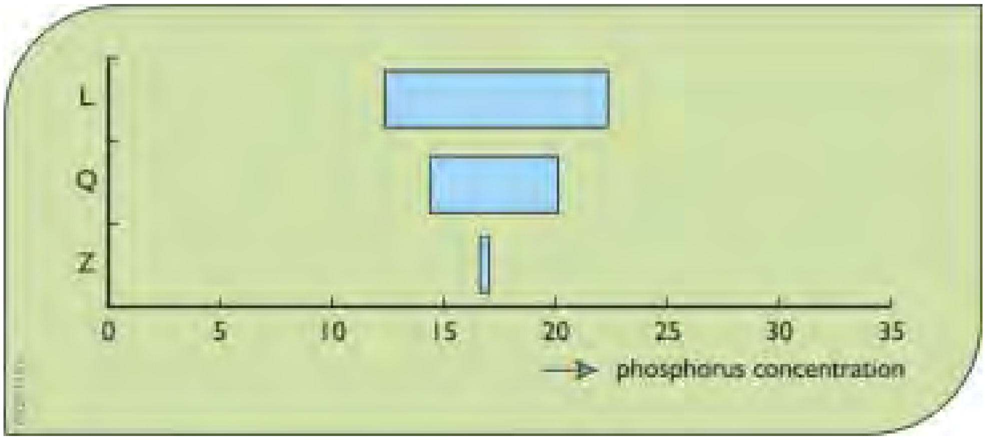


Figure 12. A Tornado diagram showing the range of the output variable representing phosphorus concentrations for high and low values of each of the parameter sets. Parameters are sorted so that the largest range is on top, and the smallest on the bottom.

An alternative to tornado diagrams is a Pareto chart showing the width of the uncertainty range associated with each variable, ordered from largest to smallest. A Pareto chart is illustrated in Figure 13.

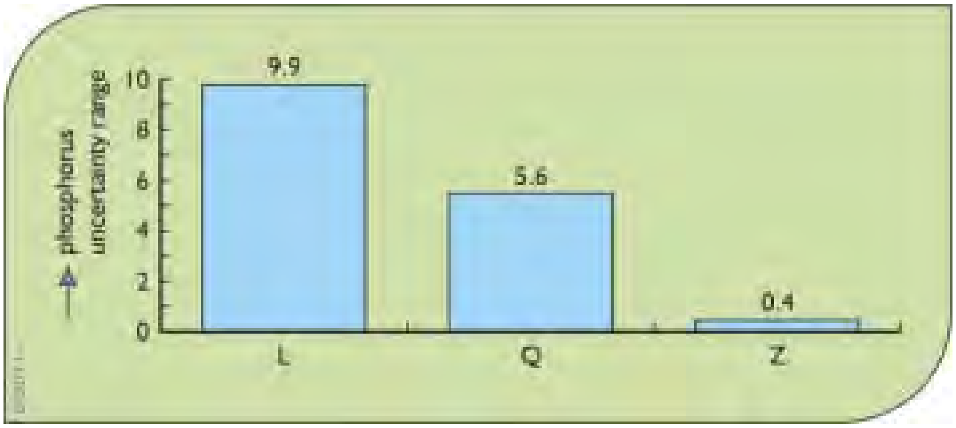


Figure 13. A Pareto Chart showing the range of the output variable representing phosphorus concentrations resulting from high and low values of each parameter set considered.

Another visual presentation is a spider plot showing the impact of uncertainty in each parameter on the variable in question, all on the same graph (Eschenback, 1992; DeGarmo, 1993, p. 401). A spider plot, Figure 14, shows the particular functional response of the output to each parameter on a common scale, so one needs a common metric to represent changes in all of the parameters. Here we use percentage change from the nominal or best values.

Spider plots are a little harder to construct than tornado diagrams, and can generally include only 4 - 5 variables without becoming crowded. However, they provide a more complete view of the relationships between each parameter and the performance measure. In particular, a spider plot reveals nonlinear relationships and the relative sensitivity of the performance measure to (percentage) changes in each variable.

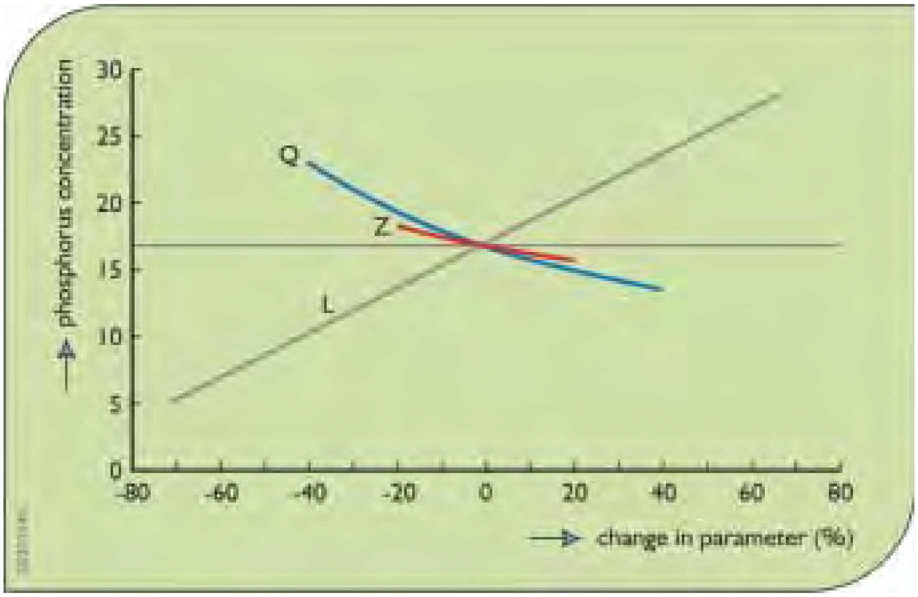


Figure 14. Spider Plot illustrates the relationships between model output describing phosphorus concentrations and variations in each of the parameter sets, expressed as a percentage deviation from their nominal values.

In the spider plot, the linear relationship between *P* and *L* and the gentle nonlinear relationship between *P* and *q* is illustrated. The range for *z* has been kept small given the limited uncertainty associated with that parameter.

4.2.3 Multiple errors and interactions

An important issue that should not be ignored is the impact of simultaneous errors in more than one parameter. Probabilistic methods directly address the occurrence of simultaneous errors, but the correct joint distribution needs to be employed. With simple sensitivity analysis procedures, errors in parameters are generally investigated one at a time, or in groups. The idea of considering pairs or sets of parameters is discussed here.

Groups of factors. It is often the case that reasonable error scenarios would have several parameters changing together. For this reason, the alternatives have been called parameter sets. For example, possible errors in water depth would be accompanied with corresponding variations in aquatic vegetation and chemical parameters. Likewise, alternatives related to changes in model structure might be accompanied with variations in several parameters. In other cases, there may be no causal relationship among possible errors (such as model structure versus inflows at the boundary of the modeled region), but they might still interact to effect the precision of model predictions.

Combinations. If one or more non-grouped parameters interact in significant ways, then combinations of one or more errors should be investigated. However, one immediately runs into a combinatorial problem. If each of m parameters can have 3 values (high, nominal, and low) there are 3^m combinations, as opposed to 2m + 1 if each parameter is varied separately. [For m = 5, the differences are $3^5 = 243$ versus 2(5)+1 = 11.] These numbers can be reduced by considering instead only combinations of extremes so that only $2^m + 1$ cases need be considered [$2^5 + 1 = 33$], which is a more manageable number. However, all of the parameters would be at one extreme or the other, and such situations would be very unusual.

Two factors at a time. A compromise is to consider all pairs of two parameters at a time. There are m(m-1)/2 possible pairs of m parameters. Each parameter has a high and low value. Since there are 4 combinations of high and low values for each pair, there are a total of 2m(m-1) combinations. [For m = 5 there are 40 combinations of two parameters each having two values.]

The presentation of these results could be simplified by displaying for each case only the maximum error, which would result in m(m-1)/2 cases that might be displayed in a Pareto diagram. This would allow identification of those combinations of two parameters that might yield the largest errors and thus are of most concern.

For the water quality example, if one plots the absolute value of the error for all four combinations of high (+) and low (-) values for each pair of parameters, they obtain Figure 15.

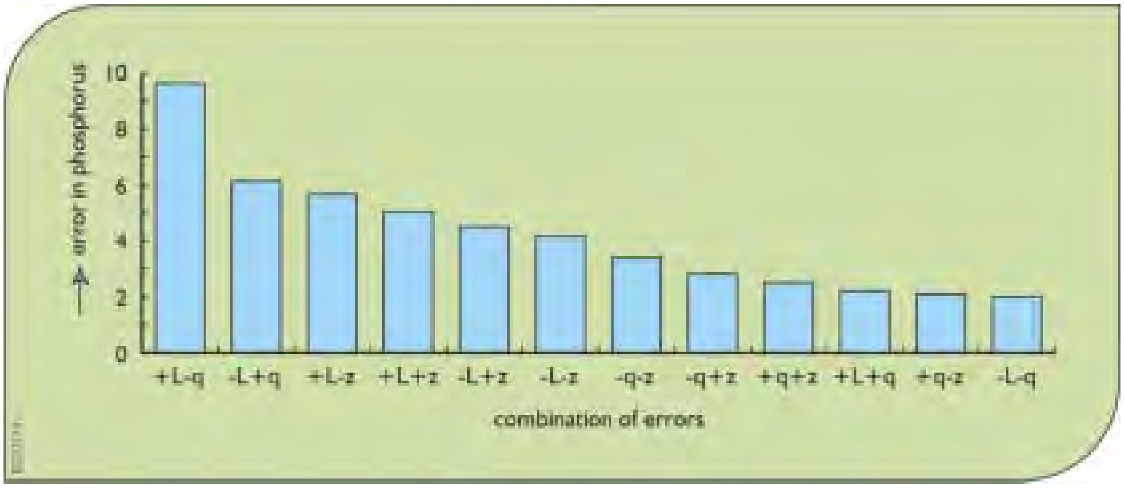


Figure 15. Pareto diagram showing errors in phosphorus concentrations for all combinations of pairs of input parameters errors. A + indicates a high value, and a - indicates a low value for indicated parameter. *L* is the phosphorus loading rate, *q* is the hydraulic loading, and *z* is the mean lake depth.

Considering only the worst error for each pair of variables yields Figure 16.

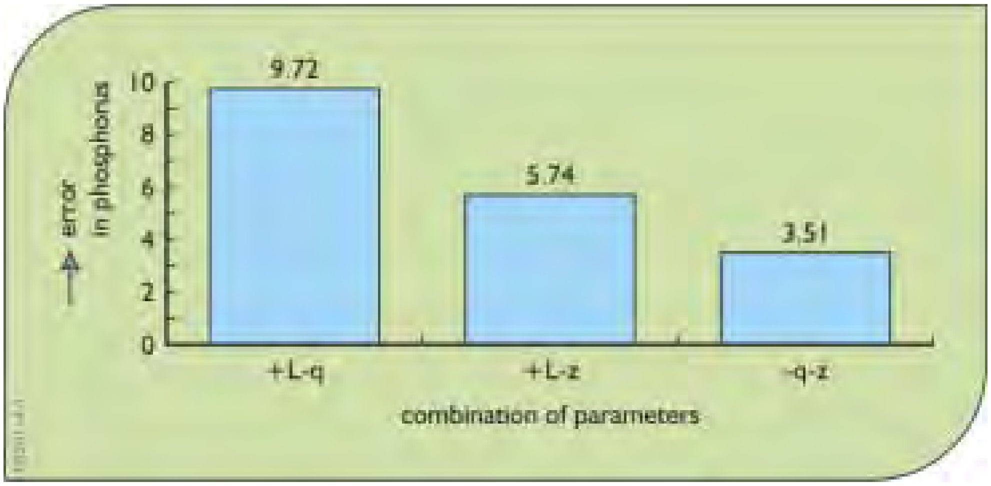


Figure 16. Pareto diagram showing worst error combinations for each pair of input parameters. A '+' indicates a high value, and a '–' indicates a low value for indicated parameter.

Here we see, as is no surprise, that the worst error results from the most unfavorable combination of *L* and *q* values. If both parameters have their most unfavorable values, the predicted phosphorus concentration would be 27 mg/m^3.

Looking for non-linearities. One might also display in a Pareto diagram the maximum error for each pair as a percentage of the sum of the absolute values of the maximum error from each parameter separately. The ratio of the joint error to the individual errors would illustrate potentially important nonlinear interactions. If the model of the system and the physical measure or economic metric were strictly linear, then the individual ratios should add to one.

4.2.4 First-order sensitivity analysis

The above deterministic analysis has trouble representing reasonable combinations of errors in several parameter sets. If the errors are independent, it is highly unlikely that any two sets would actually be at their extreme ranges at the same time. By defining probability distributions of the values of the various parameter sets, and specifying their joint distributions, a probabilistic error analysis can be conducted. In particular, for a given performance indicator, one can use multivariate linear analyses to evaluate the approximate impact on the performance indices of uncertainty in various parameters. As shown below, the impact depends upon the square of the sensitivity coefficients (partial derivatives) and the variances and covariances of the parameter sets.

For a performance indicator $I = F(Y)$, which is a function $F(\bullet)$ of model outputs Y, that are in turn a function $g(P)$ of input parameters P, one can use a multivariate Taylor series approximation of F to obtain the expected value and variance of the indicator:

$$E[I] = F(\text{ based on mean values of input parameters}) + (1/2)\{\Sigma_i\Sigma_j [\partial F^2/\partial P_i \partial P_j] \operatorname{Cov}[P_i, P_j]\} \quad (6)$$

and

$$\operatorname{Var}[I] = \Sigma_i\Sigma_j (\partial F/\partial P_i)(\partial F/\partial P_j) \operatorname{Cov}[P_i, P_j] \quad (7)$$

where $(\partial F/\partial P_i)$ are the partial derivative of the function F with respect to P_i evaluated at the mean value of the input parameters P_i, and $\partial F^2/\partial P_i \partial P_j$ are the second partial derivatives. The covariance of two random input parameters P_i and P_j is the expected value of the product of differences between the values and their means.

$$\operatorname{Cov}[P_i, P_j] = E[(P_i - E[P_i])(P_j - E[P_j])] \quad (8)$$

If all the parameters are independent of each other, and the second-order terms in the expression for the mean $E[I]$ are neglected, one obtains

$$E[I] = F(\text{ based on mean values of input parameters}) \quad (9)$$

and

$$\operatorname{Var}[I] = \Sigma_i [\partial F/\partial P_i]^2 \operatorname{Var}[P_i] \quad (10)$$

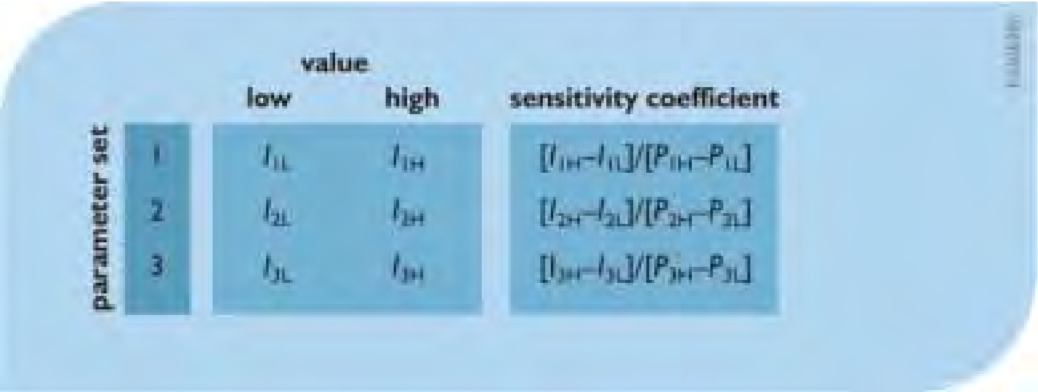
(Benjamin and Cornell, 1970). Equation 6 for $E[I]$ shows that in the presence of substantial uncertainty, the mean of the output from nonlinear systems is not simply the system output corresponding to the mean of the parameters (Gaven and Burges, 1981, p. 1523). This is true for any nonlinear function.

Of interest in the analysis of uncertainty is the approximation for the variance $\operatorname{Var}[I]$ of indicator I. In Equation 10 the contribution of P_i to the variance of I equals $\operatorname{Var}[P_i]$ times $[\partial F/\partial P_i]^2$, which are the squares of the sensitivity coefficients for indicator I with respect to each input parameter value P_i.

4.2.4.1 An example of first-order sensitivity analysis

It may appear that first-order analysis is difficult because the partial derivatives of the performance indicator I are needed with respect to the various parameters. However, reasonable approximations of these sensitivity coefficients can be obtained from the simple sensitivity analysis described in Table 3, as shown below. In that table, three different parameter sets, P_i, are defined in which one parameter of the set is at its high value, P_{iH}, and one is at its low value, P_{iL}, to produce corresponding values (called high, I_{iH}, and low, I_{iL}) of a system performance indicator I.

Table 3. Approximate parameter sensitivity coefficients.



parameter set	value low	value high	sensitivity coefficient
1	I_{1L}	I_{1H}	$[I_{1H}-I_{1L}]/[P_{1H}-P_{1L}]$
2	I_{2L}	I_{2H}	$[I_{2H}-I_{2L}]/[P_{2H}-P_{2L}]$
3	I_{3L}	I_{3H}	$[I_{3H}-I_{3L}]/[P_{3H}-P_{3L}]$

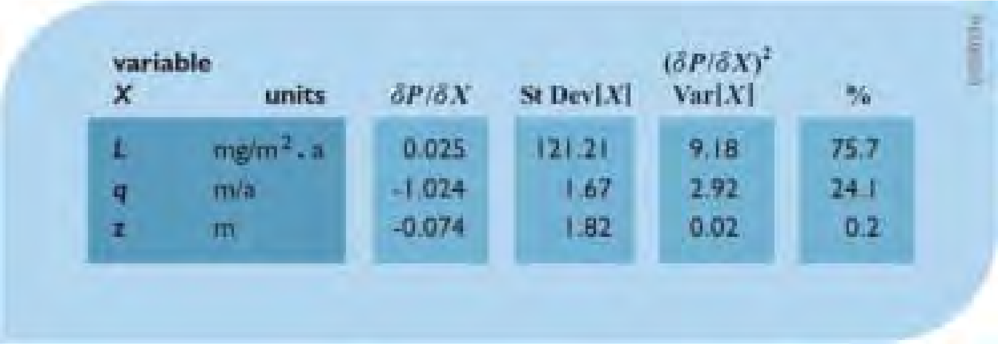
It is then necessary to estimate some representation of the variances of the various parameters with some consistent procedure. For a normal distribution, the distance between the 5 and 95 percentiles is 1.645 standard deviations on each side of the mean, or 2(1.645) = 3.3 standard deviations. Thus, if the high/low range is thought of as approximately a 5-95 percentile range for a normally distributed variate, a reasonable approximation of the variance might be

$$\mathrm{Var}[P_i] = \{\, [P_{iH}-P_{iL}]/3.3 \,\}^2. \tag{11}$$

This is all that is needed. Use of these average sensitivity coefficients is very reasonable for modeling the behavior of the system performance indicator I over the indicated ranges.

As an illustration of the method of first-order uncertainty analysis, consider the lake quality problem described above. The "system performance indicator" in this case is the model output, the phosphorus concentration P, and the input parameters, now denoted as $X = L$, q, and z. The standard deviation of each parameter is assumed to be the specified range divided by 3.3. Average sensitivity coefficients $\partial P/\partial X$ were calculated. The results are reported in the table below.

Table 4. Calculation of approximate parameter sensitivity coefficients.



variable X	units	$\delta P/\delta X$	St Dev[X]	$(\delta P/\delta X)^2$ Var[X]	%
L	$mg/m^2 \cdot a$	0.025	121.21	9.18	75.7
q	m/a	-1.024	1.67	2.92	24.1
z	m	-0.074	1.82	0.02	0.2

Assuming the parameter errors are independent:

$$\mathrm{Var}[P] = 9.18 + 2.92 + 0.02 = 12.12 \tag{12}$$

The square root of 12.12 is the standard deviation and equals 3.48. This agrees well with a Monte Carlo analysis reported below.

Note that 100*(9.18/12.12), or about 76% of the total parameter error variance in the phosphorus concentration *P* is associated in the phosphorus loading rate *L* and the remaining 24% is associated with the hydrologic loading *q*. Eliminating the uncertainty in *z* would have a negligible impact on the overall model error. Likewise, reducing the error in *q* would at best have a modest impact on the total error.

Due to these uncertainties, the estimated phosphorus concentration has a standard deviation of 3.48. Assuming the errors are normally distributed, and recalling that ± 1.645 standard deviations around the mean define a 5-95 percentile interval, the 5-95 percentile interval would be about

$$16.8 \pm 1.645\ (3.48)\ \mathrm{mg/m^3} = 16.8 \pm 5.7\ \mathrm{mg/m^3} = 11.1 \text{ to } 22.5\ \mathrm{mg/m^3}. \tag{13}$$

These error bars indicate there is substantial uncertainty associated with the phosphorus concentration *P*, primarily due to uncertainty in the loading rate *L*.

The upper bound of 22.6 $\mathrm{mg/m^3}$ is considerably less than the 27 $\mathrm{mg/m^3}$ that would be obtained if both *L* and *q* had their most unfavorable values. In a probabilistic analysis with independent errors, such a combination is highly unlikely.

4.2.4.2 Warning on accuracy.

First-order uncertainty analysis is indeed an approximate method based upon a linearization of the response function represented by the full simulation model. It may provide inaccurate estimates of the variance of the response variable for nonlinear systems with large uncertainty in the parameters. In such cases Monte Carlo simulation (discussed below and in Chapter VII) or the use of higher-order approximation may be required. Beck (1987, p. 1426) cites studies that found that Monte Carlo and first-order variances were not appreciably different, and a few studies that found specific differences. Differences are likely to arise when the distributions used for the parameters are bimodal (or otherwise unusual), or some rejection algorithm is used in the Monte Carlo analysis to exclude some parameter combinations. Such errors can result in a distortion in the ranking of predominant sources of uncertainty. However, in most cases very similar results were obtained.

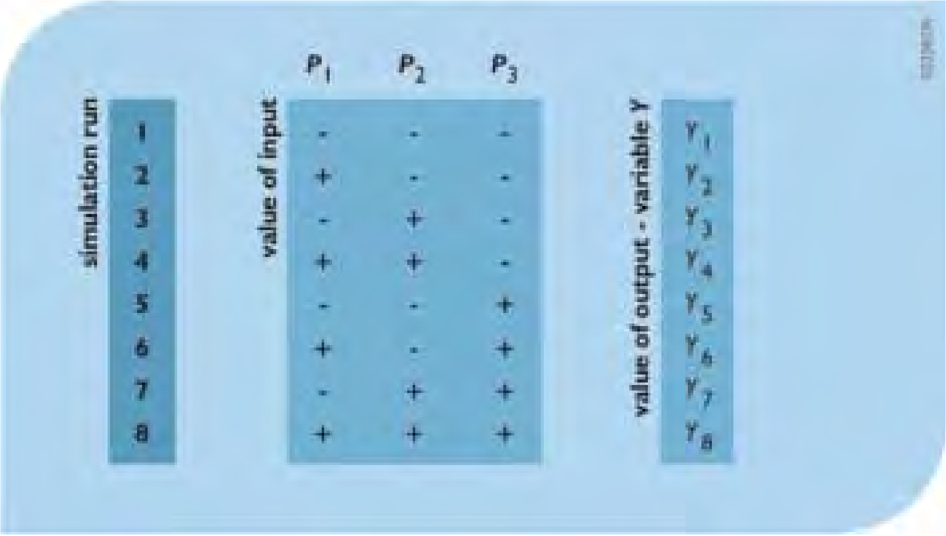
4.2.5 Fractional factorial design method

An extension of first-order sensitivity analysis would be a more complete exploration of the response surface using a careful statistical design. First consider a complete factorial design. Input data are divided into discrete "levels'. The simplest case is two levels. These two levels can be defined as a nominal value, and a high (low) value. Simulation runs are made for all combinations of parameter levels. For *n* different inputs, this would require 2^n simulation runs. Hence for a three-input variable or parameter problem, 8 runs would be required. If 4 discrete levels of each input variable or parameter were allowed to provide a more reasonable description of a continuous variable, the three-input data problem would require 4^3 or 64 simulation runs. Clearly this is not a useful tool for large regional water resources simulation models.

A fractional factorial design involves simulating only a fraction of what is required from a full factorial design method. The loss of information prevents a complete analysis of the impacts of each input variable or parameter on the output.

To illustrate the fractional factorial design method, consider the two-level with three-input variable or parameter problem. Table 5 below shows the 8 simulations required for a full factorial design method. The '+' and the '–' show the upper and lower levels of each input variable or parameter P_i where $i = 1, 2, 3$. If all 8 simulations were performed, seven possible effects could be estimated. These are the individual effects of the three inputs P_1, P_2, and P_3, the three two-input variable or parameter interactions, $(P_1)(P_2)$, $(P_1)(P_3)$, and $(P_2)(P_3)$, and the one three-input variable or parameter interaction $(P_1)(P_2)(P_3)$.

Table 5. A three-input factorial design.



simulation run	value of input P_1	P_2	P_3	value of output - variable Y
1	-	-	-	Y_1
2	+	-	-	Y_2
3	-	+	-	Y_3
4	+	+	-	Y_4
5	-	-	+	Y_5
6	+	-	+	Y_6
7	-	+	+	Y_7
8	+	+	+	Y_8

Consider an output variable Y, where Y_j is the value of Y in the jth simulation run. Then an estimate of the effect, denoted $\delta(Y|P_i)$, that input variable or parameter P_i has on the output variable Y, is the average of the four separate effects of varying P_i:

For i = 1:

$$\delta(Y \mid P_1) = 0.25\ [\ (Y_2\text{-}Y_1)+(Y_4\text{-}Y_3)+(Y_6\text{-}Y_5)+(Y_8\text{-}Y_7)\ ] \qquad (14)$$

Each difference in parentheses is the difference between a run in which P_1 is at its upper level and a run in which P_1 is at its lower level, but the other two parameter values, P_2 and P_3, are unchanged. If the effect is equal to 0, then, in this case, P_1 has no impact on the output variable Y.

Similarly the effects of P_2 and P_3, on variable Y can be estimated as:

$$\delta(Y \mid P_2) = 0.25\ \{\ (Y_3\text{-}Y_1)+(Y_4\text{-}Y_2)+(Y_7\text{-}Y_5)+(Y_8\text{-}Y_6)\ \} \qquad (15)$$

and

$$\delta(Y \mid P_3) = 0.25\ \{\ (Y_5\text{-}Y_1)+(Y_6\text{-}Y_2)+(Y_7\text{-}Y_3)+(Y_8\text{-}Y_4)\ \} \qquad (16)$$

Consider next the interaction effects between P_1 and P_2. This is estimated as the average of the difference between the average P_1 effect at the upper level of P_2, and the average P_1 effect at the lower level of P_2. This is the same as the difference between the average P_2 effect at the upper level of P_1 and the average P_2 effect at the lower level of P_1:

$$\begin{aligned}\delta(Y \mid P_1, P_2) &= (1/2)\ \{\ [\ (Y_8\text{-}Y_7) + (Y_4\text{-}Y_3)]/2 - [\ (Y_2\text{-}Y_1) + (Y_6\text{-}Y_5)]/2\ \} \\ &= (1/4)\ \{\ [\ (Y_8\text{-}Y_6)+(Y_4\text{-}Y_2)] - [\ (Y_3\text{-}Y_1) + (Y_7\text{-}Y_5)]\ \} \qquad (17)\end{aligned}$$

Similar equations can be derived for looking at the interaction effects between P_1 and P_3, and between P_2 and P_3 and the interaction effects among all three inputs P_1, P_2, and P_3.

Now assume only half of the simulation runs were performed, perhaps runs 2, 3, 5 and 8 in this example. If only outputs Y_2, Y_3, Y_5, and Y_8 are available, for our example:

$$\delta(Y \mid P_3) = \square(Y \mid P_1, P_2) = 0.5\ \{\ (Y_8 - Y_3) - (Y_2 - Y_5)\ \} \qquad (18)$$

The separate effects of P_3 and of P_1P_2 are not available from the output. This is the loss in information resulting from fractional instead of complete factorial design.

4.2.6 Monte Carlo sampling methods

The Monte Carlo method of performing sensitivity analyses, illustrated in Figure 16, first selects a random set of input data values drawn from their individual probability distributions. These values are then used in the simulation model to obtain some model output variable values. This process is repeated many times, each time making sure the model calibration is valid for the input data values chosen. The end result is a probability distribution of model output variables and system performance indices that results from variations and possible errors in all of the input values.

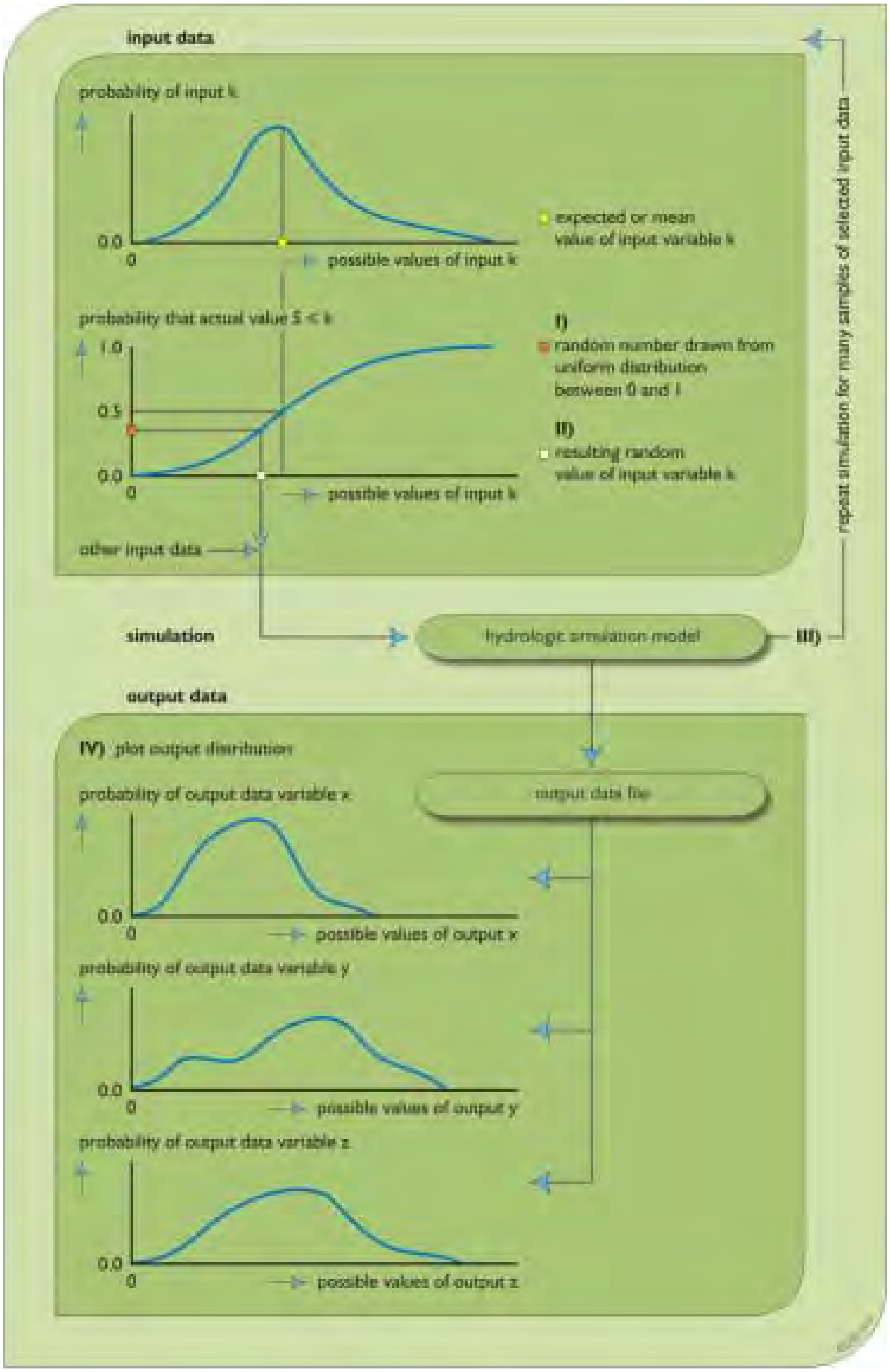


Figure 16. Monte Carlo sampling and simulation procedure for finding distributions of output variable values based on distributions, for specified reliability levels, of input data values. This technique can be applied to one or more uncertain input variables at a time. The output distributions will reflect the combined effects of this input uncertainty over the specified ranges.

Using a simple Monte Carlo analysis, values of all of the parameter sets are selected randomly from distributions describing the individual and joint uncertainty in each, and then the modeled system is simulated to obtain estimates of the selected performance indices. This must be done many times (often well over 100) to obtain a statistical description of system performance variability. The number of replications needed is generally not dependent on the number of parameters whose errors are to be analyzed. One can include in the simulation the uncertainty in parameters as well as natural variability. This method can evaluate the impact of single or multiple uncertain parameters.

A significant problem that arises in such simulations is that some combinations of parameter values result in unreasonable models. For example, model performance with calibration data sets might be inconsistent with available data sets. The calibration process places interesting constraints on different sets of parameter values. Thus, such Monte Carlo experiments often contain checks that exclude combinations of parameter values that are unreasonable. In these cases the generated results are conditioned on this validity check.

Whenever sampling methods are used, one must consider possible correlations among input data values. Sampling methods can handle spatial and temporal correlations that may exist among input data values, but the existence of correlation requires defining appropriate conditional distributions.

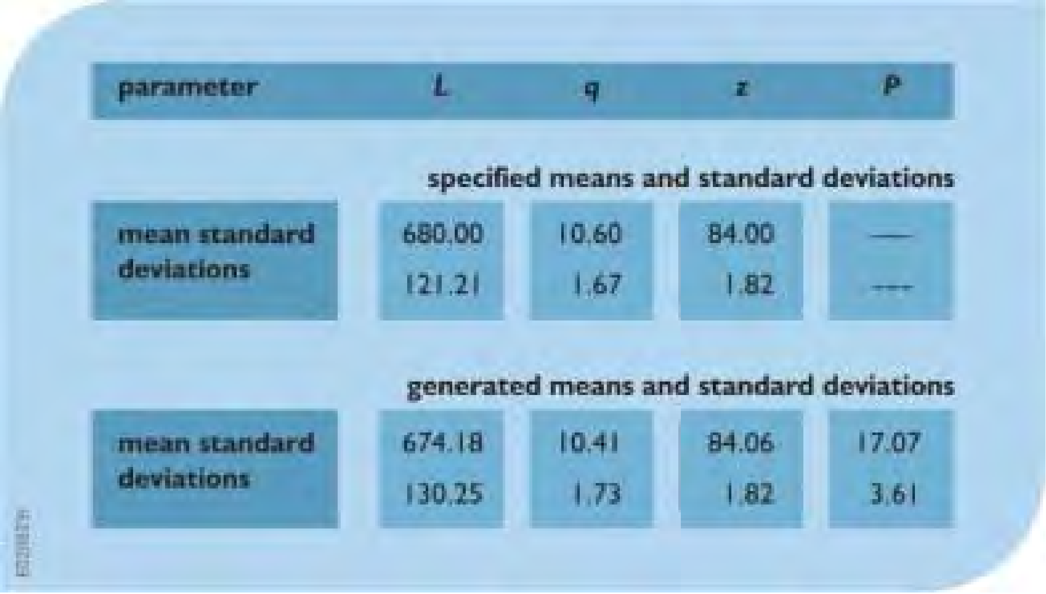
One major limitation of applying Monte Carlo methods to estimate ranges of risk and uncertainty for model output variable values, and system performance indicator values based on these output variable values, is the computing time required. To reduce the computing times needed to perform sensitivity analyses using sampling methods, some tricks and as well as stratified sampling methods are available. The discussion below illustrates the idea of a simple modification (or trick) using a “standardized” Monte Carlo analysis. The more general Latin Hypercube Sampling procedure is also discussed.

4.2.6.1 Simple Monte Carlo sampling

To illustrate the use of Monte Carlo sampling methods consider again Vollenweider’s empirical relationship, Equation 5, for the average phosphorus concentration in lakes (Vollenweider, 1976). Two hundred values of each parameter were generated independently from normal distributions with the means and variances as shown in Table 6.

The table contains the specified means and variances for the generated values of L, q and z, and also the actual values of the means and variances of the 200 generated values of L, q, z and also of the 200 corresponding generated output phosphorus concentrations, P. Figure 17 displays the distribution of the generated values of P.

Table 6. Monte Carlo analysis of lake phosphorus levels.



parameter	L	q	z	P
	specified means and standard deviations			
mean standard deviations	680.00 121.21	10.60 1.67	84.00 1.82	— ---
	generated means and standard deviations			
mean standard deviations	674.18 130.25	10.41 1.73	84.06 1.82	17.07 3.61

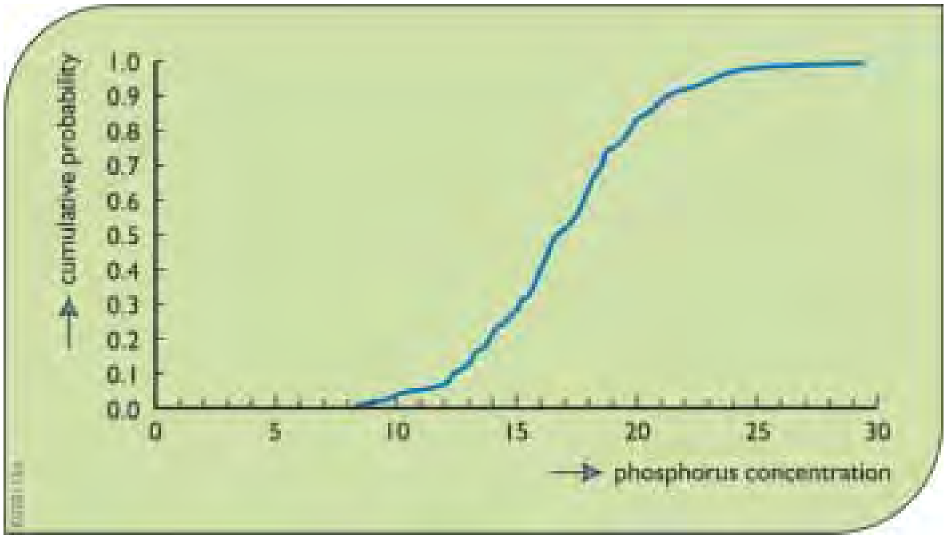


Figure 17. Distribution of lake phosphorus concentrations from Monte Carlo analysis

One can see that given the estimated levels of uncertainty, phosphorus levels could reasonably range from below 10 to above 25. The probability of generating a value greater than 20 mg/m^3 was 12.5%. The 5% to 95 percentile range was 11.1 to 23.4 mg/m^3. In the figure, the cumulative probability curve is rough because only 200 values of the phosphorus concentration were generated, but these are clearly enough to give a good impression of the overall impact of the errors.

4.2.6.2 Sampling uncertainty.

In this example, the mean of the 200 generated values of the phosphorus concentration, *P*, was 17.07. However a different set of random values would have generated a different set of *P* values as well. Thus it is appropriate to estimate the standard error, SE, of this average. The standard error equals the standard deviation □of the *P* values divided by the square root of the sample size *n*:

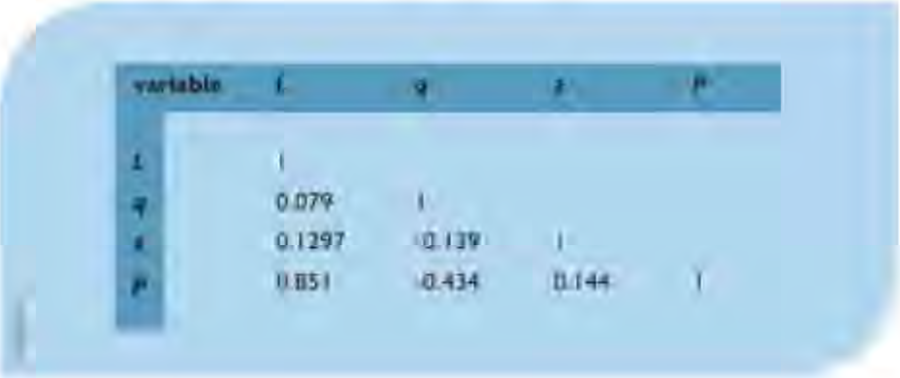
$$\text{SE} = \square/(n)^{0.5} = 3.61/(200)^{0.5} = 0.25. \qquad (19)$$

From the central limit theorem of mathematical statistics, the average of a large number of independent values should have very nearly a normal distribution. Thus, 95% of the time, the true mean of *P* should be in the interval 17.1 ± 1.96 (0.25), or 16.6 to 17.6 mg/m^3 . This level of uncertainty reflects the observed variability of *P* and the fact that only 200 values were generated.

4.2.6.3 Making sense of the results.

A significant challenge with complex models is to determine from the Monte Carlo simulation which parameter errors are important. Calculating the correlation between each generated input parameter value and the output variable value is one way of doing this. As Table 7 below shows, based upon the magnitudes of the correlation coefficients, errors in *L* were most important, and those in *q* second in importance.

Table 7. Correlation analysis of Monte Carlo results.

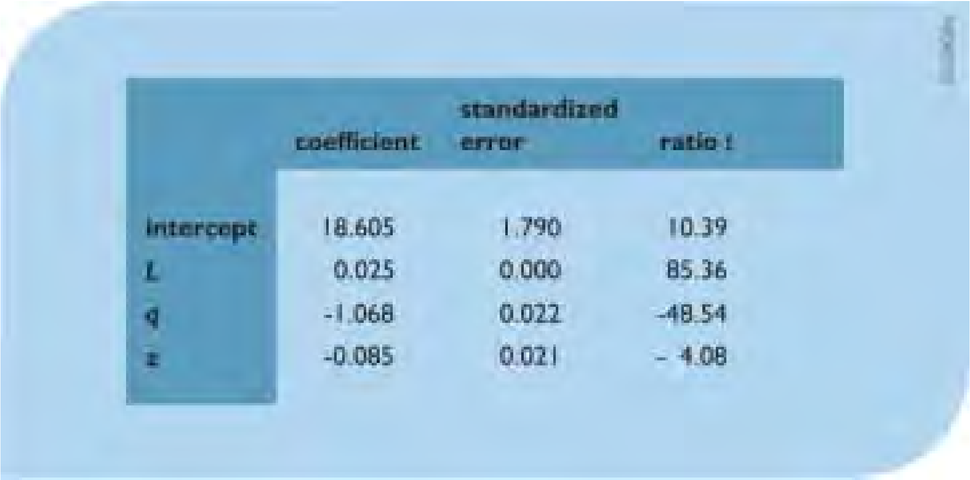


variable	L	q	z	P
L	1			
q	0.079	1		
z	0.1297	-0.139	1	
P	0.851	-0.434	0.144	1

One can also use regression to develop a linear model defining variations in the output based on errors in the various parameters. The results are shown in the Table 8. The fit is very good, and $R^2 = 98\%$. If the model for P had been linear, a R^2 value of 100% should have resulted. All of the coefficients are significantly different from zero.

Note that the correlation between P and z was positive in Table 7, but the regression coefficient for z is negative. This occurred because there is a modest negative correlation between the generated z and q values. Use of partial correlation coefficients can also correct for such spurious correlations among input parameters.

Table 8. Results of Regression Analysis on Monte Carlo Results



	coefficient	standardized error	ratio t
intercept	18.605	1.790	10.39
L	0.025	0.000	85.36
q	-1.068	0.022	-48.54
z	-0.085	0.021	- 4.08

Finally we display a plot, Figure 18, based on this regression model illustrating the reduction in the variance of P that is due to dropping each variable individually. Clearly L has the biggest impact on the uncertainty in P, and z the least.

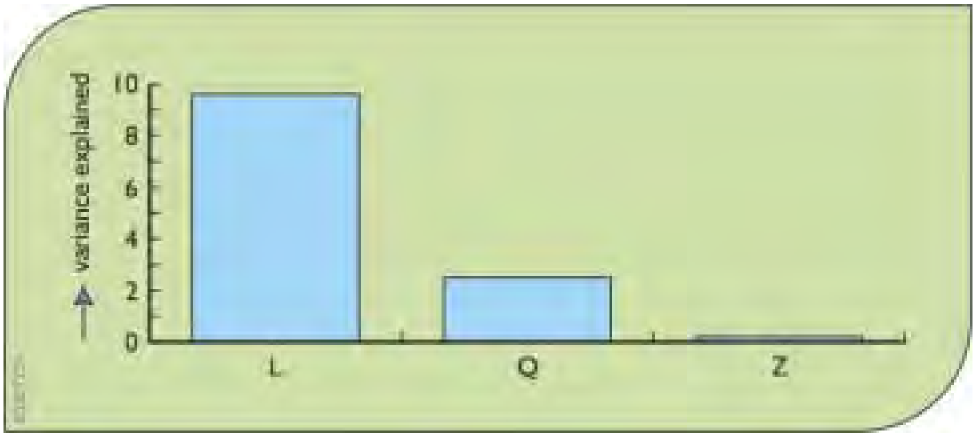
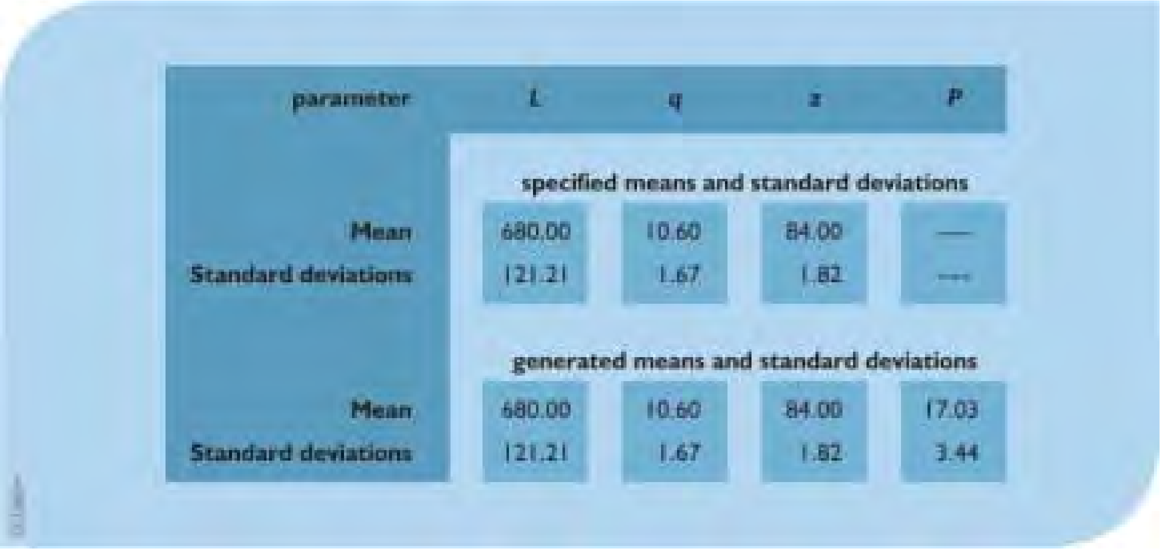


Figure 18. Reduction in the variance of *P* that is due to dropping from the regression model each variable individually. Clearly *L* has the biggest impact on the uncertainty in *P*, and *z* the least.

4.2.6.4 Standardized Monte Carlo analysis

Using a "standardized" Monte Carlo analysis, one could adjust the generated values of *L*, *q* and *z* above so that the generated samples actually have the desired mean and variance. While making that correction, one can also shuffle their values so that the correlations among the generated values for the different parameters are near zero, as is desired. This was done for the 200 generated values to obtain the statistics shown in Table 9.

Table 9. Standardized Monte Carlo analysis of lake phosphorus levels



parameter	L	q	z	P
	specified means and standard deviations			
Mean	680.00	10.60	84.00	—
Standard deviations	121.21	1.67	1.82	—
	generated means and standard deviations			
Mean	680.00	10.60	84.00	17.03
Standard deviations	121.21	1.67	1.82	3.44

Repeating the correlation analysis from before (shown in Table 10) now yields much clearer results that are in agreement with the regression analysis. The correlation between *P* and both *q* and *z* are now negative as they should be. Because the generated values of the three parameters have been adjusted to be uncorrelated, the signal from one is not confused with the signal from another.

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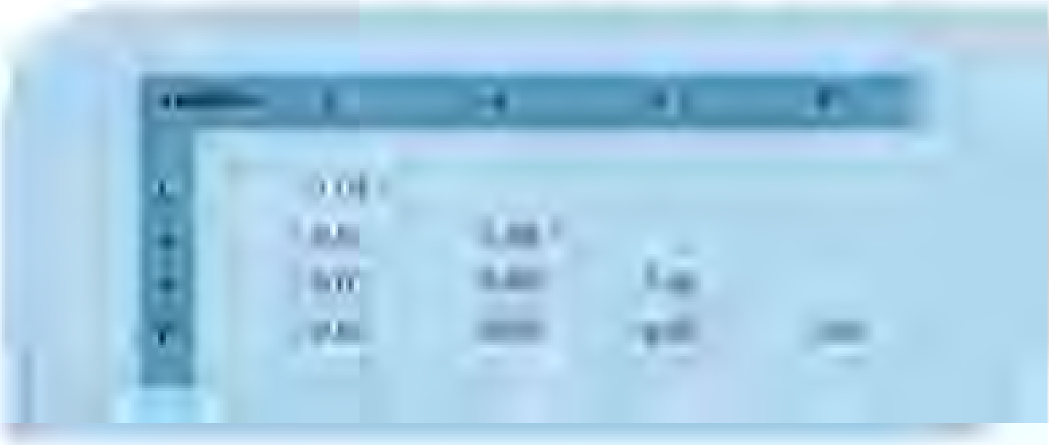
Table 10. Correlation analysis of standardized Monte Carlo results



The mean phosphorus concentration changed very little. It is now 17.0 instead of 17.1 mg/m^3.

Using control variates with a linear predictive model in conjunction with the standardized Monte Carlo variates, the standard deviation of the errors associated with the 200 observations is only 0.45. Thus the standard error for this estimate of the mean of P is $0.45/(200)^{0.5}$ or just 0.03. Thus this is a highly accurate result. The regressions were also repeated and yielded very similar results. The only real difference was that the parameter estimates had small standard errors and were more significant because of the elimination of correlation between the generated parameters.

4.2.6.5 Generalized likelihood estimation

Beven (1993) and Binley and Beven (1991) suggest a Generalized Likelihood Uncertainty Estimation (GLUE) technique for assessment of parameter error uncertainty using Monte Carlo simulation. It is described as a "formal methodology for some of the subjective elements of model calibration" (Beven, 1989, p. 47). The basic idea is to begin by assigning reasonable ranges for the various parameters and then to draw parameter sets from those ranges using a uniform or some similar (and flat) distribution. These generated parameter sets are then used on a calibration data set so that unreasonable combinations can be rejected, while reasonable values are assigned a posterior probability based upon a likelihood measure which may reflect several dimensions and characteristics of model performance.

Let $L(P_i) \geq 0$ be the value of the likelihood measure assigned to the i^{th} parameter set's calibration sequence. Then the model predictions generated with parameter set/combination P_i are assigned posterior probability, $p(P_i)$.

$$p(P_i) = L(P_i) / \Sigma_j L(P_j) \qquad (20)$$

These probabilities reflect the form of Bayes theorem, which is well supported by probability theory (Devore, 1991). This procedure should capture reasonably well the dependence or correlation among parameters, because *reasonable* sequences will all be assigned larger probabilities, whereas sequences that are unable to reproduce the system response over the calibration period will be rejected or assigned small probabilities.

However, in a rigorous probabilistic framework, the *L* would be the likelihood function for the calibration series for particular error distributions. (This could be checked with available goodness-of-fit procedures; for example, Kuczera, 1988.) When relatively ad hoc measures are adopted for the likelihood measure with little statistical validity, the $p(P_i)$ probabilities are best described as pseudo probabilities or "likelihood" weights.

Another concern with this method is the potential efficiency. If the parameter ranges are too wide, a large number of unreasonable or very unlikely parameter combinations will be generated. These will either be rejected or else will have small probabilities and thus little effect on the analysis. In this case the associated processing would be a waste of effort. A compromise is to use some data to calibrate the model and to generate a prior or initial distribution for the parameters that is at least centered in the best range (Beven 1993, p. 48). Then use of a different calibration period to generate the $p(P_i)$ allows an updating of those initial probabilities to reflect the information provided by the additional calibration period with the adopted likelihood measures.

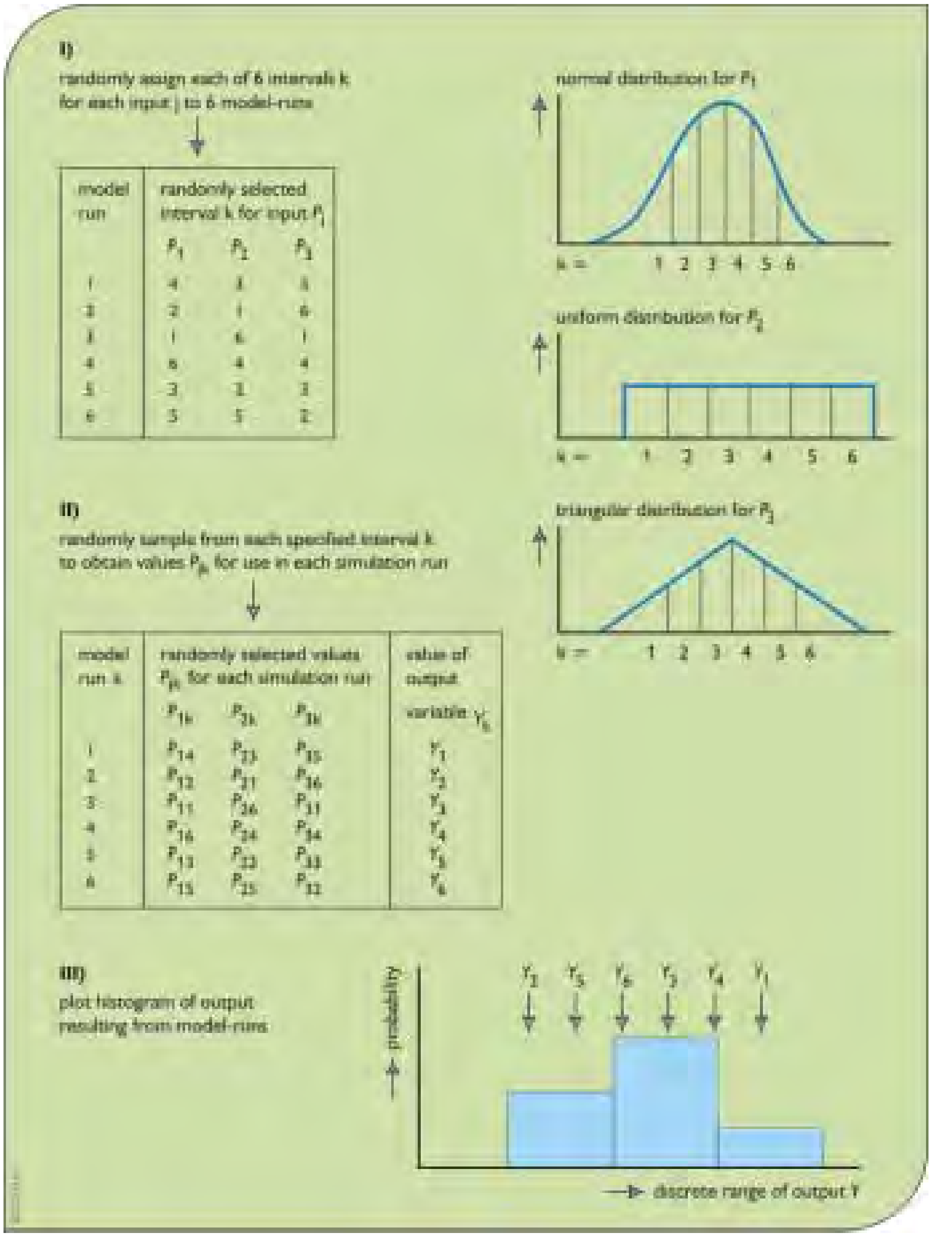
After the accepted sequences are used to generate sets of predictions, the likelihood weights would be used in the calculation of means, variances and quantiles, rather than the customary procedure of giving all the generated realizations equal weight. The resulting conditional distribution of system output reflects the initial probability distributions assigned to parameters, the rejection criteria, and the likelihood measure adopted to assign "likelihood" weights.

4.2.7 Latin hypercube sampling

For the simple Monte Carlo simulations described above, with independent errors, a probability distribution is assumed for each input parameter or variable. In each simulation run, values of all input data are obtained from sampling those individual and independent distributions. The value generated for an input parameter or variable is usually independent of what that value was in any previous run, or what other input parameter or variable values are in the same run. This simple sampling approach can result in a clustering of parameter values and hence both redundancy of information from repeated sampling in the same regions of a distribution and lack of information from no sampling in other regions of the distributions.

A stratified sampling approach ensures more even coverage of the range of input parameter or variable values with the same number of simulation runs. This can be accomplished by dividing the input parameter or variable space into sections and sampling from each section with the appropriate probability.

One such approach, Latin hypercube sampling (LHS), divides each input distribution into sections of equal probability for the specified the probability distribution, and draws one observation randomly from each range. Hence the ranges of input values within each section actually occur with equal frequency in the experiment. These values from each interval for each distribution are randomly assigned to those from other intervals to construct sets of input values for the simulation analysis. Figure 19 shows the steps in constructing a LHS for six simulations involving three inputs P_j (P_1, P_2, and P_3) and six intervals of their respective normal, uniform and triangular probability distributions.



model run	randomly selected interval k for input P_j P_1	P_2	P_3
1	4	3	5
2	2	1	6
3	1	6	1
4	6	4	4
5	3	2	3
6	5	5	2

model run k	randomly selected values P_{jk} for each simulation run P_{1k}	P_{2k}	P_{3k}	value of output variable Y_k
1	P_{14}	P_{23}	P_{35}	Y_1
2	P_{12}	P_{21}	P_{36}	Y_2
3	P_{11}	P_{26}	P_{31}	Y_3
4	P_{16}	P_{24}	P_{34}	Y_4
5	P_{13}	P_{22}	P_{33}	Y_5
6	P_{15}	P_{25}	P_{32}	Y_6

Figure 19. Schematic representation of a Latin hypercube sampling procedure for six simulation runs.

5. Performance indicator uncertainties

5.1 Performance measure target uncertainty

Another possible source of uncertainty is the selection of performance measure target values. For example, consider a target value for a pollutant concentration based on the effect of exceeding it in an ecosystem. Which target value is best or correct? When this is not clear, there are various ways of expressing the uncertainty associated with any target value. One such method is the use of fuzzy sets (Chapter VI). Use of 'grey' numbers or intervals instead of 'white' or fixed target values is another. When some uncertainty or disagreement exists over the selection of the best target value for a particular performance measure it seems to us the most direct and transparent way to do this is to subjectively assume a distribution over a range of possible target values. Then this subjective probability distribution can be factored into the tradeoff analysis, as outlined in Figure 20.

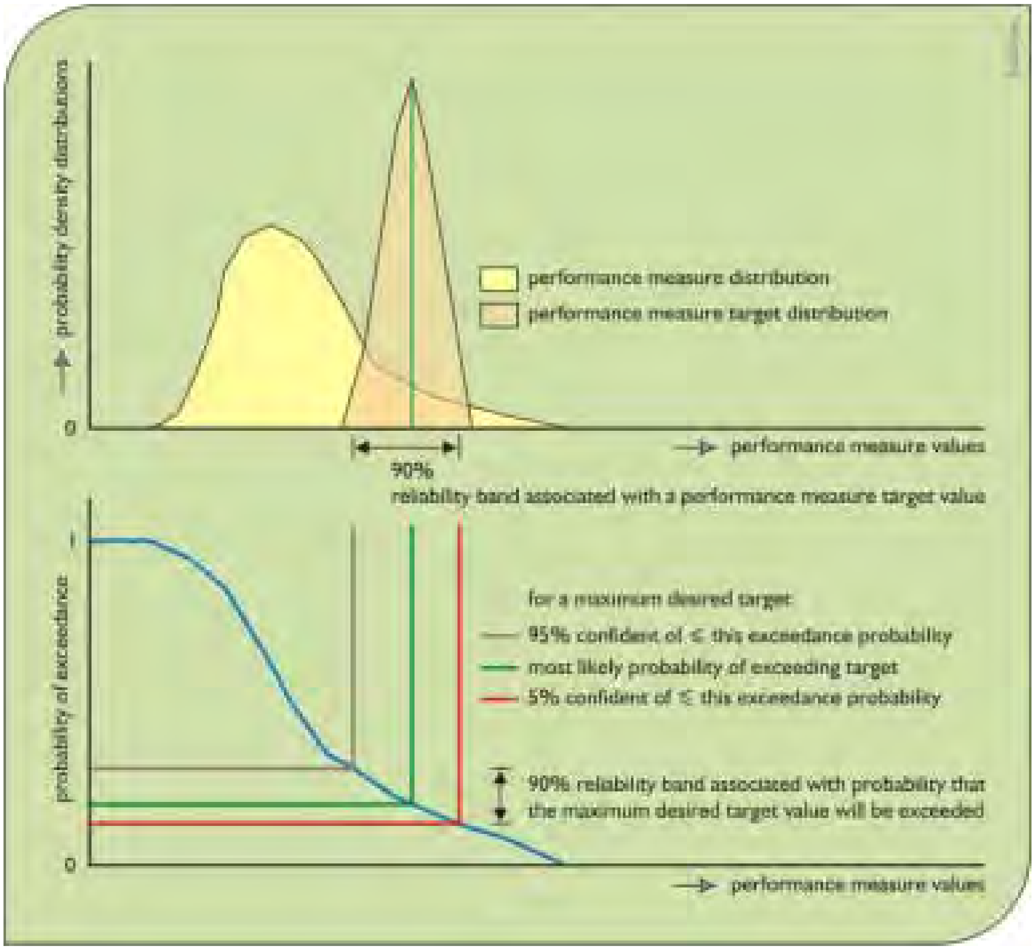


Figure 20. Combining the probability distribution of performance measure values with the probability distribution of performance measure target values to estimate the confidence one has in the probability of exceeding a maximum desired target value.

One of the challenges associated with defining and including in an analysis the uncertainty associated with a target or threshold value for a performance measure is that of communicating just what the result of such an analysis means. Referring to Figure 20, suppose the target value represents some maximum limit of a pollutant, say phosphorus, concentration in the flow during a given period of time at a given site or region, and it is not certain just what that maximum limit should be. Subjectively defining the distribution of that maximum limit, and considering that uncertainty along with the uncertainty (probability of exceedance function) of pollutant concentrations – the performance measure – one can attach a confidence to any probability of exceeding the maximum desired concentration value.

The 95% probability of exceedance shown on Figure 20, say $P_{0.95}$, should be interpreted as "we can be 95% confident that the probability of the maximum desired pollutant concentration being exceeded will be no greater than $P_{0.95}$." We can be only 5% confident that the probability of exceeding the desired maximum concentration will be no greater than the lower $P_{0.05}$ value. Depending on whether the middle line through the subjective distribution of target values in Figure 20 represents the most likely or median target value, the associated probability of exceedance is either the most likely, as indicated in Figure 20, or that for which we are only 50% confident.

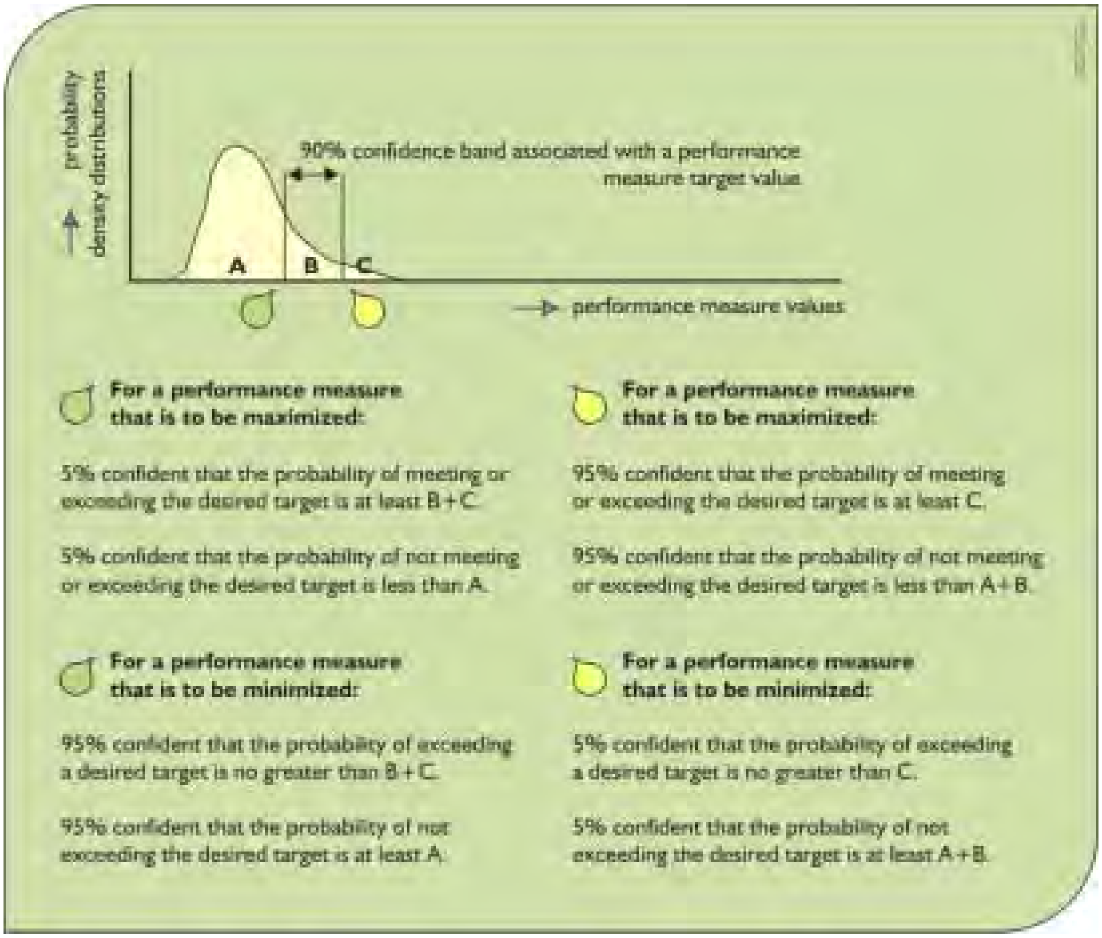
Figure 21 attempts to show how to interpret the reliabilities when the uncertain performance targets are

- minimum acceptable levels that are to be maximized,
- maximum acceptable levels that are to be minimized or
- optimum levels.

An example of a minimum acceptable target level might be the population of wading birds in an area. An example of a maximum acceptable target level might be, again, the phosphorus concentration of the flow in a specific wetland or lake. An example of an optimum target level might be the depth of water most suitable for selected species of aquatic vegetation during a particular period of the year.

For performance measure targets that are not expressed as minimum or maximum limits but that are the 'best' values, referring to Figure 21, one can state that one is 90% confident that the probability of achieving the desired target is no more than B. The 90% confidence level probability of not achieving the desired target is at least A+C. The probability of the performance measure being too low is at least A and the probability of the performance measure being too high is at least C, again at the 90% confidence levels. As the confidence level decreases the bandwidth decreases, and the probability of not meeting the target increases.

Now, clearly there is uncertainty associated with each of these uncertainty estimations, and this raises the question of how valuable is the quantification of the uncertainty of each additional component of the plan in an evaluation process. Will plan evaluators and decision makers benefit from this additional information, and just how much additional uncertainty information is useful?



For a performance measure that is to be maximized:

5% confident that the probability of meeting or exceeding the desired target is at least B+C.

5% confident that the probability of not meeting or exceeding the desired target is less than A.

For a performance measure that is to be maximized:

95% confident that the probability of meeting or exceeding the desired target is at least C.

95% confident that the probability of not meeting or exceeding the desired target is less than A+B.

For a performance measure that is to be minimized:

95% confident that the probability of exceeding a desired target is no greater than B+C.

95% confident that the probability of not exceeding the desired target is at least A.

For a performance measure that is to be minimized:

5% confident that the probability of exceeding a desired target is no greater than C.

5% confident that the probability of not exceeding the desired target is at least A+B.

Figure 21. Interpreting the results of combining performance measure probabilities with performance measure target probabilities depends on the type of performance measure. The letters A, B, and C represent proportions of the probability density function of performance measure values. (Hence probabilities A + B + C = 1.)

Now consider again the tradeoffs that need to be made as illustrated in Figure 7. Instead of considering a single target value as shown on Figure 7, assume there is a 90% confidence range associated with that single performance measure target value. Also assume that the target is a maximum desired upper limit (e.g., of some pollutant concentration).

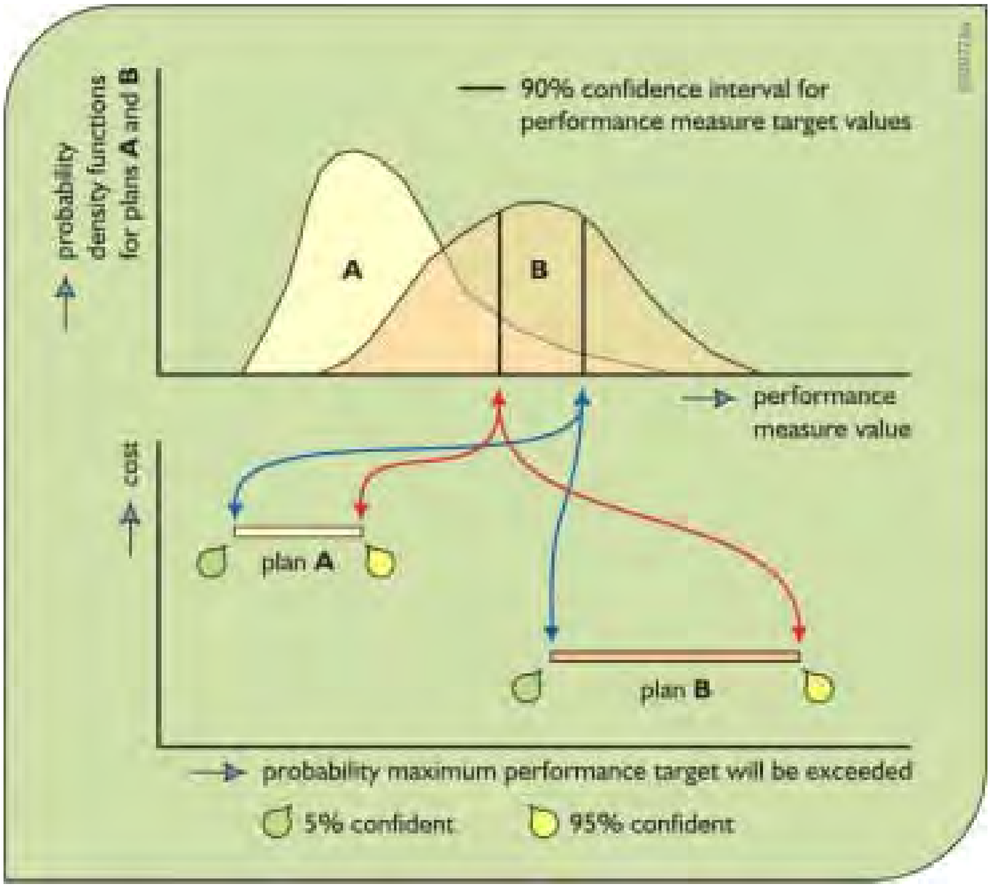


Figure 22. Two plans showing ranges of probabilities, depending on one's confidence, that an uncertain desired maximum (upper limit) performance target value will be exceeded. The 95% confidence levels are associated with the higher probabilities of exceeding the desired maximum target. The 5% confident levels are associated with the more desirable lower probabilities of exceeding the desired maximum target. Plan A with reduced probabilities of exceeding the upper limit costs more than Plan B.

In the case shown in Figure 22, the tradeoff is clearly between cost and reliability. In this example, no matter what confidence one chooses, Plan A is preferred to Plan B with respect to reliability, but Plan B is preferred to Plan A with respect to cost. The tradeoff is only between these two performance indicators or measures.

Consider however a third plan, as shown in Figure 23. This situation adds to the complexity of making appropriate tradeoffs. Now there are three criteria: cost, probability of exceedance (reliability) and the confidence in those reliabilities or probabilities. Add to this the fact that there will be multiple performance measure targets, each expressed in terms of their maximum probabilities of exceedance and the confidence in those probabilities.

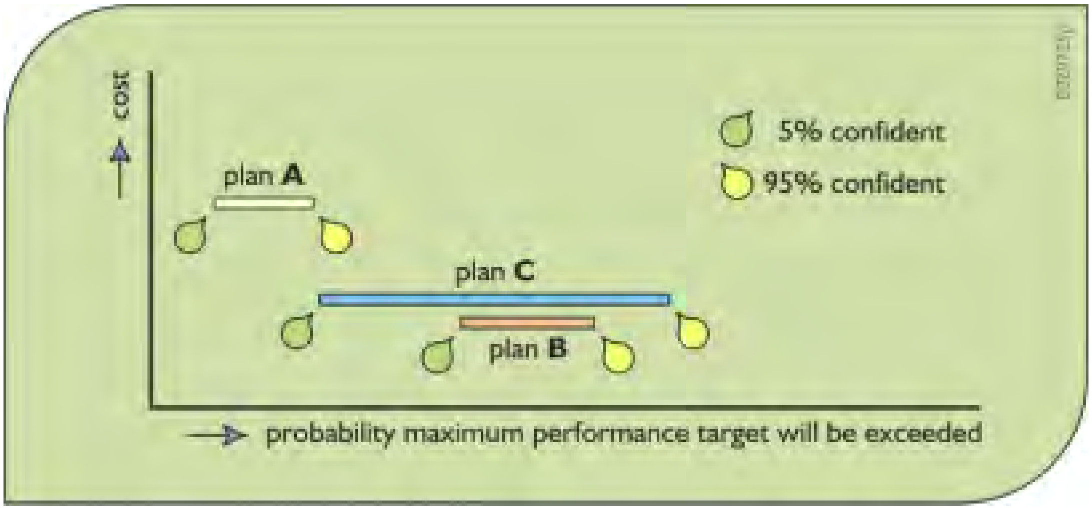


Figure 23. Tradeoffs among cost, reliabilities, and the confidence level of those reliabilities. The relative ranking of plans with respect to the probability of exceeding the desired (maximum limit) target may depend on the confidence given to that probability.

In Figure 23, in terms of cost the plans are ranked, from best to worst, B, C, and A. In terms of reliability at the 90 percent confidence level, they are ranked A, B, and C but at the 50 percent confidence level the ranking is A, C and B.

If the plan evaluation process has difficulty handling all this it may indicate the need to focus the uncertainty analysis effort on just what is deemed important, achievable, and beneficial. Then when the number of alternatives has been narrowed down to only a few that appear to be the better ones, a more complete uncertainty analysis can be performed. There is no need nor benefit in performing sensitivity and uncertainty analyses on all possible management alternatives. Rather one can focus on those alternatives that look the most promising, and then carry out additional uncertainty and sensitivity analyses only when important uncertain performance indicator values demands more scrutiny. Otherwise the work is not likely to affect the decision anyway.

5.2 Distinguishing differences between performance indicator distributions

Simulations of alternative water management infrastructure designs and operating policies require a comparison of the simulation outputs – the performance measures or indicators – associated with each alternative. A reasonable question to ask is are the observed differences statistically significant. Can one really tell if one alternative is better than another or are the observed differences explainable by random variations attributable to variations in the inputs and how the system responds?

This is a common statistical issue that is addressed by standard hypothesis tests (Devore, 1991; Benjamin and Cornell, 1970). Selection of an appropriate test requires that one first resolve what type of change one expects in the variables. To illustrate, consider the comparison of two different operating policies. Let Y_1 denote the set of output performance variable values with the first policy, and Y_2 the set of output performance variable values of the second policy. In many cases, one would expect one policy to be better than the other. One measure might be the difference in the mean of the variables; for example is $E[Y_1] < E[Y_2]$?. Alternatively one could check the difference in the median (50 percentile) of the two distributions.

In addition, one could look for a change in the variability or variance, or a shift in both the mean and the variance. Changes described by a difference in the mean or median often make the most sense and many statistical tests are available that are sensitive to such changes. For such investigations parametric and non-parametric tests for paired and unpaired data can be employed.

Consider the differences between "paired" and "unpaired" data. Suppose that the meteorological data for 1941-1990 is used to drive a simulation model generating data as described in Table 11:

Table 11. Possible flow data from a 50-year simulation

1941	$Y_1(1)$	$Y_2(1)$
1942	$Y_1(2)$	$Y_2(2)$
1943	$Y_1(3)$	$Y_2(3)$
1944	$Y_1(4)$	$Y_2(4)$
1989	$Y_1(49)$	$Y_2(49)$
1990	$Y_1(50)$	$Y_2(50)$

Here there is one sample, $Y_1(1)$ through $Y_1(50)$, for policy 1, and another sample, $Y_2(1)$ through $Y_2(50)$, for policy 2. However, the two sets of observations are not independent. For example, if 1943 was a very dry year, then we would expect both $Y_1(3)$ for policy 1 in that year and $Y_2(3)$ for policy 2 to be unusually small. With such paired data, one can use a paired hypothesis test to check for differences. Paired tests are usually easier than the corresponding unpaired tests that are appropriate in other cases. (For example, if one were checking for a difference in average rainfall depth between 1941-1960, and 1961-1990, they would have two sets of independent measurements for the two periods. With such data, one should use a two-sample unpaired test.)

Paired tests are generally based on the differences between the two sets of output, $Y_1(i) - Y_2(i)$. These are viewed as a single independent sample. The question is then are the differences positive (say Y_1 tends to be larger then Y_2), or negative (Y_1 tends to be smaller), or are positive and negative differences are equally likely (there is no difference between Y_1 and Y_2).

Both parametric and non-parametric families of statistical tests are available for paired data. The common parametric test for paired data (a one-sample t test) assumes that the mean of the differences

$$X(i) = Y_1(i) - Y_2(i) \tag{21}$$

are normally distributed. Then the hypothesis of no difference is rejected if the t statistic is sufficiently large, given the sample size n.

Alternatively, one can employ a nonparametric test and avoid the assumption that the differences X(i) are normally distributed. In such a case, one can use the Wilcoxon Signed Rank test. This nonparametric test ranks the absolute values $|X(i)|$ of the differences. If the sum S of the ranks of the positive differences deviates sufficiently from its expected value, $n(n+1)/4$ (were there no difference between the two distributions), one can conclude that there is a statistically significant difference between the $Y_1(i)$ and $Y_2(i)$ series. Standard statistical texts have tables of the distribution of the sum S as a function of the sample size n, and provide a good analytical approximation for $n > 20$ (for example, Devore, 1991). Both the parametric t test and the nonparametric Wilcoxon Signed Rank test require that the differences between the simulated values for each year be computed.

6. Communicating model output uncertainty

Spending money on reducing uncertainty would seem preferable to spending it on ways of calculating and describing it better. Yet attention to uncertainty communication is critically important if uncertainty analyses and characterizations are to be of value in a decision making process. In spite considerable efforts by those involved in risk assessment and management, we know very little about how to ensure effective risk communication to gain the confidence of stakeholders, incorporate their views and knowledge, and influence favorably the acceptability of risk assessments and risk-management decisions.

The best way to communicate concepts of uncertainty may well depend on what the audiences already know about risk and the various types of probability distributions (e.g., density, cumulative, exceedance) based on objective and subjective data, and the distinction between mean or average values and the most likely values. Undoubtedly graphical representations of these ways of describing uncertainty considerably facilitate communication.

The National Research Council (NRC 1994) addressed the extensive uncertainty and variability associated with estimating risk and concluded that risk characterizations should not be reduced to a single number or even to a range of numbers intended to portray uncertainty. Instead, the report recommended managers and the interested public should be given risk characterizations that are both qualitative and quantitative and both verbal and mathematical.

In some cases communicating qualitative information about uncertainty to stakeholders and the public in general may be more effective than quantitative information. There are, of course, situations in which quantitative uncertainty analyses are likely to provide information that is useful in a decision-making process. How else can tradeoffs such as illustrated in Figures 10 and 27 be identified? Quantitative uncertainty analysis often can be used as the basis of qualitative information about uncertainty, even if the quantitative information is not what is communicated to the public.

One should acknowledge to the public the widespread confusion regarding the differences between variability and uncertainty. Variability does not change through further measurement or study, although better sampling can improve our knowledge about variability. Uncertainty reflects gaps in information about scientifically observable phenomena.

While it is important to communicate uncertainties and confidence in predictions, it is equally important to clarify who or what is at risk, possible consequences, and the severity and irreversibility of an adverse effect should a target value, for example, not be met. This qualitative information is often critical to informed decision-making. Risk and uncertainty communication is always complicated by the reliability and amounts of available relevant information as well as how that information is presented. Effective communication between people receiving information about who or what is at risk, or what might happen and just how severe and irreversible an adverse effect might be should a target value not be met, is just as important as the level of uncertainty and the confidence associated with such predictions. A two-way dialog between those receiving such information and those giving it can help identify just what seems best for a particular audience.

Risk and uncertainty communication is a two-way street, It involves learning and teaching. Communicators dealing with uncertainty should learn about the concerns and values of their audience, their relevant knowledge, and their experience with uncertainty issues. Stakeholders' knowledge of the sources and reasons for uncertainty needs to be incorporated into assessment and management and communication decisions. By listening, communicators can craft risk messages that better reflect the perspectives, technical knowledge, and concerns of the audience.

Effective communication should begin before important decisions have been made. It can be facilitated in communities by citizen advisory panels. Citizen advisory panels can give planners and decision makers a better understanding of the questions and concerns of the community and an opportunity to test its effectiveness in communicating concepts and specific issues regarding uncertainty.

One approach to make uncertainty more meaningful is to make risk comparisons. For example, a ten parts per billion target for a particular pollutant concentration is equivalent to 10 seconds in over 31 years. If this is an average daily concentration target that is to be satisfied "99 percent," of the time, this is equivalent to an expected violation of less than one day every three months.

Many perceive the reduction of risk by an order of magnitude as though it were a linear reduction. A better way to illustrate orders of magnitude of risk reduction is shown in Figure 24, in which a bar graph depicts better than words that a reduction in risk from one in a 1,000 (10^{-3}) to one in 10,000 (10^{-4}) is a reduction of 90% and that a further reduction to one in 100,000 (10^{-5}) is a reduction 10-fold less than the first reduction of 90%. The percent of the risk that is reduced by whatever measures is a much easier concept to communicate than reductions expressed in terms of estimated absolute risk levels, such as 10^{-5}.

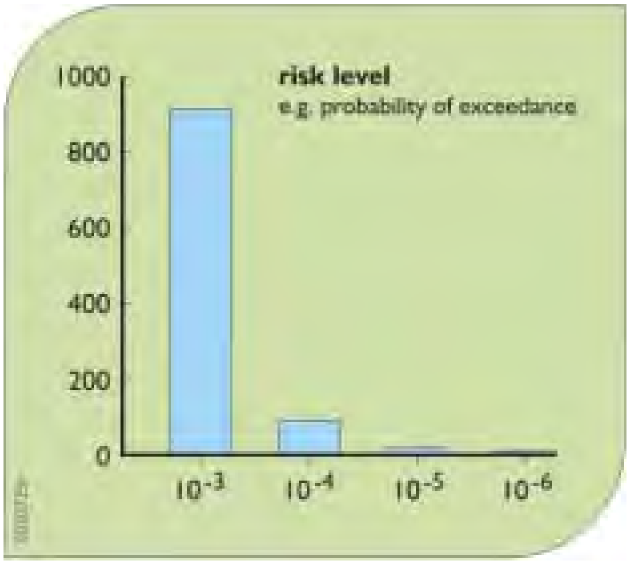


Figure 24. Reducing risk by orders of magnitude is not equivalent to linear reductions.

Risk comparisons can be helpful, but they should be used cautiously and tested if possible. There are dangers in comparing risks of diverse character, especially when the intent of the comparison is seen as minimizing a risk (NRC 1989). One difficulty in using risk comparisons is that it is not always easy to find risks that are sufficiently similar to make a comparison meaningful. How is someone able to compare two alternatives having two different costs and two different risk levels, for example, as is shown in Figure 7? One way is to perform an indifference analysis (Chapter X), but that can lead to different results depending who performs it. Another way is to develop utility functions using weights, where, for example reduced phosphorus load by half is equivalent to a 25 percent shorter hydroperiod in that area, but again each person's utility or tradeoff may differ.

At a minimum, graphical displays of uncertainty can be helpful. Consider the common system performance indicators that include:

- Time-series plots for continuous time-dependent indicators (Figure 25 upper left)
- Probability exceedance distributions for continuous indicators (Figure 25 upper right),
- Histograms for discrete event indicators (Figure 25 lower left), and
- Overlays on maps for space-dependent discrete events (Figure 25 lower right).

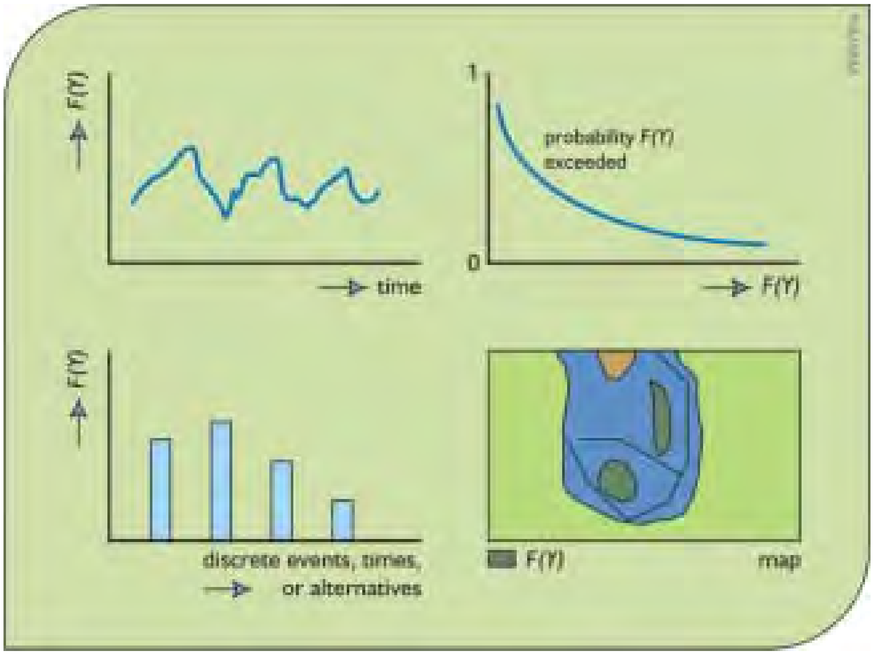


Figure 25. Different types of displays used to show model output *Y* or system performance indicator values *F*(*Y*).

The first three graphs in Figure 25 could show, in addition to the single curve or bar that represents the most likely output, a range of outcomes associated with a given confidence interval. For overlays of information on maps, different colors could represent the spatial extents of events associated with different ranges of risk or uncertainty. Figure 26, corresponding to Figure 25, illustrates these approaches for displaying these ranges.

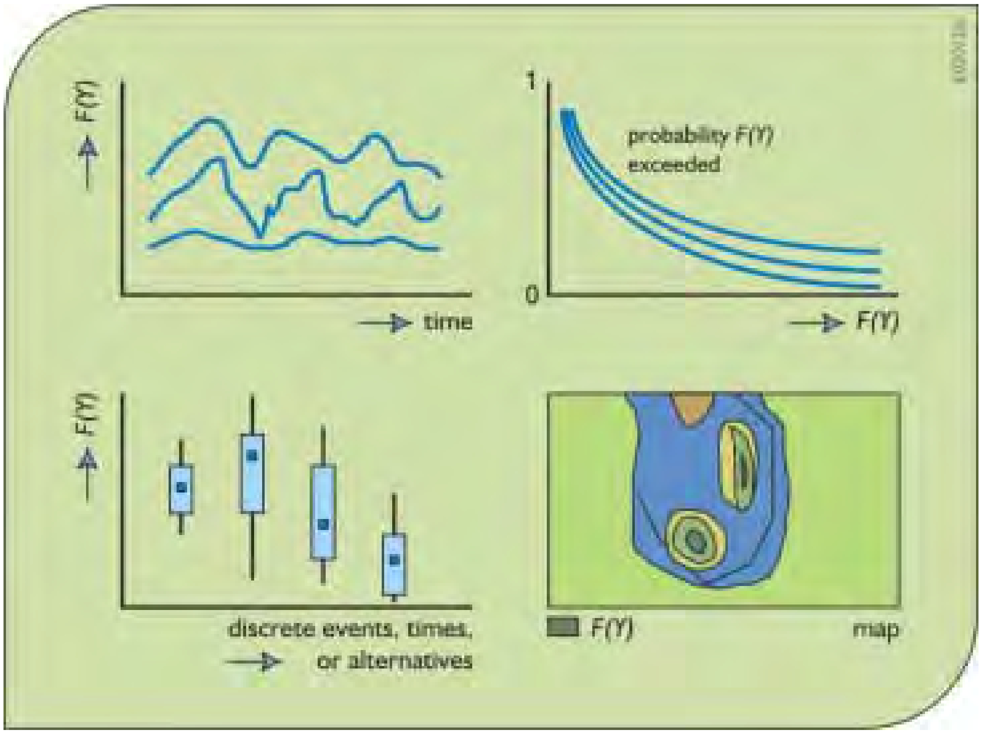


Figure 26. Plots of ranges of possible model output *Y* or system indicator values *F*(*Y*) for different types of displays.

7. Conclusions

This chapter provides an overview of uncertainty and sensitivity analyses in the context of hydrologic or water resources systems simulation modeling. A broad range of tools are available to explore, display, and quantify the sensitivity and uncertainty in predictions of key output variables and system performance indices with respect to imprecise and random model inputs and to assumptions concerning model structure. They range from relatively simple deterministic sensitivity analysis methods to more involved first-order analyses and Monte Carlo sampling methods.

Because of the complexity of many watersheds or river basins, Monte Carlo methods for uncertainty analyses may be a very major and unattractive undertaking. Therefore it is often prudent begin with the relatively simple deterministic procedures. This coupled with a probabilistically based first-order uncertainty analysis method can help quantify the uncertainty in key output variables and system performance indices, and the relative contributions of uncertainty in different input variables to the uncertainty in different output variables and system performance indices. These relative contributions may differ depending upon which output variables and indices are of interest.

A sensitivity analysis can provide a systematic assessment of the impact of parameter value imprecision on output variable values and performance indices, and of the relative contribution of errors in different parameter values to that output uncertainty. Once the key variables are identified, it should be possible to determine the extent to which parameter value uncertainty can be reduced through field investigations, development of better models, and other efforts.

Model calibration procedures can be applied to individual catchments and subsystems, as well as to composite systems. Automated calibration procedures have several advantages including the explicit use of an appropriate statistical objective function, identification of those parameters that best reproduce the calibration data set with the given objective function, and the estimations of the statistical precision of the estimated parameters.

All of these tasks together can represent a formidable effort. However, knowledge of the uncertainty associated with model predictions can be as important to management decision and policy formulation as are the predictions themselves.

No matter how much attention is given to quantifying and reducing uncertainties in model outputs, uncertainties will remain. Professionals who analyze risk, managers and decision makers who must manage risk, and the public who must live with risk and uncertainty, have different information needs and attitudes regarding risk and uncertainty. It is clear that information needs differ among those who model or use models, those who make substantial investment or social decisions, and those who are likely to be impacted by those decisions. Meeting those needs should result in more informed decision making. But it comes at a cost that should be considered along with the benefits of having this sensitivity and uncertainty information.

9. References

Anderson, J.L., 1998, Embracing uncertainty: The interface of Bayesian statistics and cognitive psychology. Conservation Ecology (online) 2(1): 2. Available from the Internet. URL: http://www.consecol.org/vol2/iss1/art2

Beck, M.B., 1987, Water Quality Modeling: A review of the Analysis of Uncertainty, Water Resour. Res., 23(8), 1393-1442

Benaman, J., 2002, A Systematic Approach to Uncertainty Analysis for a Distributed Watershed Model, Ph.D. Thesis. School of Civil and Environmental Engineering. Cornell University, Ithaca, NY

Benjamin J.R., and Cornell, C.A., 1970, Probability, Statistics and Decision for Civil Engineers, McGraw-Hill Book Co., New York

Berry, D.A. 1996, Statistics: A Bayesian Perspective, Belmont, CA: Duxbury.

Beven, K., 1989, Changing Ideas in Hydrology – The Case of Physically-based Models, J. of Hydrol., 105, 157-172

Beven, K., 1993, Prophecy, reality and uncertainty in distributed hydrologic modelling, Adv. in Water Res., 16, 41-51

Binley, A.M., and Beven, K.J., 1991, Physically-based modelling of catchment hydrology: a likelihood approach to reducing predictive uncertainty, in Computer Modelling in the Environmental Sciences, D.G. Farmer and M.J. Rycroft (ed.), Clarendon Press, Oxford

Chapra, S.C. and Reckhow, K.H., 1979, Expressing the phosphorus loading concept in probabilistic terms. J. Fish. Res. Board Can., 36.

Colwell, R.K., 1974, Predictability, consistency, and contingency of periodic phenomena, Ecology Vol. 55, pp 1148-53.

Covello, V.T. and Merkhofer, M.W., 1993, Risk Assessment Methods. Plenum Press. London.

Covello, V. T., 1987, Decision Analysis and Risk Management Decision-Making: Issues and Methods, Risk Analysis, 7, , pp. 131-139

DeGarmo, E.P., Sullivan, W.G. and Bontadelli, J.A., 1993, Engineering Economy, MacMillian, New York

Deutsch C.V. and Journel, A.G., 1992, GS-LIB: Geostatistical Software Library and User's Guide. Oxford University Press

Devore, J., 1991, Probability and Statistics for Engineering and the Sciences, 3rd Edition, Brooks/Cole Publishing Co., London

Devore, J.L. and Peck, R., 1996, Statistics: The exploration and analysis of data, 3rd ed. Brooks/Cole Publishing Co., London

Dilks, D.W., Canale, R.P., and Meier, P.G., 1992, Development of Bayesian Monte Carlo techniques for water quality model uncertainty, Ecological Modelling, Vol. 62, pp 149-162.

Dilks, D. W. and James, R. T., 2002, Application of Bayesian Monte Carlo analysis to determine the uncertainty in the Lake Okeechobee water quality model, Proceedings, Watershed 2002, Water Environment Federation

DOE, 1998, Screening Assessment and Requirements for a Comprehensive Assessment, DOE/RL-96-16, Rev. 1, U.S. Department of Energy, Richland, Washington

Duan, Q., Soroosian, S. and Ibbitt. R.P., 1988, A maximum likelihood criterion for use with data collected at unequal time intervals, Water Resources Research, 24(7), 1163-1173

Eschenback, T.G., 1992, Spider plots versus Tornado Diagrams for Sensitivity Analysis, Interfaces, 22, 40-46

Fedra, K., 1983, A Monte Carlo approach to estimation and prediction, In M. B. Beck and G. Van Straten (Eds.), Uncertainty and Forecasting of Water Quality, Springer-Verlag, Berlin, pp 259-291.

Fitz, H.C., Voinov, A. and Costanza, R., 1995, The Everglades Landscape Model: multiscale sensitivity analysis. South Florida Water Management District, Everglades Systems Research Division, West Palm Beach, FL, 88 pp.

Fontaine, T.A. and Jacomino, V.M.F., 1997, Sensitivity analysis of simulated contaminated sediment transport. Journal of the American Water Resources Association **3**3(2): 313-326.

Frey, H.C. and Patil, S.R., 2002, Identification and review of sensitivity analysis methods, Risk Analysis, Vol. 22, No. 3 pp 553-578

Gardner, R.H., Rojder, B., and Bergstrom, U., 1983, PRISM: A systematic method for determining the effect of parameter uncertainties on model predictions. Technical Report, Studsvik Energiteknik AB report NW-83-/555, Nykoping, Sweden.

Gaven, D.C. and Burges, S.J., 1981, Approximate error bounds for simulated Hydrograph, J. Hydraulic Engineering, 107(11), 1519-1534

Gelman, A., Carlin, J., Stern, H., and Rubin, D.B., 1995, Bayesian Data Analysis. Chapman and Hall, London:

Gleick, J., 1987, Chaos: making a new science, Penguin, NY

Gupta, V.K. and Sorooshian, S., 1985a, The automatic calibration of conceptual watershed models using derivative-based optimization algorithms, Water Resources Research, 21(4), 473-485

Gupta, V.K. and Sorooshian, S., 1985b, The relationship between data and the precision of parameter estimates of hydrologic models, Journal of Hydrology 81, 57-77

Haimes, Y.Y., 1998, Risk Modelling, Assessment and Management, John Wiley & Sons, Inc. New York

Harlin, J., and Kung, C-S., 1992, Parameter Uncertainty in Simulation of Design of Floods in Sweden, J. of Hydrol., 137, 2009-230

Hendrickson, J.D., Sorooshian, S. and L.E. Brazil, 1988, Comparison of Newton-type and direct-search algorithms for calibration of conceptual rainfall-runoff models, Water Research Research, 24(5), 691-700

Holling, C.S., 1978, Adaptive Environmental Assessment and Management, John Wiley & Sons, Chichester, UK

Ibrekk, H. and Morgan, M.G., 1987, Graphical Communication of Uncertain Quantities to nontechnical people, Risk Analysis, Vol. 7, No. 4, pp 519-529.

Isaaks, E.H. and Srivastava, R.M., 1989, An introduction to applied geostatistics. Oxford University Press, New York.

Jaffe, P.R., Paniconi, C., and Wood, E.F., 1988, Model calibration based on random environmental fluctuations, J. Environ. Eng., 114(5), 1136-1145

Jain S, and U Lall, 2001, Floods in a changing climate: Does the past represent the future?, Water Resources Research, 37 (12): 3193-3205 DEC

Jensen, F.V., 2001, Bayesian Networks and Decision Graphs, New York: Springer.

Kann, A. and Weyant, J.P., 1999, A comparison of approaches for performing uncertainty analysis in integrated assessment models, Journal of Environmental Management and Assessment, Vol. 5, No.1, pp 29-46.

Kelly, E. and Campbell, K., 2000, Separating variability and uncertainty-making choices, Human and Ecological Risk Assessment, An International Journal, In Press, February.

Kelly, E. and Roy-Harrison, W., 1998, A mathematical construct for ecological risk: A useful framework for assessments, Human and Ecological Risk Assessment, An International Journal, Vol. 4, No. 2, pp 229-241.

Kelly, E.J., Campbell, K., and Henrion, M., 1997, To Separate or Not to Separate - That is the Question - A Discourse on Separating Variability and Uncertainty in Environmental Risk Assessments, Learned Discourses, Society of Environmental Toxicology and Chemistry (SETAC) News, November.

Kuczera, G., 1988, On the Validity of First-order Prediction Limits for Conceptual Hydrologic Models, J. of Hydrol., 103, 229-247

Lal, W., 1995, Sensitivity and Uncertainty Analysis of a Regional Model for the Natural System of South Florida. South Florida Water Management District, West Palm Beach, FL, Draft report, November

Lal, W., Obeysekera, J. and van Zee, R., 1997, Sensitivity and Uncertainty Analysis of a Regional Simulation Model for the Natural System in South Florida, in Managing Water: Coping with Scarcity and Abundance, Proceedings, 27th Congress of International Association for Hydraulic Research, San Francisco, CA. August.

Lal, A.M.W, 2000, Numerical Errors in Groundwater and Overland Flow Models, Water Resources Research, Vol. 36, No. 5, May, pp 1237-1248

Lemons, J., ed. 1996, Scientific uncertainty and environmental problem solving. Blackwell, Cambridge, MA

Lopez, A. and Loucks, D.P., 1999, Uncertainty representations in water quality prediction. Manuscript, Civil and Environmental Engineering, Cornell University, Ithaca, NY

Loucks, D.P., Stedinger, J.R. and Haith, D.A., 1981, Water Resource Systems Planning and Analysis, Prentice-Hall, Englewood Cliffs, NJ

Ludwig, D., Hilborn, R., and Walters, C., 1993, Uncertainty, resource exploitation, and conservation: lessons from history, Science vol. 260, pp 17-36

Majoni, H. and Quade, E. S., 1980,, Pitfalls of analysis. John Wiley and Sons, New York

McCarthy, James J., Canziani, Osvaldo F., Leary, Neil A., Dokken, David J., White, Kasey S., (eds), 2001, Climate Change 2001: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Published for the Intergovernmental Panel on Climate Change. http://www.ipcc.ch/pub/tar/wg2/index.htm

McCuen, R., 1973, The role of sensitivity analysis in hydrologic modeling, Journal of Hydrology 18(1): 37-53.

McCuen, R. H. and Snyder, W. M., 1983, Hydrologic Modeling: Statistical Methods and Applications. Englewood Cliffs, NJ, Prentice-Hall.

Meixner, T., Gupta, H. V., Bastidas, L. A., and Bales, R. C., 1999, Sensitivity analysis using mass flux and concentration, Hydrological Processes 13: 2233-2244.

Miser, H J., 1980, “Operations research and systems analysis.” Science., 209, 174 -182.

Morgan, M.G., and Henrion, M., 1990, Uncertainty, A guide to dealing with uncertainty in quantitative risk and policy analysis, Cambridge University Press. Cambridge, UK.

Nearing, M. A., Deer-Ascough, L. and Laflen, J. F., 1990, Sensitivity analysis of the WEPP hillslope profile erosion model, Transactions of the American Society of Agricultural Engineers 33(3): 839-849.

National Research Council (NRC), 1989, Improving Risk Communication, National Academy Press, Washington, DC.

National Research Council (NRC), 1994, Science and Judgment in Risk Assessment, National Academy Press, Washington, DC

National Research Council (NRC), 1996, Committee on Risk Characterization, Understanding Risk: Informing Decision in a Democratic Society," P.S. Stern and H.V. Fineberg, (eds.) National Academy Press, Washington, D.C.

Phillips D.L. and Marks D.G., 1996, Spatial uncertainty analysis: propagation of interpolation errors in spatially distributed models. Ecological Modelling 91: 213-229.

Press, S.J., and Tanur, J.M., 2001, The Subjectivity of Scientists and the Bayesian Approach. New York: Wiley.

Reckhow, K.H., 1994, Water quality simulation modeling and uncertainty analysis for risk assessment and decision making. Ecological Modelling. 72:1-20.

Reckhow, K.H., 1999, Water quality prediction and probability network models. Canadian Journal of Fisheries and Aquatic Sciences. 56:1150-1158.

Reckhow K., 2002, Applications of Water Models: Prediction Uncertainty and Decision Making. Presentation at Model Uncertainty Workshop, South Florida Water Management District, West Palm Beach, FL, January

Saltelli, A., Chan, K., and Scott, E.M., (ed.), 2000, Sensitivity Analysis, John Wiley & Sons, Chichester, UK

Schweppe, F.C., 1973, Uncertain Dynamic Systems, Prentice-Hall, Englewood Cliffs, NJ

Shapiro, H.T., 1990, The willingness to risk failure, Science, 250(4981), 609.
.
Simon, I-I. A., 1988, Prediction and prescription in system modeling, 15th Anniversary of IIASA, Int, Inst. for Applied Systems Analysis, Laxenburg, Austria.

Sklar, F. H. and Hunsaker, C.T., 2001, The Use and Uncertainties of Spatial Data for Landscape Models: An Overview with Examples from the Florida Everglades, Chapter 2 in Spatial Uncertainty in Ecology, Implications for Remote Sensing and GIS Applications, Hunsaker et al. eds, Springer

Sorooshian, S., Gupta, V.K., and Fulton, J.L., 1983, Evaluation of maximum likelihood parameter estimation techniques for conceptual rainfall-runoff models--influence of calibration data variability and length on model credibility, Water Resources Research, 19(1), 251-259

Sorooshian, S., Duan, Q. and Gupta, V.K., 1993, Calibration of Rainfall-Runoff Models: Application of global optimization to the Sacramento soil moisture accounting model, Water Resources Research, 29(4), 1185-94

Soutter, M. and Musy, A., 1999, Global sensitivity analyses of three pesticide leaching models using a Monte-Carlo approach, Journal of Environmental Quality 28: 1290-1297.

Spear, R.C. and Hornberger, G.M, 1980, Eutrophication in Peel Inlet – II. Identification of critical uncertainties via generalized sensitivity analysis. Water Research 14: 43-49.

Stedinger, J.R. and Taylor, M.R., 1982, Synthetic Streamflow Generation, Part II. Effect of Parameter Uncertainty, Water Resources Research, 18(4), 919-924

Stokey, E. and Zeckhauser, R., 1977, A primer for policy analysis,. W. W. Norton and Co., Inc., New York, N. Y.

Suter, G.W., II. 1993, Ecological Risk Assessment. Lewis Publishers. Boca Raton, FL

Tattari, S. and Barlund, I., 2001, The concept of sensitivity in sediment yield modelling, Physics and Chemistry of the Earth 26(1): 27-31.

van Griensven, A., Francos, A. and Bauwens, W., 2001. "Sensitivity Analysis and Auto-calibration of an Integral Dynamic Model for River Water Quality." In Progress.

van Harn Adams, B.A., 1998, "Parameter Distributions for Uncertainty Propagation in Water Quality Modeling." Doctoral Dissertation, Duke University.

van Straten, G., 1983, Maximum likelihood estimation of parameters and uncertainty in phytoplankton models, in Uncertainty and Forecasting of Water Quality, M.B. Beck and G. van Straten (ed.), Springer Verlag, New York

Vollenweider, R.A., 1976, Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication, Memorie dell'Istituto Italiano di Idrobiologia, 33, 53-83

von Winterfeldt, D., and Edwards, W., 1986, Decision Analysis and Behavioral Research, Cambridge University Press, Cambridge, UK.

Warwick, J.J. and Cale, W.G., 1987, Determining likelihood of obtaining a reliable model, J. Env. Eng., 113(5), 1102-1119

Appendix I: Model Calibration Examples

- *Calibration of models in the Murray-Darling Basin*

In the Murray-Darling Basin, in order to preserve water quality, water reliability and the environment, a decision was made in 1995 to restrict water use to the 1993/94 level of development. Computer models of the major tributary streams are now used at the end of each year to determine the annual use target for the previous season based on that level of development. Rules are in place to ensure that long term usage is maintained at the agreed level. Because the models now define the overall water rights of each valley, there are legal requirements to calibrate models and each model is independently audited and certified as being unbiased before being approved as fit for purpose. The key model output of interest is water use but emphasis is also placed on the modeling of downstream flow which impacts the rights of downstream regions. Each model must be calibrated over at least ten years and this often means that changes in infrastructure, operating rules and growth in demand have to be incorporated into the calibration run. Calibration reports contain plots of modeled and observed water use, storage behavior and flow and statistics such as mean error, correlation coefficients and standard errors. The aim of calibration is to ensure that the model is unbiased and to give confidence to stakeholders.

An issue that is sometimes raised with model development is the role of calibration, where the model is fine-tuned to match the observed data, and validation where the model is tested against data that was not used in the calibration process to get an independent assessment of the model's accuracy. For the Murray River, because of the variability of our climate, we like to calibrate our model against a long period of data including the most recent years when the current operating rules were being used and the historical data is generally the most reliable. Validation is considered to be less important and is typically carried out using the two or three years of data available following the completion of model calibration.

- *Use of models for Allocating Water in Texas*

Recent legislation in Texas revised the State Water Planning process and mandated the development of water allocation models for every river basin in the state (http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/permits.html). Similar to the Murray – Darling situation, these models are used to provide estimates of reliability for all permitted water diversions in the state as well as analysis of the effects of all permit applications. Naturalized, or predevelopment, time series of flows were constructed for the basins, and then the effects of developments were added in to achieve models of the current situation. The process of developing the basin models was an iterative, peer reviewed calibration process subject to stakeholder comment at several critical junctures. The naturalized flows and subsequent development of the basins now form an accepted and legal basis for future water allocations. Currently, similar activities are ongoing to provide calibrated and verified models of the state's groundwater aquifers and usage.

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

California Sportfishing Protection Alliance
"An Advocate for Fisheries, Habitat and Water Quality"

california water impact network

January 19, 2010

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Subject: Comments on the Draft Environmental Assessment and Findings of No Significant Impact for the *2010-2011 Water Transfer Program*

Dear Messrs. Hubbard and Messer:

AquAlliance, the California Sportfishing Protection Alliance, and the California Water Impact Network ("the Coalition") submit the following comments and questions for the Draft Environmental Assessment ("EA") and Findings of No Significant Impact ("FONSI"), for the *2010-2011 Water Transfer Program* ("Project"). We also provide comments about the purpose and need for the 2010-2011 state and federal water transfer programs that are mirror images of the 2009 Drought Water Bank.

The Bureau of Reclamation's draft environmental review of the Project does not comply with the requirements of National Environmental Policy Act ("NEPA"), 42 U.S.C. §4321 *et seq.* First, we believe that the Bureau needs to prepare an environmental impact statement ("EIS") on this proposal, as we believed for the 2009 Drought Water Bank ("DWB") that allowed up to 600,000 acre-feet (AF) of surface water transfers, up to 340,000 AF of groundwater substitution, and significant crop idling. The *2010-2011 Water Transfer Program* seeks approval for 200,000 AF of CVP related water and suggests that the EA covers non-CVP transfer water. Unfortunately, the non-CVP water appears late in the EA (section 3.18 Cumulative impacts), where the table identifies the non-CVP water (p. 3-107), but does not supply a sub-total. When added, non-CVP water equals 195,910 AF of additional water for transfers. The EA reveals that "the cumulative total amount potentially transferred from all sources would be up to 392,000 acre feet," (p. 3-108) but the actual cumulative number is 395,910 AF of CVP and non-CVP water**.** The failure to supply sub-totals and the mathematical carelessness leaves the reader wondering what other liberties have been taken within the 2010-2011 Water Transfer Program.

Bureau reliance on the EA itself violates NEPA requirements because, among other things, the EA fails to provide a reasoned analysis and explanation to support the Bureau's proposed finding of no significant impact. The EA contains a fundamentally flawed alternatives analysis, and treatment of the chain of cause and effect extending from project implementation leading to inadequate analyses of nearly every resource, growth inducing impacts, and cumulative impacts. An EIS would afford the Bureau, DWR, the State Water Resources Control Board, and the California public far clearer insight into how, where, and why the *2010-2011 Water Transfer Program* might or might not be needed. The draft EA/FONSI as released this month fails to provide adequate disclosure of these impacts.

Second, California Environmental Quality Act (CEQA) analysis of the 2010-2011 Water Transfer Program is completely absent at the programmatic level. Is the negligence in this regard due to the present litigation that challenges the 2009 Drought Water Bank exemption? The Project's actual environmental effects —which are similar to the 2009 DWB, the Sacramento Valley Water Management Agreement, and the proposed 1994 Drought Water Bank (for which a final Program Environmental Impact Report was completed in November 1993) – are not presented in the EA, FONSI, or in any CEQA document. The Sacramento Valley Water Management Agreement was signed in 2002 and the need for a programmatic EIS/EIR was clear and initiated, but never completed. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken. Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate. So, the Bureau's failure to conduct scientifically supported environmental review in an EIS and DWR's negligence to provide CEQA review reflects an end-run around established law through the use of water transfers, and is therefore vulnerable to legal challenge under the National Environmental Protection Act ("NEPA") and CEQA.

Finally, we also question the merits of and need for the Project itself. The existence of drought conditions at this point in time is highly questionable and reflects the state's abandonment of a sensible water policy framework. Our organizations believe the Bureau's EA/FONSI and the absence of DWR's programmatic review go too far to help a few junior water right holders at the expense of agriculture, communities, and the environment north of the Delta. The 2010-2011 Water Transfer Program will directly benefit the areas of California whose water supplies are the least reliable by operation of state water law. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The proposed Project will have significant effects on the environment—both standing alone and when reviewed in conjunction with the multitude of other plans and programs (including the non-CVP water that is mentioned in the EA cumulative impacts section) that incorporate and are dependent on Sacramento Valley water. Ironically, the Bureau appears to recognize in its cumulative impacts discussion that there is potential for significant adverse impacts associated with the Project, but instead of conducting an EIS as required, attempts to assure the public that the 2010-2011 Water Transfer Program will be deferred to the "willing sellers" through individual "monitoring and mitigation programs" as well as through constraining actions taken by both DWR and Bureau professional staff whose criteria ought instead be incorporated into the Proposed Action Alternative (EA at p. 2-1, FONSI at p. 1-9). It is impossible to evaluate whether or not the mitigation and monitoring pans will be adequate to relieve the Bureau and DWR of responsibility for impacts from the Project (including the non-CVP water transfers). The language used in the EA (p.3-25) and the *Draft Technical Information for Water Transfers in 2010* (November 2009) (p. 26-31) fail to pass the blush test (details below).Of course, this is not a permissible approach under NEPA; significant adverse impacts should be mitigated—or avoided altogether as CEQA normally requires.[1] Moreover, in light of the wholly inadequate monitoring and mitigation planned for the 2010-2011 Water Transfer Program's extensive water transfer program, the suggestion that the public should be required to depend on the insufficient monitoring to provide the necessary advance notice of "significant adverse impacts" is an unacceptable position.

We incorporate by reference the following documents:

- Butte Environmental Council's comments on the Supplemental Environmental Water Account EIR/EIR, 2006.
- Butte Environmental Council's letter to DWR regarding the Drought Water Bank Addendum from Lippe Gaffney Wagner LLP, 2009.
- Butte Environmental Council's letter to DWR regarding the Drought Water Bank Addendum.
- Multi-Signatories letter regarding the Drought Water Bank, 2008.
- Professor Kyran Mish's White Paper, 2008.
- Professor Karin Hoover's Declaration, 2008.

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[1] Perhaps even more telling, the Bureau actually began its own Programmatic EIS to facilitate water transfers from the Sacramento Valley and the interconnected actions that are integrally related to it, but never completed that EIS and now has impermissibly broken out this current segment of the overall Program for piecemeal review in the present draft EA. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "include[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" *Id.* At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").

I. The Bureau and DWR Must Prepare an Environmental Impact Statement/ Environmental Impact Report on the Proposed 2010-2011 Water Transfer Program

We strongly urge the Bureau to withdraw this inadequate environmental document and instead prepare a joint EIS/R on the 2010-2011 Water Transfer Program, before approval by the State Water Resources Control Board (SWRCB), in order to comply with both NEPA and CEQA requirements for full disclosure of human and natural environmental effects.

NEPA requires federal agencies to prepare a detailed environmental impact statement on all "major Federal actions significantly affecting the quality of the human environment . . . ." 42 U.S.C. §4332(2)(C). This requirement is to ensure that detailed information concerning potential environmental impacts is made available to agency decision makers and the public before the agency makes a decision. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989). CEQA has similar requirements and criteria.

Under NEPA's procedures, an agency may prepare an EA in order to decide whether the environmental impacts of a proposed agency action are significant enough to warrant preparation of an EIS. 40 C.F.R. §1508.9. An EA must "provide sufficient evidence and analysis for determining whether to prepare an [EIS]" (*id.*), and must demonstrate that it has taken a "'hard look' at the potential environmental impact of a project." *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208, 1212 (9th Cir. 1998) (internal quotation marks omitted). However, the U.S. Court of Appeals for the Ninth Circuit has cautioned that "[i]f an agency decides not to prepare an EIS, it must supply a convincing statement of reasons to explain why a project's impacts are insignificant." *Id.* (internal quotation marks omitted). The Bureau has not provided a convincing statement of reasons explaining why the DWB's impacts are not significant. So long as there are "substantial questions whether a project *may* have a significant effect on the environment," an EIS must be prepared. *Id.* (emphasis added and internal quotation marks omitted). Thus, "the threshold for requiring an EIS is quite low." *NRDC v. Duvall*, 777 F. Supp. 1533, 1538 (E.D. Cal. 1991). Put another way, as will be shown through our comments, the bar for sustaining an EA/FONSI under NEPA procedures is set quite high, and the Bureau fails to surmount it on the 2010-2011 Water Transfer Program.

NEPA regulations promulgated by the Council on Environmental Quality identify factors that the Bureau must consider in assessing whether a project may have significant environmental effects, including:

(1) "The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks." 40 C.F.R. §1508.27(b)(5).
(2) "The degree to which the effects on the quality of the human environment are likely to be highly controversial." *Id.* §1508.27(b)(4).
(3) "Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate on a cumulatively significant impact on the environment. Significance

cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

(4) "The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration." *Id.* §1508.27(b)(6).

(5) "The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973." *Id.* §1508.27(b)(9).

Here, the Bureau has failed to take a hard look at the environmental impacts of the Project. As detailed below, there are substantial questions about whether the 2010-2011 Water Transfer Program's proposed water transfers will have significant effects on the region's environmental and hydrological conditions especially groundwater, the interactions between groundwater and surface streams of interest in the Sacramento Valley region, and the species dependent on aquatic and terrestrial habitat. There are also substantial questions about whether the 2010-2011 Water Transfer Program will have significant adverse environmental impacts when considered in conjunction with the other related water projects that have occurred in the last decade and that are underway and proposed in the region. The Bureau simply cannot rely on the EA/FONSI for the foreseeable environmental impacts of the proposed 2010-2011 Water Transfer Program and still comply with NEPA's requirements.

A. The Proposed Action Alternative is poorly specified making it difficult to identify chains of cause and effect necessary to analyze adequately the alternative's environmental effects.

The Proposed Action Alternative is poorly specified and needs additional clarity before decision makers and the public can understand the human and environmental consequences of the 2010-2011 Water Transfer Program. The EA describes the Proposed Action Alternative as one reflecting the Bureau's intention to approve transfers of Central Valley Project water from willing sellers who contract with the Bureau ordinarily to use surface water on their croplands. Up to 200,000 AF of CVP water are offered from these sellers, according to Table 2-1 of the EA. In contrast to the EA/FONSI for the 2009 Drought Water Bank, the EA contains no "priority criteria" to determine water deliveries and simply acknowledges that water will be transfered to agricultural and urban interests (p. 3-88). The EA fails to indicate how much water has been requested by the buyers of CVP or non-CVP water, which is also in contrast to the EA/FONSI and DWR's addendum for the 2009 Drought Water Bank. This denial of information further obfuscates the need for the Project.

The EA/FONSI's statement of purpose and need (p. 1-1) states specifically that, "To help facilitate the transfer of water throughout the State, Reclamation and the Department of Water Resources (DWR) are considering whether they should approve and facilitate water transfers between willing sellers and buyers." This paragraph omits coherent discussion of need. Merely stating that, "The transfer water would be conveyed, using CVP or SWP facilities, to water users that are at risk of experiencing water shortages in 2010 and 2011 due to drought conditions and that require supplemental water supplies to meet anticipated demands," lacks specificity and rigor. The purpose and need should also state that this transfer program would be subject to specific criteria for prioritizing transfers.

The EA's description of the proposed action alternative needs to make clear what would occur if sale criteria are in fact applied and if exceptions will be allowed, and if so, by what criteria would exceptions be made.. Do both Project agencies lack criteria to prioritize water transfers? What is the legal or policy basis to act without providing priority criteria? Without foundational criteria, the public is not provided with even a basic understanding of the need for the Project.

There is considerable ambiguity over just how many potential sellers there are and how much water they would make available. The EA states that, "Entities that are not listed in this table [2-1] may decide that they are interested in selling CVP water, but those transfers may require supplemental NEPA analysis to allow Reclamation to complete the evaluation of the transfers," (p. 2-3 and 2-4). Allowing a roving Project location is not permissible and avoids accurate analysis of all impacts including growth inducing and cumulative impacts.

Absent buyers' request numbers and the potential for the participation of unknown additional sellers signals that neither the Bureau nor DWR have a clear idea what the 2010-2011 Water Transfer Program is intended to be. This problem contributes greatly to and helps explain the poorly rendered treatment of causes and effects that permeate the Bureau's EA. The project agencies, decision-makers, and the public all face a moving target with the 2010-2011 Water Transfer Program. Such discrepancies reflect hasty consideration and poor planning by project proponents. Nor can the agencies reasonably attribute their inadequate environmental reviews on lack of warning. The Governor, Senator Dianne Feinstein, and congressional representatives from the San Joaquin Valley have all made fear of drought a centerpiece of their water statements in 2008 and 2009. Yet DWR and the Bureau apparently are not able to present a stable Project with clear needs and criteria.

From data available in the EA and the Addendum, it is not possible to determine with confidence just how much water is requested by potential urban and agricultural buyers. There is no attempt to describe how firmly tendered are offers of water to sell or requests to purchase. Guessing at the possible requests based on the 2009 DWB where there were between 400,000 and 500,000 AF of presumably urban buyer requests[2] alone (which had priority over agricultural purchases, according to the 2009 DWB priorities) and a cumulative total of less than 400 TAF from willing sellers, which is also true for the 2010-2011 Water Transfer Program (with just over half that coming from CVP water), it would appear that many buyers are not likely to have their needs addressed by the 2010-2011 Water Transfer Program. If so, the Bureau and DWR should state

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[2] Neither DWR's Addendum nor the Bureau's EA specify numerical requests for the cities of Huron, Avenal, Coalinga, and the Avenal State Prison making it impossible to have a firmer number for the amount of urban request for water. Our estimate assumes SCVWD's 30,000 AF and MWD's 300,000 AF requests are for entirely urban uses of DWB-purchased water.

the likelihood that many requests will not be fulfilled in order to achieve a full and correct environmental compliance treatment of the proposed action. Such an estimate is necessary for accurate explication of the chains of cause and effect associated with the 2010-2011 Water Transfer Program—and which must propagate throughout a NEPA document for it to be adequate as an analysis of potential natural and human environmental effects of the proposed project. We have additional specific questions:

- What are the requests of the San Luis and Delta Mendota Water Authority (SLDMWA)? Is the request for an agricultural use or an urban use of Project water? If it is entirely for agricultural uses, how likely is it to be fulfilled under the non-stated Project priorities for water sales?
- What are the specific urban requests for water made by Avenal State Prison, and the cities of Avenal, Huron, and Coalinga, nested within the SLDMWA request?
- Will sale criteria be premised on full compliance with all applicable environmental and water rights laws? If so, how will cumulative impacts be analyzed under CEQA?

If priority criteria were revealed, how will intervening economic factors beyond the control of the Project be analyzed? Given the added uncertainty, an EIS should be prepared to provide the agencies with advance information and insight into what the sensitivity of the program's sellers and buyers are to the influences of prices—prices for water as well as crops such as rice, orchard and vineyard commodities, and other field crops. It is plausible that crop idling will occur more in field crops, while groundwater substitution would be more likely for orchard and vineyard crops. However, high prices for rice—the Sacramento Valley's largest field crop—would undermine this logic, and could lead to substantial groundwater substitution. These potential issues and impacts should be recognized as part of the 2010-2011 Water Transfer Program description and should directly apply to the Agriculture and Land Use, and Socioeconomic sections of the EA, because crop prices are key factors in choices potential water sellers would weigh in deciding whether to idle crops, substitute groundwater, or decline to participate in the DWB altogether. The EA is inadequate because it fails to identify and analyze the market context for crops as well as water that would ultimately influence the size and scope of the 2010-2011 Water Transfer Program.

Rice prices are high because of conditions for the grain in the world market. Drought elsewhere is a factor in reduced yields, but growing populations in south and east Asia demand more rice and the rice industry has struggled to meet that demand.[3]

This is very important. The Bureau tacitly admits that the Bureau—and by logical extension, DWR—has no idea how many sales of what type (public health, urban, agricultural) can be expected to occur. Put another way, there is a range of potential outcomes for the 2010-2011 Water Transfer Program, and yet the Bureau has failed utterly to use the EA to examine a

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[3] "Panic over rice prices hits California," *AZCentral.com*, April 24, 2008; UN News Service, "Bumper rice harvests could bring down prices but poor may not benefit, warns UN," 25 February 2009; "Era of cheap rice at an end in Taiwan: COA," *The China Post*, March 5, 2009; Jim Downing, "Sacramento Valley growers se rice prices soar," *Sacramento Bee*, 18 January 2009.

reasonable and representative range of alternatives as it concerns how the priority criteria would be established and affect Project transfers. And DWR has not bothered to conduct an appropriate level of review under CEQA...

Nor does the 2010-2011 Water Transfer Program prevent rice growers (or other farmers) from "double-dipping." It appears to us they could opt to turn back their surface supplies from the CVP and the State Water Project and substitute groundwater to cultivate their rice crop—thereby receiving premiums on both their CVP contract surface water as well as their rice crop this fall when it goes to market. There appear to be no caps on water sale prices to prevent windfall profits to sellers of Sacramento Valley water in the event that groundwater is substituted in producing crops—especially for crops where market prices are high, such as in rice. The DWB in the 1990s capped water prices at $125/acre-foot, much to the disappointment of some water sellers at that time. Why are the state and federal projects encouraging such potential windfall profits at a time when many others suffer through this recession?

As stated, neither the Bureau nor DWR state how much of these transfers would go to public health, urban or agricultural buyers. The EA must also (but fails to) address the ability and willingness of potential buyers to pay for Project water given the supplies that may be available. Historically, complaints from agricultural water districts were registered in the comments on the Draft EWA EIS/R and reported in the Final EIS/R in January 2004 indicating that they could not compete on price with urban areas buying water from the EWA. Given the DWB's priority criteria, will agricultural water buyers identified in Table 2-2 of the EA be able to buy water when competing with the likes of the Santa Clara Valley Water District and the Metropolitan Water District, representing two of the wealthiest regions of California? As a matter of statewide water, infrastructure, and economic policy, is it wise to foment urban versus agricultural sector competition for water based solely on price? Shouldn't other factors be considered in allocating water among our state's regions? This fails dramatically to encourage regions to develop their own water supplies more efficiently and cost-effectively without damage to resources of other regions.

Full disclosure of each offer of and each request for 2010-2011 Water Transfer Program water should be provided as part of the EA. This is necessary so the public can understand and have confidence in the efficacy of the Project's purpose and need, benefit from full disclosure of who requests what quantity of water and for what uses, and so that the public may easily verify chains of cause and effect. Urban application of transferred surface water is not examined in the EA/FONSI, as though how urban buyers would use their purchased water had no environmental effects. Since the dry period in California has lasted for over three years, how will purchased water be used and conserved? What growth inducing impacts will transferred water facilitate?

Nor is a hierarchy of priority uses among urban users for purchasing Project water presented. Could purchased water be used for any kind of landscaping, rather than clearly domestic purposes or strictly for drought-tolerant landscaping? We cannot tell from the EA/FONSI narrative. How can the citizens of California be assured that water purchased through the 2010-

2011 Water Transfer Program will not be used wastefully, in violation of the California Constitution, Article X, Section 2?

Will urban users need their Project purchased water only in July through September, or is that the delivery period preferred in the DWB because of ecological and fishery impact constraints on conveyance of purchased water?

Should agricultural water users be able to buy any Project water, how will DWR and the Bureau assure that transferred water for irrigation is used efficiently? Many questions are embedded within these concerns that DWR and the Bureau should address, especially when they approach the State Water Resources Control Board to justify consolidating their places of use in their respective water rights permits:

- How much can be expected to be purchased by agricultural water users, given the absence of any criteria, let alone priority criteria, in the 2010-2011 Water Transfer Program?
- How much can be expected to be consumptively used by agricultural water buyers?
- How much can be expected to result in tailwater and ag drainage?
- How much can be expected to add to the already high water table in the western San Joaquin Valley?
- What selenium and boron loads in Mud Slough and other tributaries to the San Joaquin River may be expected from application of this water to WSJ lands?
- What mitigation measures are needed to limit such impacts consistent with the public trust doctrine, Article X, Section 2 of the California Constitution, the Porter-Cologne Water Quality Control Act, and California Fish and Game Code Section 5937?

In other words, the most important chains of cause and effect—extending from the potential for groundwater resource impacts in the Sacramento Valley to potential for contaminated drainage water from farm lands in the western San Joaquin Valley where much of the agricultural buyers are located—are ignored in the Bureau's EA/FONSI and completely missing due to DWR's failure to comply with CEQA.

Will more of surface water transfers go to urban users than to ag users? The EA's silence on this is disturbing, and highlights the absence of priority criteria. What assurances will the Bureau and DWR provide that criteria exist or will be developed and how will these criteria be presented to the public and closely followed?

- The more that goes to urban water agencies the less environmental impacts there would be on drainage impaired lands of the San Joaquin Valley, a neutral to beneficial impact of the Project's operation on high groundwater and drainage to the SJR.
- However, the more Project water goes to agricultural users than to urban users, the higher would be groundwater levels, and more contaminated the groundwater would be in the western San Joaquin Valley and the more the San Joaquin River would be negatively affected from contaminated seepage and tailwater by operation of the Project.

The EA fails to provide a map indicating where the cumulative sources of the Project are located, and where the service areas are to which water would be transferred under the 2010-2011 Water Transfer Program.

Two issues concerning water rights are raised by this EA/FONSI:

- **Consolidated Place of Use.** Full disclosure of what the consolidated places of use for DWR and USBR would be, since the permit request to SWRCB will need NEPA coverage. Why is the flexibility claimed for the consolidated place of use necessary to this year's water transfer program? Couldn't the transfers be facilitated through transfer provisions of the Central Valley Project Improvement Act? Will the consolidation be a permanent or temporary request be limited to the duration of the governor's 2009 emergency declaration or of just the 2010-2011 Water Transfer Program? When is the 2010-2011 Water Transfer Program scheduled to sunset? How do the consolidated place of use permit amendments to the SWP and CVP permits relate to their joint point of diversion? Why doesn't simply having the joint point of diversion in place under D-1641 suffice for the purpose of the Project?
- **Description of the water rights of both sellers and buyers.** This would necessarily show that buyers clearly possess junior water rights as compared with those of willing sellers. Lack of full disclosure of these disparate rights is needed to help explain the actions and motivations of buyers and sellers in the 2010-2011 Water Transfer Program, otherwise the public and decision makers have insufficient information on which to support and make informed choices.
    - **Sacramento Valley water rights** – correlative groundwater rights, riparian rights and CVP settlement contract rights
    - **San Joaquin Valley water rights** – CVP contract rights only, junior-most contractors within the CVP priority system (especially Westlands Water District).
    - **Priority of allocations among water contractors within the CVP and SWP.**

To establish a proper legal context for these water rights, the Project Action Alternative section of the EA/FONSI should also describe more extensively the applicable California Water Code sections about the treatment of water rights involved in water transfers.

Thus, there are many avenues by which the 2010-2011 Water Transfer Program is a poorly specified program for NEPA and CEQA purposes, leaving assessment of its environmental effects at best murky, and at worst, risky to all involved, especially users of Sacramento Valley groundwater resources.

B. Correcting the EA's poorly specified chains of cause and effect forces consideration of an expanded range of alternatives.

The Proposed Action Alternative need not have sophisticated forecasts of prices for rice and other commodities. Instead, for an adequate treatment of alternatives, the EA should have examined several reasonable scenarios beyond simply the 2010-2011 Water Transfer Program and a "no action" alternative. Three reasonable permutations would have considered relative proportions of crop idling versus groundwater substitution (e.g., high/low, low/high, and equal proportions of crop idled water and groundwater substitution). Other reasonable drought response alternatives that can meet operational and physical concerns merit consideration and analysis by the Bureau includes:

- Planned permanent retirement of upslope lands in the western San Joaquin Valley where CVP-delivered irrigation water is applied to lands contaminated with high concentrations of selenium, boron and mercury, and which contribute to high water table and drainage problems for lowland farmers, wetlands and tributaries of the San Joaquin River. Retirement of these lands would permanently free up an estimated 3 million acre-feet of state and federal water during non-critical water years. Ending irrigation of these lands would also result in substantial human environmental benefits for the San Joaquin River, the Bay-Delta Estuary, and the Suisun Marsh from removal of selenium, boron, and salt contamination. Having such reasonable and pragmatic practices in place would go a long way to eliminate the need for drought water banks in the foreseeable future.
- More aggressive investment in agricultural and urban water conservation and demand management among CVP and SWP contractors even on good agricultural lands, including metering of all water supply hook-ups by all municipal contractors, statewide investment in low-flush toilets and other household and other buildings' plumbing fixtures, and increased capture and reuse of recycled water. Jobs created from such savings and investments would represent an economic stimulus that would have lasting job and community stability benefits as well as lasting benefits for water supply reliability and environmental stabilization.

C. The 2010-2011 Water Transfer Program EA fails to specify adequate environmental baselines, or existing conditions, against which impacts would be assessed and mitigation measures designed to reduce or avoid impacts.

The 2010-2011 Water Transfer Program environmental review by the Bureau incorporate by reference for specific facets of their review the 2003/2004 and 2007/2008 Environmental Water Account EIS/R documents. In both cases, these environmental reviews were conducted on a program whose essential purpose is to "provide protection to at-risk native fish species of the Bay-Delta estuary through environmental beneficial changes in State Water Project/Central Valley Project operations at no uncompensated water cost to the Projects' water users. This approach to fish protection involves changing Project operations to benefit fish and the acquisition of alternative sources of project water supply, called the 'EWA assets,' which the EWA agencies use to replace the regular Project water supply lost by pumping reductions."

The two basic sets of actions of the EWA were to:

- Implement fish actions that protect species of concern (e.g., reduction of export pumping at the CVP and SWP pumps in the Delta); and

- Increase water supply reliability by acquiring and managing assets to compensate for the effects of the fish actions (such as by purchasing water from willing sellers for instream flows that compensates the sellers for foregone consumptive use of water).

Without going into further detail on the EWA program, there is no attempt by the EWA agencies to characterize its environmental review as reflective of water transfer programs generally; the EWA was a specific set of strategies whose purpose was protection of fish species of concern in the Delta, not drought aid for junior water right-holding areas of California. One consequence of this attempt to rely on the EWA EIS/R is that it makes the public's ability to understand the environmental baseline of the 2010-2011 Water Transfer Program impossible, because environmental baselines, differing purpose and need for the project, and many relevant mitigation measures are not readily available to the public. Merely referring to the EWA documents (e.g.) p. 3-47) mocks NEPA and CEQA missions to inform the public adequately about the environmental setting and potential impacts of the proposed project's actions. Moreover, a Water Transfer Program for urban and agricultural sectors is plainly not the same thing as an Environmental Water Account.

Another consequence is that the chains of cause and effect of an EWA versus a 2010-2011 Water Transfer Program are entirely different because of their different purposes. While the presence of water purchases, willing sellers, and requesting buyers is similar, the timing of EWA water flows are geared to enhancing and protecting fish populations; the water was to flow in Delta channels to San Francisco Bay and the Pacific Ocean. In stark contrast, the DWB's water flows focus water releases from the SWP and CVP reservoirs to be exported for deliveries in the July through September period, whereas EWA assets would be "spent" year-round depending on the specific need to protect fish. EWA was about purchasing water to provide instream flows in the Delta, while the DWB is to acquire water to serve consumptive uses outside of the Delta.

Furthermore, to tease out the various ways in which the EWA review—itself a two-binder document consisting of well over 1,000 pages—could be used to provide appropriate environmental compliance for the DWB is not even attempted by DWR and the Bureau which at least has staff that could have been assigned to undertake it; yet they do not. It is therefore well beyond the reach of non-expert decision-makers and the public, and the use of the EWA EIS/R as the basic environmental review for the DWB therefore violates both NEPA and CEQA.

Nor is any attempt made in the EWA EIS/R to characterize the EWA as a "program level" environmental review off of which a Water Transfer Program-like project could perhaps legitimately tier. In our view, this reliance on the EWA EIS/R obscures the environmental baselines of the DWB from public view, inappropriately conflates the purposes of two distinct environmental reviews, and flagrantly violates NEPA and CEQA. This could only be redressed by preparation of an EIS/R on the 2010-2011 Water Transfer Program.

Finally, the most significant baseline condition omitted in the Bureau's inadequate and DWR's negligent reporting relates to Sacramento Valley groundwater resources, discussed in the next section.

D. Scientific uncertainties and controversy about Sacramento Valley groundwater resources merit consideration that only an EIS can provide.

There is substantial evidence that the 2010-2011 Water Transfer Program may have significant impacts on the aquifer system underlying the project and the adjacent region that overlies the Tuscan Formation. This alone warrants the preparation of an EIS.

Additionally, an EIS is necessary where "[a] project['s] … effects are 'highly uncertain or involve unique or unknown risks.'" *Blue Mountains Biodiversity Project*, 161 F.3d at 1213 (quoting 40 C.F.R. §1508.27(b)(5)). Here, the draft EA/FONSI fails to adequately address gaps in existing scientific research on the hydrology of the aquifer system and the extent to which these gaps affect the Bureau's ability—and by logical extension, DWR's ability—to assess accurately the Project's environmental impacts.

1. Existing research on groundwater conditions indicates that the 2010-2011 Water Transfer Program may have significant impacts on the aquifer system.

The EA fails to describe significant characteristics of the aquifers that the 2010-2011 Water Transfer Program proposes to exploit. These characteristics are relevant to an understanding of the potential environmental effects associated with the 2010-2011 Water Transfer Program's potential extraction of up to 154,237 AF of groundwater (p, 2-4 and 3-107). First, the draft EA/FONSI fails to describe a significant saline portion of the aquifer stratigraphy of the 2010-2011 Water Transfer Program area. According to Toccoy Dudley, former Groundwater Geologist with the Department of Water Resources and former director of the Butte County Water and Resources Department, saline groundwater aquifer systems of marine origin underlie the various freshwater strata in the northern counties of Butte, Colusa, Glenn, and Tehama ("northern counties"). The approximate contact between fresh and saline groundwater occurs at a depth ranging from 1500 to 3000 feet. (Dudley 2005) (A list of all references cited in these comments can be found at the end of this letter.)

Second, the EA fails to discuss the pressurized condition of the down-gradient portion of the Tuscan formation, which underlies the northern counties Project area. Dudley finds that the lower Tuscan aquifer located in the Butte Basin is under pressure. "It is interesting to note that groundwater elevations up gradient of the Butte Basin, in the lower Tuscan aquifer system, are higher than the ground surface elevations in the south-central portion of Butte Basin. This creates an artesian flow condition when wells in the central Butte Basin are drilled into the lower Tuscan aquifer." (Dudley 2005). The artesian pressure indicates recharge is occurring in the up-gradient portions of the aquifer located along the eastern margin of the Sacramento Valley.

Third, the EA fails to describe the direction of movement of water through the Lower Tuscan Formation that underlies the northern counties. According to Dudley: "From Tehama County south to the city of Chico, the groundwater flow direction in the lower Tuscan is westerly toward the Sacramento River. South of Chico, the groundwater flow changes to a southwesterly direction along the eastern margin of the valley and to a southerly direction in the central portion of the Butte Basin." (Dudley 2005)

Fourth, the draft EA fails to disclose that the majority of wells used in the Sacramento Valley are individual wells that pump from varying strata in the aquifers. The thousands of domestic wells in the target export area that are vulnerable to groundwater manipulation and lack historic monitoring. The Bureau's 2009 DWB EA elaborated on this point regarding Natomas Central MWC (p. 39) stating that, "Shallow domestic wells would be most susceptible to adverse effects. Fifty percent of the domestic wells are 150 feet deep or less. Increased groundwater pumping could cause localized declines of groundwater levels, or cones of depression, near pumping wells, possibly causing effects to wells within the cone of depression. As previously described, the well review data, mitigation and monitoring plans that will be required from sellers during the transfer approval process will reduce the potential for this effect."

As the latter statement makes clear (even though this information was excluded from the Project EA), the Bureau hopes that individual mitigation and monitoring plans created by the sellers will reduce the potential for impact, but there is no assurance in the EA that it will reduce it to a level of insignificance for the thousands of well owners in the Sacramento Valley. The Coalition questions the adequacy of individual mitigation and monitoring plans and suggests that an independent third party, such as USGS, oversee the mitigation and monitoring program and not the Bureau and DWR. After the fiasco in Butte County during the 1994 Drought Water Bank and with the flimsy, imprecise proposal for mitigation and monitoring in the 2010-2011 Water Transfer Program (see details below), the agencies lack credibility as oversight agencies.

Fifth, the draft EA fails to provide recharge data for the aquifers. Professor Karin Hoover, Assistant Professor of hydrology, hydrogeology, and surficial processes from CSU Chico, found in 2008 that, "Although regional measured groundwater levels are purported to 'recover' during the winter months (Technical Memorandum 3), data from Spangler (2002) indicate that recovery levels are somewhat less than levels of drawdown, suggesting that, in general, water levels are declining." According to Dudley, "Test results indicate that the 'age' of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the Lower Tuscan Formation along the eastern margin of the valley have the 'youngest' water and the deeper wells in the western and southern portions of the valley have the 'oldest' water," adding that "the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas." (Dudley 2005). "This implies that there is currently no active recharge to the Lower Tuscan aquifer system (M.D. Sullivan, personal communication, 2004)," explains Dr. Hoover. "If this is the case, then water in the Lower Tuscan system may constitute fossil water with no known modern recharge mechanism, and, once it is extracted, it is gone as a resource," (Hoover 2008).

All of these aquifer characteristics are important to a full understanding of the environmental impacts of the 2010-2011 Water Transfer Program because there are numerous indications that other aquifer strata associated with the Lower Tuscan Formation are being operated near the limit of overdraft and could be affected by the 2010-2011 Water Transfer Program (Butte County 2007). The Bureau has not considered this important historic information in the draft EA. According to Dudley, the Chico area has a "*long term average decline in the static groundwater level of about 0.35 feet-per-year*." (2007) (emphasis added.) Declining aquifer levels are not limited to the Chico Municipal area. This trend of declining aquifer levels in Chico, Durham and the Cherokee Strip is illustrated in a map submitted with this comment letter (CH2M Hill 2006).

Declining groundwater elevations have been observed specifically in Butte County. A 2007 Butte Basin Groundwater Status Report describes the "historical trend" in the Esquon Ranch area as showing "seasonal fluctuation (spring to fall) in groundwater levels of about 10 to 15 feet during years of normal precipitation and less than 5 feet during years of drought." The report further notes: "Long-term comparison of spring-to-spring groundwater levels shows a decline of approximately 15 feet associated with the 1976-77 and 1986-94 droughts (Butte Basin Water Users Association, 2007). The 2008 report indicates that, "The spring 2008 groundwater level measurement was approximately three feet higher than the 2007 measurment, however it was still four feet lower than the average of the previous ten spring measurements. Fall groundwater levels are approximately nine feet lower than the averages of those measured during either of the previous drought periods on the hydrograph. At this time it appears that there may be a downward trend in groundwater levels in this well," (Butte Basin Water Users Association, 2008).Thus, "*it appears that there may be a downward trend in groundwater levels in this well*." *Id.* (emphasis added).

Groundwater elevations in the Pentz sub-area in Butte County also reveal significant historical declines. The historical trend for this sub-area "…shows that the average seasonal fluctuation (spring to fall) in groundwater levels averages about 3 to 10 feet during years of normal precipitation and approximately 3 to 5 feet during years of drought. Long-term comparison of spring-to-spring groundwater levels shows a decline in groundwater levels during the period of 1971-1981, perhaps associated with the 1976-77 drought. Since a groundwater elevation high of approximately 145 feet in 1985 the measured groundwater levels in this well have continued to decline. Recent groundwater level measurements indicate that the groundwater elevation in this well is approximately 15-25 feet lower than the historical high in 1985. *Id.* Water elevations at the Pentz sub-area well have been monitored since 1967. "Since 1985 spring groundwater levels in this well have been declining and the spring 2009 measurement hit an historic low level ten feet below historical high levels and continues the downward trend on the hydrograph." *Id.* The Pentz area is located east of U.S. 99, in the eastern, upslope portion of the Tuscan aquifer. Further evidence of changing groundwater levels appear in the Vina sub-region of Butte County, where water elevations have been monitored since 1947 at well 23N/01W09E001M . The historical averages, including 2008 data, are; Spring=156 feet and Fall=150 feet (Butte County p. 37-38). Unfortunately, the groundwater level measurement at this well in 2008 was the lowest recorded since 1994 (Butte County p. 38). Rock Creek, which is also in the Vina sub-unit once held water all year and salmon fishing was robust prior to the 1930s (Hennigan 2010). Declining groundwater levels have caused the valley portion of Rock Creek to run completely dry each year and have also been noticed with Hennigan Farms' wells since the 1960s. For example, a 1968 well had to be lowered 40 feet in 1974, another well constructed in 1978 had to be lowered 20 feet in 2009, and an old 1940s flood pump was lowered in the early 1960s, lowered again in 1976 when it was converted to a pressure pump, and lowered again in 1997 (Hennigan 2010).

In light of this downward trend in regional groundwater levels, the Bureau's EA should closely analyze replenishment of the aquifers affected by the proposed 2010-2011 Water Transfer Program. The draft EA fails to provide any in-depth assessment of these issues. For example, the EA fails to discuss the best available estimates of where groundwater replenishment occurs. Lawrence Livermore National Laboratory analyzed the age of the groundwater in the northern counties to shed light on this process: "Utilizing the Tritium (H3) Helium-3 (He3) ratio, the age of each sample was estimated. Test results indicate that the "age" of the groundwater samples ranges from less than 100 years to tens of thousands of years,: (Dudley et al. 2005). As mentioned above, Dudley opines that the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas. (2005).

Are isotopic groundwater data available for other regions in the Sacramento Valley? If so, they would be crucial for all concerned to understand the potential impacts from the proposed 2010-2011 Water Transfer Program. For example, the EA states, "The WFA area that could be affected by the proposed action includes only the 'North Area' bounded on the north and east by the Sacramento County line, by the Sacramento River on the west, and by the American River on the south." EA at p. 34. If this is the area in Sacramento County that is identified as most vulnerable to groundwater impacts, yet two major rivers surround it, shouldn't the Bureau understand the hydrologic relationship between the groundwater basin and the rivers? If that understanding exists, where is it presented in the EA? It is well known that the Sacramento River is already a losing river south of Princeton.

The City of Sacramento proposes to transfer surface water into the state water market and substitute 3,000 AF of groundwater (EA p.2-4), but the *Sacramento County Water Agency Water Management Plan* indicates that intensive use of this groundwater basin has resulted in a general lowering of groundwater elevations that will require extensive conservation measures to remediate. The Sacramento County Water Agency has devised a plan to help lead the city to a sustainable groundwater use to avoid problems associated with unrestrained overuse. The most reliable strategy is to reduce demand. Integrating the City's water supply into the state water supply would obviously increase demand and make the SCWA goals impossible to achieve.

The Bureau should prepare an EIS that discloses the fallacies inherent in its policies and actions. The need for almost 400,000 AF of water south of the Delta springs from failed business planning. The Bureau and DWR must acknowledge this and further disclose that their agencies are willing to socialize the risks taken by corporate agribusiness and developers while facilitating private profit. Instead of asking northern California water districts and municipal water purveyors to place their own water at risk as well as the water of their neighboring communities and thousands of residential well owners, water quality, fisheries, recreation, stream flow, terrestrial habitat, and geologic stability, the Bureau and DWR must disclose all the uncertainty in the 2010-2011 Water Transfer Program and then evaluate the risks with scientific methodology. This has clearly not been done.

2. The 2010-2011 Water Transfer Program proposes to rely on inadequate monitoring and mitigation to avoid the acknowledged possibility of significant adverse environmental impacts.

The draft EA and the Draft Technical Information for Water Transfers in 2010 referenced in the EA (Bureau and DWR 2009) require "willing sellers" to prepare individual monitoring and mitigation plans and to conduct the monitoring with oversight provided by the Bureau and DWR (p. 3-24 and 3-25). This fails to provide the most basic framework for governmental authority to enforce the state's role as trustee of the public's water in California, let alone a comprehensive and coordinated structure, for a very significant program that could transfer up to 154,239 AF of water from the Sacramento Valley. (Recall that DWR believes it has environmental compliance coverage for up to 600,000 AF of water sales from the Sacramento Valley, including 340,000 AF in groundwater substitution alone under the Governor's 2009 emergency exemption) The draft EA further defers responsibility to "willing sellers" for compliance with local groundwater management plans and ordinances to determine when the effects of the proposed extraction become "adverse," (p. 3-25). "Each district will be required to confirm that the proposed groundwater pumping will be compatible with state and local regulations and groundwater management plans," (EA at p. 3-25). It is not acceptable that the draft EA and the Draft Technical Information for Water Transfers in 2010 merely provide monitoring direction to "willing sellers" without identifying rigorous standards for the risks at hand, specific actions, acceptable monitoring and reporting entities, or funding that will be necessary for this oversight.

The Coalition proposes instead that the Bureau and DWR require, at a minimum, that local governments select independent third-party monitors, who are funded by surcharges on Project transfers paid by the buyers, to oversee the monitoring that is proposed in lieu of Bureaus and DWR staff, and that peer reviewed methods for monitoring be required. If this is not done, the Project's proposed monitoring is insufficient and cannot justify the significant risk of adverse environmental impacts.

For example, the EA and the Draft Technical Information for Water Transfers in 2010 fail to identify standards that would be used to monitor the 2010-2011 Water Transfer Program's impacts. It fails to identify any specific monitoring protocols, locations (particularly in up-gradient recharge portions of the groundwater basins), and why chosen locations should be deemed effective for monitoring the effects of the proposed groundwater extraction. It also fails to describe how the objectives in the Draft Technical Information for Water Transfers in 2010 will be met and by whom (EA at p.3-24 and 3-25). Moreover, it fails to provide a mitigation strategy for review and comment by the public, but defers this vital mitigation planning effort to future documents created by "willing sellers," (EA at p.3-24 and 3-25) despite the fact that the EA acknowledges the potential for significant impacts. For example:

- Surface water and groundwater interact on a regional basis, and, as such, gains and losses to groundwater vary significantly geographically and temporally. In areas where groundwater levels have declined, such as in Sacramento County, streams that formerly gained water from groundwater now lose water to the groundwater system through seepage (EA at p. 3-12).
- . *Groundwater substitution transfers would alter ground water levels and potentially affect natural and managed seasonal wetlands and riparian communities, upland habitats and wildlife species depending on these habitats.* As a part of groundwater substitution transfers, the willing sellers would use groundwater to irrigate crops and decrease use of surface water. Pumping additional groundwater would decrease groundwater levels in the vicinity of the sellers' pumps. Natural and managed seasonal wetlands and riparian communities often depend on surface water/groundwater interactions for part or all of their water supply. Under the Proposed Action, subsurface drawdown related to groundwater substitution transfers could result in hydrologic changes to nearby streams and marshes, potentially affecting these habitats. Reduced groundwater elevations could also affect trees that access groundwater as a source of water through taproots in addition to extensive horizontal roots that use soil moisture as a water source. Decreasing groundwater levels could reduce part of the water base for species within these habitats (EA at p. 3-53 and 3-54).

The reader is directed to the Draft Technical Information for Water Transfers in 2010 to discover the minimal objectives and required elements of the monitoring and mitigation component of the Project. "The seller must implement an effective mitigation program to verify and correct problems that could arise due to transfer-related groundwater pumping," but the reader and possibly the sellers are left wondering what exactly is an "effective mitigation plan" since there is no particular guidance to manage and analyze the very complex hydrologic relationships internal to groundwater and connected to surface waters. Certainly the public has no idea or ability to comment, which fails the full disclosure mandate in NEPA and CEQA. Located on pages 30 and 31 of the Draft Technical Information for Water Transfers in 2010 is a brief list of a "number of potential impacts [that] are sufficiently serious that they must be avoided or mitigated for a project to continue."

- Contribution to long-term conditions of overdraft;
- Dewatering or substantially reducing water levels in nonparticipating wells;
- Measurable contribution to land subsidence;
- • Degradation of groundwater quality that substantially impairs beneficial uses or violates water quality standards; and
- Affecting the hydrologic regime of wetlands and/or streams to the extent that ecological integrity is impaired.

The Draft Technical Information for Water Transfers in 2010 continues with suggestions to curtail pumping lower bowls, and pay higher energy costs to ease the impacts to third party wells owners (p. 30 and 31). While this bone thrown at mitigation is appreciated, the glaring omissions are notable. The Draft Technical Information for Water Transfers in 2010 completely fails to mention, even at a very general level, how individual well owners will determine and prove where the impacts to their wells are coming from, that water quality and health could become a significant impact for impacted wells and users and streams, and that there are no mitigation measures even mentioned for streams and wetlands. There also appears to be no consideration for species monitoring, just “practices” or “conservation measures” to “minimize impacts to terrestrial wildlife and waterfowl,” (Draft Technical Information p. 16). And please disclose why the 2009 DWB Biological Opinion is a reference to guide “specific practices on page 17 of the Draft Technical Information for Water Transfers in 2010.

Another example of the inadequacy of the proposed monitoring is that the draft EA fails to include any coordinated, programmatic plan to monitor stream flow of creeks and rivers located in proximity to the “willing sellers” that will evacuate more water than used historically. The potential for immediate impacts would be very close to water sellers’ wells, but the long term impacts could be more subtle and more geographically diverse. What precautions has the Bureau and DWR made for the cumulative impacts that come not only from this two-year Project, but in combination with the water sales from the last three years and those that are planned by the Bureau into the future (see list in g, iv below)? Bureau and DWR water transfers are not just one or two year transfers, but many serial actions in multiple years by the agencies, sellers, and buyers without the benefit of comprehensive environmental analysis under NEPA and CEQA.

As discussed above, adequate monitoring is vital to limit the significant risks posed by the Project to the health of the region’s groundwater, streams, and fisheries (more discussion below). One unfortunate example is the EA’s focus on groundwater substitution impacts that reflect the priority for water accounting and payment accuracy as opposed to the impacts to the groundwater system and streams. “The implementation of groundwater substitution pumping can lower the groundwater table and may change the relative difference between the groundwater and surface water levels. This change has a direct impact on the volume that a seller receives credit for being transferred,” (EA p.3-22 and 3-23). Moreover, to the extent this Project is conceived as a two-year drought or hardship program that will provide knowledge for future groundwater extraction and fallowing, its failure to include adequate monitoring protocols is even more disturbing and creates the risk of significant long-term and even irreversible impacts from the Project.

a. The Bureau’s assertion that the Project may be modified or halted in the event of significant adverse impacts to hydrologic resources is an empty promise in light of the wholly inadequate monitoring provided for in the 2010-2011 Water Transfer Program. Knowing that the Bureau and DWR knowingly violated the X2 standard in the Delta in February 2009 does little to instill confidence from the Coalition in non-specific program and mitigation criteria.

The EA repeatedly illustrates that there is potential for significant injury to other groundwater users, water quality, streams, flora and fauna, and the soil profile (p. 3-12, 3-23, 3-24, 3-53, 3-54). Chapter three contains numerous examples that illustrate the need for an EIS since there is insufficient, comprehensive planning for, let alone preparation to mitigate, adverse environmental impacts:

- *Acquisition of water via groundwater substitution or cropland idling would change the rate and timing of flows in the Sacramento River compared to the No Action Alternative.*
- *In Figure 3.2-2, groundwater substitution pumping results in a change in the groundwater/surface water interaction characteristics. In this case, the water pumped from a groundwater well may have two impacts that reduce the amount of surface water compared to pre-pumping conditions. These mechanisms are:*
    - *Induced leakage. The lowering of the groundwater table causes a condition where the groundwater table is lower than that the water level in the surface water. This conditions causes leakage out of the surface water.*
    - *Interception of groundwater. The placement of groundwater substitution pumping may intercept groundwater that may normally have discharged to the surface water (i.e., water that has already percolated into the ground may be pumped out prior the water reaching the surface water and being allowed to enter the "gaining" stream).*
- *The changes in groundwater flow patterns (e.g., direction, gradient) due to increased groundwater substitution pumping may result in changes in groundwater quality from the migration of reduced quality water.*
- *Groundwater substitution transfers would alter ground water levels and potentially affect natural and managed seasonal wetlands and riparian communities, upland habitats and wildlife species depending on these habitats.*
- *Rice land idling transfers would reduce habitat and forage for resident and migratory wildlife populations.*
- *Water transfers could change reservoir releases and river flows and potentially affect special status fish species and essential fish habitat.*
- *Water transfers could affect fisheries and aquatic ecosystems in water bodies, including Sacramento and American River systems, the Sacramento-San Joaquin Delta, San Luis Reservoir, and DWR and Metropolitan WD reservoirs in southern California.*
- *Increased groundwater pumping for groundwater substitution transfers would increase emissions of air pollutants.*

The Bureau thus recognizes the potential for significant decline in groundwater levels as a result of the proposed activity (EA at p. 3-23, 3-24, 3-53, 3-54). This acknowledgement alone is sufficient to require a full EIS. Moreover, as detailed below, the monitoring proposed by the 2010-2011 Water Transfer Program is so inadequate that there can be no guarantee that adverse impacts will be discovered, or that they will be discovered in time to avoid significant environmental impacts.

Glenn County will have groundwater substitution if the Project moves forward. The County realizes that its management plan may not be sufficient for the challenges presented by this Project and the myriad others and cautions that "[s]ince the groundwater management plan is relatively new and not fully implemented, the enforcement and conflict resolution process has not been vigorously tested," (http://www.glenncountywater.org/management_plan.aspx). Moreover, the Glenn County Groundwater Management Plan does not have any provisions to monitor or protect the environment. The 2010-2011 Water Transfer Program EA fails to disclose the inadequacies of this and other local ordinances and plans.

b. Monitoring based on the Glenn County Groundwater Management Plan is inadequate. Since the Bureau omitted discussion of the Glenn County Groundwater Management Plan in the 2010-2011 Water Transfer Program, we refer to the language used in the 2008 Stony Creek Fan EA/FONSI that explained that the existing Glenn County groundwater management plan will ensure the testing project will have no significant adverse effects on groundwater levels: "This Finding of No Significant Impact (FONSI) is based upon the following: … Implementation of the Glenn County Groundwater Management Plan during the aquifer performance testing plan will ensure that the proposed action will not result in any significant adverse effect to existing groundwater levels." Stony Creek Fan EA/FONSI at p. 2.

But the Butte County Department of Water and Resource Conservation explains that local plans are simply not up to the task of managing a regional resource:

> *Glenn County does not have an export ordinance because it relies on Basin Management Objectives (BMO) to manage the groundwater resource, and subsequently to protect third parties from transfer related impacts. Recently, Butte County also adopted a BMO type of groundwater management ordinance. Butte County, Tehama County and several irrigation districts in each of the four counties have adopted AB3030 groundwater management plans. All of these groundwater management activities were initiated prior to recognizing that a regional aquifer system exists that extends over more than one county and that certain activities in one county could adversely impact another. Clearly the current ordinances, AB3030 plans, and local BMO activities, which were intended for localized groundwater management, are not well suited for management of a regional groundwater resource like that theorized of the Lower Tuscan aquifer system.*

(Butte County DWRC 2007)[4]

c. The EA fails to propose real time monitoring for land subsidence. Third-party independent verification, perhaps by scientists from the U.S. Geological Survey, should be incorporated by DWR and the Bureau into the project description of the 2010-2011 Water Transfer Program. We applaud the initiation of a regional GPS network in the Sacramento

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Valley, but remain concerned about the 13 existing extensometers in the Sacramento Valley that measure land subsidence, and a Global Positioning System land subsidence network established by one county (EA p. 13). The remaining responsibility is again deferred to the "willing sellers." Unfortunately, voluntary monitoring by pumpers does not strike us as a responsible assurance given the substantial uncertainties involved in regional aquifer responses to extensive groundwater pumping in the Sacramento Valley.

Not only is there a failure to discuss real time monitoring for subsidence, there also is no discussion regarding delayed subsidence that should also be monitored according to the findings of Dr. Kyran Mish, Presidential Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma. Dr. Mish notes: "It is important to understand that *all* pumping operations have the potential to produce such settlement, and when it occurs with a settlement magnitude sufficient enough for us to notice at the surface, we call it *subsidence*, and we recognize that it is a serious problem (since such settlements can wreak havoc on roads, rivers, canals, pipelines, and other critical infrastructure)," (Mish 2008).. Dr. Mish further explains that "[b]ecause the clay soils that tend to contribute the most to ground settlement are highly impermeable, their subsidence behavior can continue well into the future, as the rate at which they settle is governed by their low permeability." *Id.* "Thus simple real-time monitoring of ground settlement can be viewed as an *unconservative* measure of the potential for subsidence, as it will generally tend to underestimate the long-term settlement of the ground surface." *Id.* (emphasis added).

The EA acknowledges the existence and cause of serious subsidence in one area of the valley. "The area between Zamora, Knights Landing, and Woodland has been most affected (Yolo County 2009). Subsidence in this region is generally related to groundwater pumping and subsequent consolidation of aquifer sediments," (EA p. 3-13). This fact alone illustrates the need for more extensive analysis throughout the export area in an EIS.

d. The 2010-2011 Water Transfer Program EA fails to require streamflow monitoring. The 2009 DWB EA/FONSI deferred the monitoring and mitigation planning to "willing sellers," but even that requirement has been completely eliminated. We can't emphasize enough the importance of frequent and regular streamflow monitoring by either staff of the project agencies or a third, independent party such as the USGS, paid for by Project transfer surcharges mentioned above. It is clear from existing scientific studies and the EA that the Project may have significant impacts on the aquifers replenishment and recharging of the aquifers, so the 2010-2011 Water Transfer Program should therefore require extensive monitoring of regional streams. The radius for monitoring should be large, not the typical two to three miles as usually used by DWR and the Bureau. Though not presented for the 2010-2011 Water Transfers Program, the *Stony Creek Fan Aquifer Performance Testing Plan,* which is a much smaller project, recognized that there may be a drawdown effect on the aquifer by considering results from a DWR Northern District spring 2007 production well test (EA/FONSI p. 28). However, it did not assess the anticipated scope of that effect—or even what level of effect would be considered acceptable. Moreover, the results from that test well indicate that the recharge source for the solitary production well "is most likely from the foothills and mountains, to the east and north"—which at a minimum is more than fifteen miles away. (DWR, Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California).

The Butte County Department of Water and Resource Conservation have identified streams that must be monitored to determine impacts to stream flows that would be associated with pumping the Lower Tuscan Aquifer. These "[s]treams of interest" are located on the eastern edge of the Sacramento Valley and include: Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and Little Dry Creek (The Butte County DWRC 2007). The department described the need and methodology for stream flow gauging:

> *The objective of the stream flow gaging is to determine the volume of surface water entering into or exiting the Lower Tuscan Aquifer along perennial streams that transect the aquifer formation outcropping for characterization of stream-aquifer interactions and monitoring of riparian habitat. Measurement of water movement into or out of the aquifer will allow for testing of the accuracy of the Integrated Water Flow Model, an integrated surface water-groundwater finite differential model developed for the eastern extent of the Lower Tuscan aquifer.*
>
> *Two stream gages will be installed on each of five perennial streams crossing the Lower Tuscan Formation to establish baseline stream flow and infiltration information. The differences between stream flow measurements taking upstream and downstream of the Lower Tuscan Formation are indications of the stream-aquifer behavior. Losses or gains in stream volume can indicate aquifer recharge or discharge to or from the surface waters.*
> *Id.*

As evident in the following conclusory assertions, the draft EA/FONSI fails to define the radius of influence associated with the aquifer testing and thus entirely fails to identify potential significant impacts to salmon:

> "An objective in planning a groundwater substitution transfer is to ensure that groundwater levels recover to their typical spring high levels under average hydrologic conditions. Because groundwater levels generally recover at the expense of stream flow, the wells used in a transfer should be sited and pumped in such a manner that the stream flow losses resulting from pumping peak during the wet season, when losses to stream flow minimally affect other legal users of water," (EA p. 2-7).

As mentioned above, streamflow monitoring is not a requirement of the Project, which is unfathomable. Monitoring of flow on streams associated with the Lower Tuscan Formation is particularly important to the survival of Chinook salmon which use these "streams of interest" to spawn and where salmon fry rear. Intensive groundwater pumping would likely lower water table elevations near these streams of interest, decreasing surface flows, and therefore reducing salmon spawning and rearing habitat through dewatering of stream channels in these northern counties. This would be a significant adverse impact of the Project and is ignored by the EA.

A similar effect has been observed in the Cosumnes River, where "[d]eclining fall flows are limiting the ability of the Cosumnes River to support large fall runs of Chinook salmon," (Fleckenstein, et al 2004). This is a river that historically supported a large fall run of Chinook Salmon. *Id.* Indeed, "[a]n early study by the California Department of Fish and Game . . . estimated that the river could support up to 17,000 returning salmon under suitable flow conditions." *Id.*, citing CDFG 1957 & USFWS 1995. But "[o]ver the past 40 years fall runs ranged from 0 to 5,000 fish according to fish counts by the CDFG (USFWS 1995)," and "[i]n recent years, estimated fall runs have consistently been below 600 fish, according to Keith Whitener," (Fleckenstein, *et al*. 2004). Indeed, "[f]all flows in the Cosumnes have been so low in recent years that the entire lower river has frequently been completely dry throughout most of the salmon migration period (October to December)." *Id.*

Research indicates that "groundwater overdraft in the basin has converted the [Cosumnes River] to a predominantly losing stream, practically eliminating base flows…." (Fleckenstein, *et al*. 2004). And "investigations of stream-aquifer interactions along the lower Cosumnes River suggest that loss of base flow support as a result of groundwater overdraft is at least partly responsible for the decline in fall flows." *Id.* Increased groundwater withdrawals in the Sacramento basin since the 1950s have substantially lowered groundwater levels throughout the county." *Id.*

The draft EA acknowledges the potential for impacts to special status fish species from altered river flows and commits to maintaining flow and temperature requirements already in place (p. 3-59). The coalition would like to have greater assurance of a commitment considering that the Bureau and DWR failed to meet the X2 standard in February 2009. The Bureau and DWR should make X2 compliance and streams of interest monitoring in real time part of their permit amendment applications to the SWRCB this spring. If stream levels are affected by groundwater pumping, then pumping would cease.

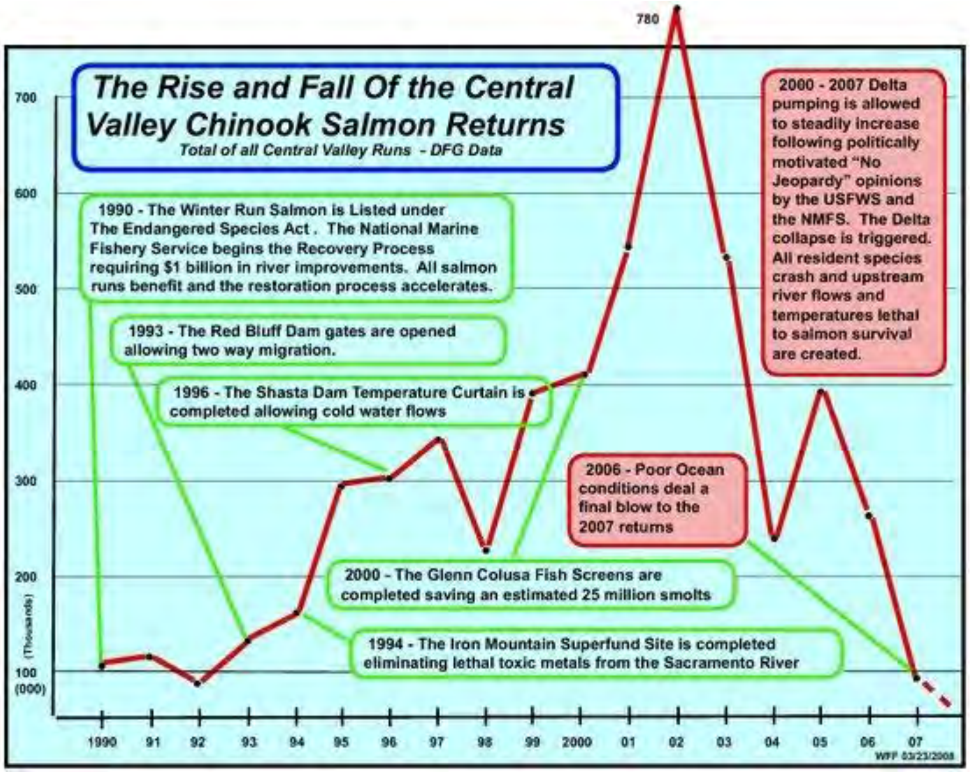
Unfortunately, the draft EA fails to anticipate possible stream flow declines in important salmon rearing habitat in the 2010-2011 Water Transfer Program area. Many important streams, such as Mud Creek, are located within the 2010-2011 Water Transfer Program and flows through probable Tuscan recharge zones, yet are not mentioned in the EA (also see comments above regarding Rock Creek). While a charged aquifer is likely to add to base flow of this stream, a de-watered aquifer would pull water from the stream. According to research conducted by Dr. Paul Maslin, Mud Creek provides advantageous rearing habitat for out-migrating Chinook salmon (1996). Salmon fry feeding in Mud Creek grew at over twice the rate by length as did fry feeding in the main stem of the Sacramento River. *Id.*

Another tributary to the Sacramento River, Butte Creek, hosts spring-run Chinook salmon, a threatened species under the Endangered Species Act. 64 Fed. Reg. 50,394 (Sept. 16, 1999).

Butte Creek contains the largest remaining population of the spring-run Chinook and is designated as critical habitat for the species. *Id*. at 50,399; 70 Fed. Reg. 52,488, 52,590-91 (Sept. 2, 2005). Additionally, Butte Creek provides habitat for the threatened Central Valley steelhead. *See* 63 Fed. Reg. 13,347 (Mar. 19, 1998); 70 Fed. Reg. at 52,518. While Butte Creek is mentioned in the EA (p. 2-11, 3-4, 3-49, 3-57), the only protection afforded this vital tributary are statements that cropland idling will not occur adjacent to it, yet that is contradicted on page 3-19. The Bureau should not overlook the importance of rearing streams, and should not proceed with this Project unless and until adequate monitoring and mitigation protocols are established.

Existing mismanagement of water in California's rivers, creeks, and groundwater has already caused a precipitous decline in salmon abundance. There is no mention of the fall-run salmon numbers in the main stem Sacramento River or its essential tributaries despite the fact that their numbers dropped precipitously in 2007 (see graphic below) 2008, and 2009. After the commercial salmon fishery was closed for two years for fear of pushing these fish to extinction, scientists are waiting until February 2010 to determine if the commercial and sport fishing seasons will open this year. As noted above, the EA casually asserts that maintaining flow and temperature requirements in the main stem will be sufficient to protect aquatic species, but it fails to consider the impacts of almost 400,000 AF of water transfers, fallowing, and groundwater substitution on the tributaries. How much additional pumping does the Project represent, given CVP and SWP contractual commitments, available reservoir supplies, and other environmental restrictions south of the Delta? The EA and DWR's missing environmental review are silent on this.

Where are the data to support assertions that impacts to aquatic species will be below a level of significance? Habitat values are also essential to many other special status species that utilize the aquatic and/or riparian landscape including, but not limited to, giant garter snake, bank swallow, greater sandhill crane, American shad, etc. Where is the documentation of the potential impacts to these species?



Graphic is courtesy of Dick Pool.

In addition to the direct decline in the salmon populations is the food chain affect that will influence species such as killer whales.

3. The EA fails to address the significant unknown risks raised by the 2010-2011 Water Transfer Program's proposed groundwater extraction.

The EA fails to identify and address the significant unknown risks associated with this Project. There are substantial gaps in scientists' understanding of how the aquifer system recharges.

The EA fails to reveal the scientifically known and unknown characteristics of the Lower Tuscan aquifer. Expert opinion and experience is offered by Professor Karin Hoover from CSU Chico who asserts that: "[T]o date there exists no detailed hydrostratigraphic analysis capable of distinguishing the permeable (water-bearing) units from the less permeable units within the subsurface of the Northern Sacramento Valley. In essence, the thickness and extent of the water-bearing units has not been adequately characterized." (p. 1)

Though the Project fails to disclose the limitations in knowledge of the geology and hydrology of the northern counties, it was disclosed in 2008 in the EA for the *Stony Creek Fan Aquifer Performance Testing Plan* (Testing Plan EA). It revealed that there is also limited understanding of the interaction between the affected aquifers, and how that interaction will affect the ability of the aquifers to recharge. The Testing Plan EA provides:

> *The Pliocene Tuscan Formation lies beneath the Tehama Formation in places in the eastern portion of the SCF Program Study Area, although its extent is not well defined. Based on best available information, it is believed to occur at depths ranging between approximately 300 and 1,000 feet below ground surface. It is thought to extend and slope upward toward the east and north, and to outcrop in the Sierra Nevada foothills. The Tuscan Formation is comprised of four distinct units: A, B C and D (although Unit D is not present within the general project area). Unit A, or Upper Tuscan Formation, is composed of mudflow deposits with very low permeability and therefore is not important as a water source. Units B and C together are referred to as the Lower Tuscan Formation. Very few wells penetrate the Lower Tuscan Formation within the SCF Program study area.*

(The Testing Plan EA/FONSI at p. 23). The Tehama Formation, however, generally behaves as a semi-confined aquifer system and the EA contains no discussion of its relationship with the adjoining formations. Nor is there any discussion of the role of the Pliocene Tehama Formation as "the primary source of groundwater produced in the area," (DWR 2003).

The EA fails to offer any in-depth analysis of which strata in the aquifers will be most likely affected by the 2010-2011 Water Transfer Program's proposed extraction of groundwater. Thousands of domestic wells are in the upper layers of the aquifers are not even considered in the EA. In addition, the EA provides no assessment of the interrelationship of varying strata in the aquifers in the Sacramento Valley or between the aquifers themselves.

The EA fails to provide basic background information regarding the recharge of groundwater. The documents states, "Groundwater is recharged by deep percolation of applied water and rainfall infiltration from streambeds and lateral inflow along the basin boundaries," (EA p. 3-10). How was the conclusion reached that applied water leads to recharge of the aquifer? Where are the supporting data? This claim is unsubstantiated by any of the work that has been performed to date. For example, the RootZone water balance model used by a consultant with Glenn Colusa Irrigation District, Davids Engineering, was designed to simulate root zone soil moisture. It balances incoming precipitation and irrigation against crop water usage and evaporation, and whatever is left over is assigned to "deep percolation." Deep percolation in this case means below the root zone, which is anywhere from a few inches to several feet below the surface, depending on the crop. There is absolutely no analysis that has been performed to insure that applied water does, indeed, recharge the aquifer. For example, if the surface soils were to dry out, water that had previously migrated below the root zone might be pulled back up to the surface by capillary forces. In any case, the most likely target of the "deep percolation" water in the Sacramento Valley is the unconfined, upper strata of the aquifer and possibly the Sacramento River. The EA has not demonstrated otherwise.

A public hearing concerning the Monterey Agreement was held in Quincy on November 29, 2007 and hosted by DWR. At the hearing Barbara Hennigan presented the following testimony: "So for the issues of protecting the water quality, protecting the stream flow in the Sacramento, one of the things that we have learned is that the Sacramento River becomes a permanently losing stream at the Sutter buttes. When I first started looking at the water issues that point was at Grimes south of the [Sutter B]uttes, now it is at Princeton, moving north of the buttes. As the Sacramento becomes a losing stream farther and farther north because of loss of the Lower Tuscan Aquifer, that means that it, there will be less water that the rest of the State relies on," (http://www.water.ca.gov/environmentalservices/docs/mntry_plus/comments/Quincy.txt). How and when will the Bureau and DWR address this enormously important condition and amplify the risk to not only the northstate, but the entire State of California?

4. The EA contains numerous errors and omissions regarding groundwater resources.

There are numerous errors, omissions, and negligence in addressing existing conditions before and with the Project in Section 3.2 Groundwater Resources. The failure to address stated problematic conditions and the lack of accuracy in this section of so many elemental issues and facts raises questions about the content of the entire EA and FOSI. A partial list of statements and questions follows.

- On pages 3-10, 3-12, and 3-13 of the EA the Sierra Nevada [mountain range] and "Coast ranges" are identified, but there is no mention of the southern Cascade Range that is a prominent geologic feature of the northern Sacramento Valley and a significant contributor to the hydrology of the region.
- Page 3-12 mentions "major tributaries" to the Sacramento River, but omits the northern rivers the McCloud and the Pit. It also mentions "Stony, Cache, and Putah Creeks," but fails to mention Battle, Mill, Big Chico, and Butte creeks. These omissions again reflect an odd lack of understanding of the Cascade Range.
- The EA states quite straightforwardly on page 3-12 that, "Surface water and groundwater interact on a regional basis, and, as such, gains and losses to groundwater vary significantly geographically and temporally. In areas where groundwater levels have declined, such as in Sacramento County, streams that formerly gained water from groundwater now lose water to the groundwater system through seepage." This knowledge alone requires substantive environmental review under NEPA and CEQA.
- Page 3-12. "Groundwater production in the basin has recently been estimated to be about 2.5 million acre-feet or more in dry years." What is the citation for this assertion?
- Page 3-12. "Historically, groundwater levels in the Basin have remained steady, declining moderately during extended droughts and recovering to pre-drought levels after subsequent wet periods. DWR extensively monitors groundwater levels in the basin. The groundwater level monitoring grid includes active and inactive wells that were drilled by different methods, with different designs, for different uses. Types of well use include domestic, irrigation, observation, and other wells. The total depth of monitoring grid wells ranges from 18 to 1,380 feet below ground surface.". As presented above, groundwater levels have been changing, historically. Since the Bureau and DWR have access to a monitoring grid, for NEPA and CEQA compliance, they must present current facts, not general statements that relate to social science.
- Page 3-12. "In general, groundwater flows inward from the edges of the basin and south parallel to the Sacramento River. In some areas there are groundwater depressions associated with extraction that influence local groundwater gradients." Where are the groundwater depressions? How have they affected groundwater gradients? How will the Project exacerbate a negative existing condition?
- Page 3-12. "Prior to the completion of CVP facilities in the area (1964-1971), pumping along the west side of the basin caused groundwater levels to decline. Following construction of the Tehama-Colusa Canal, the delivery of surface water and reduction in groundwater extraction resulted in a recovery to historic groundwater levels by the mid to late-1990s." Please provide the citation(s).
- Pg 3-15 "According to the SWRCB, there are no elevated concentrations of arsenic or selenium in the Sacramento Groundwater Basin." The GAMA domestic well Project, Tehama County Focus Area, 2009, Arsenic in Domestic and Public Wells indicates variable levels of arsenic in the cited basin. The study found that, "Fourteen percent of

the wells [in the Tehema County focus area] had concentrations of both arsenic and iron above their associated CDPH MCLs or secondary MCLs."

- Page 3-15. "The State Water Code (Section 1745.10) requires that for short term water transfers, the transferred water may not be replaced with groundwater unless the following criteria are met (SWRCB 1999)…" The Project is not a short term water transfer, but a set of serial actions in multiple years by the agencies, sellers, and buyers without the benefit of comprehensive environmental analysis under NEPA and CEQA.
- Page 3-16. "California Water Code Section 1810 and the CVPIA protect against injury to third parties as a result of water transfers. Three fundamental principles include (1) no injury to other legal users of water; (2) no unreasonable effects on fish, wildlife or other in-stream beneficial uses of water; and (3) no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred. These principles must be met for approval of water transfers." The disclosures and analyses contained in the EA, FONSI, and its appendices are inadequate to satisfy the California Water Code requirements and the Bureau's requirements under NEPA. DWR has clearly failed its obligations under CEQA by providing no disclosure or analysis.

E. Other resource impacts flowing from corrected chains of cause and effect are unrecognized in the EA and should be considered in an EIS instead.

Regarding surface water reservoir operations in support of the 2010-2011 Water Transfer Program, we have several questions and concerns:

- Regarding fisheries, we note that the Bureau intends to comply with the State Water Resources Control Board's Water Rights Orders 90-05 and 91-01 in order to provide temperature control at or below 56 degrees Fahrenheit for anadromous fish, their redds, and hatching wild salmonid fry, and to provide minimum instream flows of 3,250 cubic feet per second (cfs) between September 1 and February 28, and 2,300 cfs between March 1 and August 31. How will the Bureau and DWR comply with Fish and Game Code Section 5937—to keep fish populations below and above their dams in good condition, as they approve transfers of CVP water from willing CVP contractors to willing buyers? We urge this compliance effort be integrated with the streams of interest and groundwater monitoring programs we recommended above.

- We also find confusing the EA's treatment of instream flows for fisheries. On one hand, minimum flows and temperature criteria established in the above-mentioned water rights orders is to be adhered to by the Bureau for the Sacramento River. The necessity for April and May storage is not well explained.

- Concerning the social and economic effects of the proposed 2010-2011 Water Transfer Program, crop idling transfers will delete fields from production and result in employment impacts on Sacramento Valley's agricultural labor market at a time when the national recession is at its worst. The lack of descriptive information about what crops are to be idled by specific "willing sellers" means that a reasonably plausible estimate of employment impacts in the Sacramento Valley are unavailable, rendering the EA inadequate from this standpoint. Has the Bureau reviewed the President's policies on economic recovery to be certain that its water transfer program that would shift employment impacts from one Valley to another rather than work to increase employment generally is consistent with the intent of the President and Congress? What would be the effects of employment shifting on the poverty rates of Sacramento Valley counties? Such an estimate, provided with basic information about what acreages of specific crops are to be idled, is within the reach of the Bureau to make.

- On its own terms, the Bureau's EA makes no attempt to establish baseline agricultural crop acreages for each agricultural county offering or seeking DWB water in order to calculate and apply its 20 percent threshold for limiting economic impacts to agriculture in selling counties. Moreover, this 20 percent threshold needs to be incorporated into the description of the Proposed Action Alternative, since it appears to be an integral part of DWB actions.

- Regarding public health and safety, the EA negligently denies the potential for impacts (p.3-1). Fluctuating domestic wells can lead to serious contamination from heavy metals and non-aqueous fluids. Additionally, there are numerous hazardous waste plumes in Butte County, which could easily migrate with the potential increased groundwater pumping proposed for the Project. All of this must be disclosed and analyzed.

In general, the 2010-2011 Water Transfer Program EA/FONSI—and by logical implication, DWR's actions—consistently avoids full disclosure of existing conditions and baseline data, rendering their justifications for the 2010-2011 Water Transfer Program at best incoherent, and at worst, dangerous to groundwater users and resources, and to vulnerable fisheries in tributary streams of the Sacramento River.

F. The 2010-2011 Water Transfer Program is likely to have a cumulatively significant impact on the environment.

The draft EA/FONSI does not reveal that the current Project is part of a much larger set of plans to develop groundwater in the region, to develop a "conjunctive" system for the region, and to integrate northern California's groundwater into the state's water supply. These are plans that the Bureau, together with DWR and others, have pursued and developed for many years. Indeed, one of the plans—the short-term phase of the Sacramento Valley Water Management Program—is the subject of an ongoing scoping process for a Programmatic EIS that has not yet been completed.

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3) (emphasis added).

As detailed below, instead of assessing the cumulative impacts of the proposed action as part of the larger program that even the Bureau has recognized should be subject to a programmatic EIS (but for which no programmatic EIS has been completed), the Bureau has attempted to separate this program and approve it through an inadequate EA. Further, the Bureau has failed to take into account the cumulative effects of other groundwater and surface water projects in the region, the development of "conjunctive" water systems, and the anticipated further integration of Sacramento Valley surface and ground water into the state water system.

G. The Environmental Assessment Fails to Meet the Requirements of NEPA.

Even if an EIS were not clearly required here, the draft EA/FONSI prepared by the Bureau violates NEPA on its own. As discussed above, the draft EA does not provide the analysis necessary to meet NEPA's requirements and to support its proposed finding of no significant impact. Further, as outlined above, the draft document fails to provide a full and accurate description of the proposed Project, its relationship to myriad other water transfer and groundwater extraction projects, its potentially significant adverse effects on salmon critical habitat in streams of interest tributary to the Sacramento River, and an assessment of the cumulative environmental impacts of the 2010-2011 Water Transfer Program when considered together with other existing and proposed water programs.

Additionally, the draft EA/FONSI fails to provide sufficient evidence to support its assertions that the 2010-2011 Water Transfer Program would have no significant impacts on the human or natural environments, neither decision makers nor the public are fully able to evaluate the significance of the 2010-2011 Water Transfer Program's impacts. These informational failures complicate the Coalition's efforts to provide meaningful comments on the full extent of the potential environmental impacts of the DWB and appropriate mitigation measures. Accordingly, many of the Coalition's comments include requests for additional information.

1. The EA Fails to Consider a Reasonable Range of Alternatives.

NEPA's implementing regulations call for analysis of alternatives is "the heart of the environmental impact statement," 40 C.F.R. §1502.14, and they require an analysis of alternatives within an EA. *Id.* §1408.9. The statute itself specifically requires federal agencies to:

> *study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning available uses of resources.*

42 U.S.C. §4332(2)(E). Here, because the Bureau's EA considers only the proposed Project and a "No Action" alternative, the EA violates NEPA.

The case law makes clear that an adequate analysis of alternatives is an essential element of an EA, and is designed to allow the decision maker and the public to compare the environmental consequences of the proposed action with the environmental effects of other options for accomplishing the agency's purpose. The Ninth Circuit has explained that "[i]nformed and meaningful consideration of alternatives … is … an integral part of the statutory scheme." *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228 (9th Cir. 1988) (holding that EA was flawed where it failed adequately to consider alternatives). An EA must consider a reasonable range of alternatives, and courts have not hesitated to overturn EAs that omit consideration of a reasonable and feasible alternative. *See People ex rel. Van de Kamp v. Marsh*, 687 F.Supp. 495, 499 (N.D. Cal. 1988); *Sierra Club v. Watkins*, 808 F.Supp. 852, 870-75 (D.D.C. 1991).

Here, there are only two alternatives presented: the No Action and the Proposed Action. The lack of *any* alternative action proposal is unreasonable and is by itself a violation of NEPA's requirement to consider a reasonable range of alternatives.

Even more significantly, there are numerous other alternative ways to ensure water is allocated reliably when California experiences dry hydrologic years. We described several elements of reasonable alternatives above. These are the alternatives that should have been presented for the Bureau's draft EA/FONSI on the 2010-2011 Water Transfer Program to comply with NEPA. 42 U.S.C. § 4332(2)(E).

2. The EA Fails to Disclose and Analyze Adequately the Environmental Impacts of the Proposed Action

The discussion and analysis of environmental impacts contained in the EA is cursory and falls short of NEPA's requirements and stems from having an unclear and poorly described narrative for the proposed 2010-2011 Water Transfer Program. It obscures realistic chains of cause and effect, which in turn prevent accurate and comprehensive accounting of environmental baselines and measurement of the DWB's potential impacts. NEPA's implementing regulations require that an EA "provide sufficient evidence and analysis for determining whether to prepare an

[EIS].” 40 C.F.R. §1508.9(a). For the reasons discussed above, the EA fails to discuss and analyze the environmental effects of the water transfers, crop idling, and groundwater substitution proposed by the 2010-2011 Water Transfer Program. The Bureau must consider and address the myriad of environmental consequences that are likely to flow from this proposed agency action.

Along with our significant concerns about the adequacy of the proposed monitoring, the draft EA/FONSI also fails to explain what standards will be used to evaluate the monitoring data, and on what basis a decision to modify or terminate the pumping would be made. In light of the document’s silence on these crucial issues, the draft EA/FONSI’s conclusion that there will not be significant adverse impacts withers quickly under scrutiny.

3. The EA Fails to Analyze Cumulative Impacts Adequately.

The Ninth Circuit Court makes clear that NEPA mandates “a useful analysis of the cumulative impacts of past, present and future projects.” *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). Indeed, “[d]etail is required in describing the cumulative effects of a proposed action with other proposed actions.” *Id.* The very cursory cumulative effects discussion contained in the EA plainly fails to meet this standard.

As discussed in Part I.C. above, the proposed DWB does not exist in a vacuum, and is in addition to a broader program to develop regional groundwater resources and a conjunctive use system. The 2010-2011 Water Transfer Program is also only one of several proposed and existing projects that affect the regional aquifers. The existence of these numerous related projects makes an adequate analysis of cumulative impacts especially important.

4. The Bureau Has Failed to Consider the Cumulative Impact of Other Groundwater Development and Surface Water Diversions Affecting the Region

In addition to the improper segmentation evident in the draft EA/FONSI, the assessment of environmental impacts is further deficient because the Bureau has failed to consider the cumulative impacts of the proposed groundwater extraction when taken in conjunction with other projects proposed for the development of groundwater and surface water.

The Bureau and its contractors are party to numerous current and reasonably foreseeable water programs that are related to the water transfers contemplated in the DWB including the following:

- Sacramento Valley Integrated Regional Water Management Plan (2006)
- Sacramento Valley Regional Water Management Plan (January 2006)
- Stony Creek Fan Conjunctive Water Management Program
- Sacramento Valley Water Management Agreement (Phase 8, October 2001)

- Draft Initial Study for 2008-2009 Glenn-Colusa Irrigation District Landowner Groundwater Well Program
- Regional Integration of the Lower Tuscan Groundwater Formation into the Sacramento Valley Surface Water System Through Conjunctive Water Management (June 2005)
- Stony Creek Fan Aquifer Performance Testing Plan for 2008-09
- Lower Tuscan Integrated Planning Program, a program funded by the Bureau that will "integrate the Lower Tuscan formation aquifer system into the management of regional water supplies."
- Annual forbearance agreements (2008 had an estimated 160,00 acre feet proposed).

We briefly describe some of their key elements here.

Stony Creek Fan Conjunctive Water Management Program. The SCF Aquifer Plan is part of and in furtherance of the Stony Creek Fan Conjunctive Water Management Program ("SCF Program"). This program is being carried out by GCID, Orland-Artois and Orland Unit Water Association.

The long-term objective of the SCF Program is the development of a "regional conjunctive water management program consisting of a direct and in-lieu recharge component, a groundwater production component, and supporting elements.…" (SVWMA: Project 8A Stony Creek Fan Conjunctive Water Management Program ("SVWMA Project 8A"), at 8A-1). The potential supply from such a program was estimated at 50,000 af per year to 100,000 af per year. *Id.*

The SCF Program has 3 Phases: (1) a feasibility study; (2) a demonstration project; and (3) project implementation. Phase I of the SCF Program has already been completed. The SCF Aquifer Plan described in a draft EA/FONSI is part of Phase II of the larger SCF Program. Phase III of the SCF Program will implement the program's goal of integrating test and operational production wells into the water supply systems for GCID, Orland-Artois, and Orland Unit Water Association for long-term groundwater production in conjunction with surface water diversions.

The Bureau is well aware of the SCF Program, but declined to analyze the environmental effects of the program as a whole, and simply considered the effects of an isolated component of the larger program. Indeed, the Bureau recently awarded a grant to GCID to fund the SCF Program. The Bureau's grant agreement states that the SCF Program "target[s] the Lower Tuscan Formation and possibly other deep aquifers in the west-central portion of the Sacramento Valley … as the source for all or a portion of the additional groundwater production needed to meet [the SCF Partners'] respective integrated water management objectives." BOR Assistance Agreement No. 06FG202103 at p. 2. The agreement further provides that provides that "[a]dditional test wells and production wells will be installed within the Project Area." *Id.*

Moreover, the Bureau's own description of the reasons for not choosing the "No Action" alternative indicate the Bureau's recognition that the primary goal of the SCF Aquifer Plan is to realize the objectives of the SCF Program – "increas[ing] reliable water supplies through conjunctive management of groundwater and surface water" at a fast pace. *See* EA/FONSI at p. 5. The Bureau was obligated to assess the potentially significant environmental impacts associated with such conjunctive management of groundwater and surface water, and wholly failed to do so.

There are serious concerns raised by the proposal to engage in conjunctive management of groundwater and surface water that are not addressed in the EA. For example, in 1994, following seven years of low annual precipitation, Western Canal Water District and other irrigation districts in Butte, Glenn and Colusa counties exported 105,000 af of water extracted from the Tuscan aquifers to buyers outside of the area. This early experiment in the *conjunctive use* of the groundwater resources – conducted without the benefit of environmental review – caused a significant and immediate adverse impact on the environment (Msangi 2006). Until the time of the water transfers, groundwater levels had dropped but the aquifers had sustained the normal demands of domestic and agricultural users. The water districts' extractions, however, lowered groundwater levels throughout the Durham and Cherokee areas of eastern Butte County (Msangi 2006). The water level fell and the water quality deteriorated in the wells serving the City of Durham (Scalmanini 1995). Irrigation wells failed on several orchards in the Durham area. One farm never recovered from the loss of its crop and later entered into bankruptcy. Residential wells dried up in the upper-gradient areas of the aquifers as far north as Durham.

<u>The SCF Program is a Component of the Sacramento Valley Water Management Program.</u> The Sacramento Valley Water Management Program (Phase 8) ("SVWMP") also includes the SCF Program as one of its elements. (SVWMA Project 8A at pp. 8A-1 to 8A-13).

The SVWMP recognizes that the SCF Program "has the potential to improve operational flexibility on a regional basis resulting in measurable benefits locally in the form of predictable, sustainable supplies, *and improved reliability for water users' elsewhere in the state*." *Id.* at p. 8A-2 (emphasis added). By piecemealing this program improperly and analyzing only the small component of the SCF Program, the Bureau has failed to assess the environmental impacts associated not just with the anticipated conjunctive use of the groundwater, but also the effect of the anticipated export of water to other regions of the state.

Additionally, approximately seven years ago, on August 5, 2003, the Bureau published a notice in the Federal Register announcing its intention to prepare a programmatic EIS to analyze the short-term phase of the SVWMP. 68 Fed. Reg. 46218, 46219 (Aug. 5, 2003). Like the SVWMP, this "Short-term Program" for which the Bureau stated its intent to conduct a programmatic EIS included implementation of the SCF Program. *Id.* at 46219, 46220.

<u>The SCF Program is Also a Component of the Sacramento Valley Integrated Regional Water Management Program.</u> The Bureau has been working with GCID and others to realize the

Sacramento Valley Integrated Regional Water Management Program ("SVIRWMP"). SVIRWMP is comprised of a number of sub-regional projects, including the SCF Program. *See* SVIRWMP, Appendix A at A-5; BOR Assistance Agreement No. 06FG202103. Here again, even though the SCF Aquifer Plan is clearly a necessary component of the SCF Program – which is in turn a component of the SVIRWMP – the draft EA/FONSI failed to even acknowledge, let alone assess, the cumulative impacts of these related projects.

Most obviously, the draft EA wholly fails to assess the impact of the Bureau's *Sacramento Valley Regional Water Management Plan (2006)* (SVRWMP) and the forbearance water transfer program that the Bureau and DWR facilitate jointly. As noted above, the Programmatic EIS for the 2002 Sacramento Valley Water Management Agreement or Phase 8 Settlement was initiated, but never completed, so the SVRWMP was the next federal product moving the Phase 8 Settlement forward. The stated purpose of the Phase 8 Settlement and the SVRWMP are to improve water quality standards in the Bay-Delta and local, regional, and statewide water supply reliability. In the 2008 forbearance program, 160,000 af was proposed for transfer to points south of the Delta. To illustrate the ongoing significance of the demand on Sacramento Valley water, we understand that GCID alone entered into "forbearance agreements" to provide 65,000 af of water to the San Luis and Delta Mendota Water Association in 2008, 80,000 af to State Water Project contractors in 2005, and 60,000 af to the Metropolitan Water District of Southern California in 2003.

Less obvious, but certainly available to the Bureau, are the numerous implementation projects that Phase 8 signatories are pursuing, such as Glenn Colusa Irrigation District's (GCID) 2008 proposal to divert groundwater pumped from private wells to agricultural interests in the District. *See* Attach. (GCID Proposed Negative Declaration, GCID Landowner Groundwater Well Program for 2008-09). Additionally, the draft EA does not consider the cumulative effect of the Lower Tuscan Integrated Planning Program, a program funded by the Bureau that will "integrate the Lower Tuscan formation aquifer system into the management of regional water supplies." Grant Agreement at 4. This program, as described by the Bureau, will culminate in the presentation of a proposed water management program for the Lower Tuscan Formation for approval and implementation by the appropriate authorities. Clearly, the cumulative impact of this program and the 2010-2011 Water Transfer Program's proposed groundwater extraction should have been assessed.

Finally, with the myriad projects and programs that are ignored in the EA and have never been analyzed cumulatively, the EA finally discloses that there could be a *devastating* impact to groundwater: "The reduction in recharge due to the decrease in precipitation and runoff in the past years in addition to the increase in groundwater transfers would lower groundwater levels. Multi-year groundwater acquisition under cumulative programs operating in similar areas of the Sacramento Valley could further reduce groundwater levels. Groundwater levels may not fully recover following a transfer and may experience a substantial net decline in groundwater levels over several years. This would be a substantial cumulative effect," (EA p. 3-108). While the honesty is refreshing, the lack of comprehensive monitoring, mitigation, and project cessation mechanisms is startling. This alone warrants the preparation of an EIS.

Here again, the current document does not discuss or analyze these potential impacts, their potential scope or severity, or potential mitigation efforts. Instead, it relies on the existence of local ordinances, plans, and oversight with the monitoring and mitigation efforts of individual "willing sellers" to cope with any adverse environmental effects. However, as we have shown above, for example, the Glenn County management plan is untested and does not provide adequate protection and monitoring of the region's important groundwater resources. To further clarify the inadequacy of relying on local plans and ordinances, Butte County's Basin Management Objectives have no enforcement mechanism and Butte County's Chapter 33, while it requires CEQA review for transfers that include groundwater, has never been tested. As one can see, there is very limited local protection for groundwater and no authority to influence pumping that is occurring in a different county.

5. The 2010-2011 Water Transfer Program is likely to serve as precedent for future actions with significant environmental effects.

As set forth above, this Project is part of a broader effort by the Bureau and DWR to develop groundwater resources and to integrate GCID's water into the state system. For these reasons, the 2010-2011 Water Transfer Program is likely to "establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration" (40 C.F.R. §1508.27(b)(6)), and should be analyzed in an EIS.

6. The 2010-2011 Water Transfer Program has potential adverse impacts for a threatened species.

As the Bureau of Reclamation is well aware, the purpose of the ESA is to conserve the ecosystems on which endangered and threatened species depend and to conserve and recover those species so that they no longer require the protections of the Act. 16 U.S.C. § 1531(b), ESA § 2(b); 16 U.S.C. § 1532(3), ESA §3(3) (defining "conservation" as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary"). "[T]he ESA was enacted not merely to forestall the extinction of species (i.e., promote species survival), but to allow a species to recover to the point where it may be delisted." *Gifford Pinchot Task Force v. U.S. Fish & Wildlife Service*, 378 F3d 1059, 1069 (9th Cir. 2004). To ensure that the statutory purpose will be carried out, the ESA imposes both substantive and procedural requirements on all federal agencies to carry out programs for the conservation of listed species and to insure that their actions are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. 16 U.S.C. § 1536. *See NRDC v. Houston*, 146 F.3d 1118, 1127 (9th Cir. 1998) (action agencies have an "affirmative duty" to ensure that their actions do not jeopardize listed species and "independent obligations" to ensure that proposed actions are not likely to adversely affect listed species). To accomplish this goal, agencies must consult with the Fish and Wildlife Service whenever their actions "may affect" a listed species. 16 U.S.C. § 1536(a)(2); 50 C.F.R. § 402.14(a). Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to "mean all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States." 50 C.F.R. § 402.02.

The giant garter snake ("GGS") is an endemic species to Central Valley California wetlands. (Draft Recovery Plan for the Giant Garter Snake ("DRP") 1). The giant garter snake, as its name suggests, is the largest of all garter snake species, not to mention one of North America's largest native snakes, reaching a length of up to 64 inches. Female GGS tend to be larger than males. GGS vary in color, especially depending on the region, from brown to olive, with white, yellow, or orange stripes. The GGS can be distinguished from the common garter snake by its lack of red markings and its larger size. GGS feed primarily on aquatic fish and specialize in ambushing small fish underwater, making aquatic habitat essential to their survival. Females give birth to live young from late July to early September, and brood size can vary from 10 to up to 46 young. Some studies have suggested that the GGS is sensitive to habitat change in that it prefers areas that are familiar and will not typically travel far distances. The EA discloses that one GGS study in Colusa County revealed the "longest average movement distances of 0.62 miles, with the longest being 1.7 miles, for sixteen snakes in 2006, and an average of 0.32 miles, with the longest being 0.6 miles for eight snakes in 2007. However, in response to droughts and other changes in water availability, the GGS has been known to travel up to 5 miles in only a few days, but the impacts on GGS survival and reproduction from such extreme conditions are unknown due to the deficiency in data and analysis.

Flooded rice fields, irrigation canals, and wetlands in the Sacramento Valley can be used by the giant garter snake for foraging, cover and dispersal purposes. The draft EA fails to comprehensively analyze the movements and habitat requirements for the federal and state-threatened giant garter snake and yet again defers responsibility to a future time. The 2009 Biological Assessment acknowledged the failure of Bureau and DWR to complete the Conservation Strategy that was a requirement of the 2004 Biological Opinion. (BA at p. 19-20) [The BA appears to have no page numbers] What possible excuse delayed this essential planning effort?

The 2010-2011 Water Transfer Program also proposes to delete or modify other mitigation measures previously adopted as a result of the EWA EIR process to substantially reduce significant impacts, but without showing they are infeasible. For example, the Bureau and DWR propose to delete the 160 acre maximum for "idled block sizes" for rice fields left fallow rather than flooded and to substitute for it a 320 acre maximum. (See 2003 Draft EWA EIS/EIR, p. 10-55; 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 4.) There is no evidence to support this change. In light of the agencies failure to complete the required Conservation Strategy mentioned above and the data gathered in the Colusa County study, how can the EA suggest that doubling the fallowing acreage is in any way biologically defensible? The agencies additionally propose to delete the mitigation measure excluding Yolo County east of Highway 113 from the areas where rice fields may be left fallow rather than flooded, except in three specific areas. (See 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 2.) What is the explanation for this change? What are the impacts from this change?

Deleting these mitigation measures required by the EWA approval would violate NEPA and CEQA's requirements that govern whether, when, and how agencies may eliminate mitigation measures previously adopted under NEPA and CEQA. (See *Napa Citizens for Honest Government v. Napa County Board.*

The 2010-2011 Water Transfer Program fails to include sufficient safeguards to protect the giant garter snake and its habitat. The EA concludes, "The frequency and magnitude of rice land idling would likely increase through implementation of water transfer programs in the future. Increased rice idling transfers could result in chronic adverse effects to giant garter snake and their habitats and may result in long-term degradation to snake populations in the lower Sacramento Valley. In order to avoid potentially significant adverse impacts for the snake, additional surveys should be conducted prior to any alteration in water regime or landscape," (p. 3-110). To address this significant impact the Bureau proposes relying on the 2009 DWB Biological Opinion, which was a one-year BO. The expired BO highlights the Bureau and DWR's avoidance of meeting federal and state laws stating, "This office has consulted with Reclamation, both informally and formally, approximately one-half dozen times over the past 8 years on various forbearance agreements and proposed water transfers for which water is made available for delivery south of the delta by fallowing rice (and other crops) or substituting other crops for rice in the Sacramento Valley. Although transfers of this nature were anticipated in our biological opinion on the environmental Water Account, that program expired in 2007 and, to our knowledge, no water was ever made available to EWA from rice fallowing or rice substitution. The need to consult with such frequency on transfers involving water made available from rice fallowing or rice substitution suggests to us a need for programmatic environmental compliance documents, including a programmatic biological opinion that addresses the additive effects on giant garter snakes of repeated fallowing over time, and the long-term effects of potentially large fluctuations and reductions in the amount and distribution of rice habitat upon which giant garter snakes in the Sacramento Valley depend," (p.1-2). The Coalition agrees with the U.S. Fish and Wildlife Service that programmatic environmental compliance is needed under the Endangered Species Act, NEPA, CEQA, and the California Endangered Species Act.

It is conspicuously noticeable that there isn't a claim of a less-than-significant impact for the Giant Garter Snake (*Thamnophis gigas*), in the EA/FONSI. There is really no conclusion reached due to the fundamental absence of science for the species. The Bureau should also prepare an EIS because the 2010-2011 Water Transfer Program will likely have significant environmental effects on the Giant Garter Snake, a listed threatened species under the federal Endangered Species Act and California Endangered Species Act. 40 C.F.R. §1508.27(b)(9).

II. Purpose and Need Issues of the 2010-2011 Water Transfer Program

A. The Purpose and Need Section of the EA/FONSI fails to specify the policy framework upon which the 2010-2011 Water Transfer Program is based.

Avoiding the requirements of the California Environmental Quality Act (CEQA) for the 2010-2011 Water Transfer Program does not reflect the actual environmental effects of the proposal—which are similar to the proposed 1994 Drought Water Banks and for which a final Program Environmental Impact Report was completed in November 1993. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken. Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate. So, the 2009 DWB Notice of Exemption and complete avoidance of CEQA review for the 2010-2011 Water Transfer Program reflects an end-run around established water law through the use of water transfers, and is therefore vulnerable to legal challenge under the California Environmental Quality Act.

We question the merits of and need for the 2010-2011 Water Transfer Program itself. The existence of drought conditions at this point in time is highly questionable and reflects the state's abandonment of a sensible water policy framework given our state and national economic recession and tattered public budgets. Our organizations believe the agencies continue to go too far to help a few junior water right holders, and that at bottom the 2010-2011 Water Transfer Program is not needed. The Project intends to directly benefit the areas of California whose water supplies are the least reliable by operation of state water law. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The EA/FONSI's statement of purpose and need on page 1-2 states specifically that, "The purpose of the Proposed Action is to help facilitate the transfer of water throughout the State from willing sellers of CVP water upstream of the Delta to buyers that are at risk of experiencing water shortages in 2010 and 2011." This paragraph and the section that it is in omit a coherent discussion of need. The purpose and need should also state that this transfer program would be subject to specific criteria and delineate priorities, but they are absent.

The EA/FONSI makes no attempt to place the 2010-2011 Water Transfer Program into the context of the 2005 California Water Plan that the state recently completed. It appears to us that this plan is largely on the shelf now, perhaps because of the state's dire fiscal problems. It does contain many good recommendations concerning increasing regional water self-sufficiency. However, our review of the 2005 California Water Plan reveals no mention of the 2000 Critical Water Shortage Reduction Marketing Program or any overarching drought response plan that the state could have planned for in 2005, but did not. We sadly conclude that the state of California has no meaningful adopted drought response policy, save for gubernatorial emergency declarations to suspend protective environmental regulations. This is not a sustainable water policy for California.

The purpose and need section of the EA/FONSI *and the 2009 Governor's drought emergency declaration* cry out for placing the 2010-2011 Water Transfer Program into a policy framework. What is the state doing otherwise to facilitate regional water self-sufficiency for these areas with the least reliable water rights? How does the 2010-2011 Water Transfer Program fit into the state and federal government's water and drought policy framework? Instead, the state and federal response to this third consecutive dry year falls back on simply the Drought Water Bank model that ran into environmental and water users' opposition in 1991 and 1992. Is anybody home at our water agencies?

B. The 2010-2011 Water Transfer Program is not needed because the state's current allocation system—in which the federal Bureau of Reclamation participates—wastes water profligately.

The incentive from the state's lax system of regulation of California's State Water Project and Central Valley projects is to deliver the water now, and worry about tomorrow later. Indeed, the State Water Resources Control Board (SWRCB) has been AWOL for decades. In response to inquiries from the Governor's Delta Vision Task Force last fall, the SWRCB acknowledged that while average runoff in the Delta watershed between 1921 and 2003 was 29 million acre-feet annually, the 6,300 active water right permits issued by the SWRCB is approximately 245 million acre-feet. In other words, **water rights on paper are 8.4 times greater than the real**

water in California streams diverted to supply those rights on an average annual basis. *And the SWRCB acknowledges that this "water bubble" does not even take account of the higher priority rights to divert held by pre-1914 appropriators and riparian water right holders, of which there are another 10,110 disclosed right holders.* Many more remain undisclosed.

Like federal financial regulators failing to regulate the shadow financial sector, subprime mortgages, Ponzi schemes, and toxic assets of our recent economic history, the state of California has been derelict in its management of scarce water resources here. This in no way justifies suspension of environmental and water quality regulations, for which the Governor's drought emergency declaration calls. We supplement our comments on this matter of wasteful use and diversion of water by incorporating by reference the joint complaint to the State Water Resources Control Board of the California Water Impact Network and the California Sportfishing Protection Alliance on public trust, waste and unreasonable use and method of diversion as additional evidence of a systematic failure of governance by the State Water Resources Control Board, the Department of Water Resources and the U.S. Bureau of Reclamation, filed with the Board on March 18, 2008 (attached).

We question the Bureau and DWR's contention of continued dry conditions, since the current storms have greatly increased reservoir levels throughout California. Non-state and non-federal reservoirs indicate conditions fast approaching normal for their facilities: Bullard's Bar in Yuba County is at 99 percent of the 15-year average for this time of year, EBMUD's Pardee Lake is at 97 percent of normal, San Francisco's Hetch Hetchy Reservoir on the Tuolumne River is at 152 percent of normal, while Don Pedro Reservoir on the same river is at 106 percent. The CVP's Millerton and Folsom reservoirs are below average for this time of year, but with the strong storms California is now getting through this week and into next, their storage figures are likely to improve dramatically when snowpack melts. These two reservoirs must provide water to the agricultural San Joaquin River Exchange Contractors first, and they have among the most senior rights on that river. Rice growers in the Sacramento Valley are generally expecting close to full deliveries from the CVP and their Yuba River water supplies. The CVP's own New Melones Reservoir on the Stanislaus River, which contributes to Delta water quality as well as to meeting eastern San Joaquin Valley irrigation demands, is at 87 percent of normal for this time of year.

Moreover, the SWP's terminal reservoirs at Pyramid (104 percent of average) and Castaic (99 percent of average) Lakes are right at about normal storage levels for this time of year, presumably because DWR has been releasing water from Oroville for delivery to these reservoirs.

The fact that reservoirs of the CVP with more senior responsibilities in the water rights hierarchy do well with storage for this time of year suggests that at worst this will be a year of below normal runoff in 2010—hardly a drought scenario. Low storage levels at Oroville, Shasta and San Luis may easily be attributed to redirected releases to terminal reservoirs or groundwater banks in the San Joaquin Valley and Tulare Lake Basin—these latter storage venues and their current performance are not disclosed on DWR's Daily Reservoir Storage levels web site. Still, given what is known, from what these reservoir levels indicate many major cities and most Central Valley farmers are very likely to have enough water for this year.

The ones expecting to receive little water this year do so because of the low priority of their water service contracts within the Central Valley Project—their imported surface supplies are therefore less reliable in dry times. It is the normal and appropriate functioning of California‘s system of water rights law that makes it so. Among those with more junior water contractor allocations, the Metropolitan Water District and the Santa Clara Valley Water District are the wealthiest regions and the agencies most capable of undertaking aggressive regional water self-sufficiency actions. They should be further encouraged and assisted to do so through coherently formulated state and federal water policies and programs.

On the agricultural side, the Bureau and DWR's efforts appear to benefit mainly the few western San Joaquin Valley farmers whose contractual surface water rights have always been less reliable than most—and whose lands are the most problematic for irrigation. In excess of 1 million acres of irrigated land in the San Joaquin Valley and the Tulare Lake Basin are contaminated with salts and trace metals like selenium, boron, arsenic, and mercury. These lands should be retired from irrigation to stop wasteful use of precious fresh water resources. This water drains back—after leaching from these soils the salts and trace metals—into sloughs and wetlands and the San Joaquin River carrying along these pollutants. Retirement of these lands from irrigation usage would help stem further bioaccumulation of these toxins that have settled in the sediments of these water bodies.

The 2010-2011 Water Transfer Program would exacerbate pumping of fresh water from the Delta, which has already suffered from excessive pumping in earlier years of this decade. Pumped exports cause reverse flows to occur in Old and Middle Rivers and can result in entrainment of fish and other organisms in the pumps. Pumping can shrink the habitat for Delta smelt as well, since less water flows out past Chipps Island through Suisun Bay which Delta smelt often prefer. Our organizations share the widely held view that operation of the Delta export pumps is the major factor causing the Pelagic Organism Decline (POD) and in the deteriorating populations of fall-run Chinook salmon. The State Water Resources Control Board received word in early December that the Fall Midwater Trawl surveys for September and October showed the lowest abundance indices for Delta smelt, American shad, and striped bass in history. The index for longfin smelt is the third lowest in history. 2009 was the second consecutive year where no commercial fishing of fall-run Chinook fish will be allowed because of this species‘population decline. While it is too early to know, 2010 could be the third straight year where no commercial fishing will be allowed, which would be unprecedented. Operation of the DWB at a time when others refrain from taking these fish and other organisms strikes us as a consummate unwillingness on the part of the State of California and the U.S. Bureau of Reclamation to share in the sacrifices needed to help aquatic ecosystems and anadromous fisheries of the Bay-Delta Estuary recover.

New capital facilities should be avoided to save on costly, unreliable, and destructive water supplies that new dams and canals represent. Moreover, these facilities would need new water rights; yet the most reliable rights in California are always the ones that already exist—and of those, they are the ones that predate the California State Water Project and the federal Central Valley Project. We should apply our current rights far more efficiently—and realistically—than we do now. California should instead pursue a "no-regrets" policy incorporating aggressive water conservation strategies, careful accounting of water use, research and technological innovation, and pro-active investments.[5]

III. Conclusion

The Bureau's EA/FONSI states on page 3-16:

> *California Water Code Section 1810 and the CVPIA protect against injury to third parties as a result of water transfers. Three fundamental principles include (1) no injury to other legal users of water; (2) no unreasonable effects on fish, wildlife or other in-stream beneficial uses of water; and (3) no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred.*

We unreservedly state to you that the draft EA/FONSI on the proposed 2010-2011 Water Transfer Program appears to describe a project that would fail all three of these tests as currently described. The 2010-2011 Water Transfer Program clearly has the potential to affect the human and natural environments, both within the Sacramento Valley as well as in the areas of conveyance and delivery. It is entirely likely that injuries to other legal users of water, including those entirely dependent on groundwater in the Sacramento Valley, will occur if this project is approved. Groundwater, fishery and wildlife resources are likely also to suffer harm as instream users of water in the Sacramento Valley. And the economic effects of the proposed DWB are at best poorly understood through the EA/FONSI. To its credit, at least the Bureau studied the proposed project, while DWR has completely avoided CEQA, thereby enabling the agency to ignore these potential impacts.

Taken together, the Bureau and DWR treat these serious issues carelessly in the EA/FONSI, and in DWR's specious avoidance of CEQA review. In so doing, they deprive decision makers and the public of their ability to evaluate the potential environmental effects of this Project, and violate the full-disclosure purposes and methods of both the National Environmental Policy Act and the California Environmental Quality Act.

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[5] See especially, Pacific Institute, *More with Less: Agricultural Water Conservation and Efficiency in California, A Special Focus on the Delta*, September 2008; Los Angeles Economic Development Corporation, *Where Will We Get the Water? Assessing Southern California's Future Water Strategies*, August 2008, and Lisa Kresge and Katy Mamen, *California Water Stewards: Innovative On-farm Water Management Practices*, California Institute for Rural Studies, January 2009.

None of the signatory organizations to this letter received notice from the Bureau that this EA/FONSI had been released on January 5, 2010. With the Coalition's 2009 DWB comments on the EA/FONSI, we had the following request: *Our organizations request advance notification of any meetings that address this proposed Project or any other BOR projects in Butte, Colusa, Glenn, or Tehama counties that require consideration of NEPA/CEQA as well as water rights applications that will be needed as the 2010-2011 Water Transfer Program moves forward. Please add C-WIN, CSPA, BEC, and the Center for Biological Diversity to your basic public notice list on this Project, and send us each any additional documents that pertain to this particular Project.* While we do find record of a news release about the EA/FONSI on the Bureau's Mid-Pacific Region web site, we believe the Bureau has not met its obligations under NEPA for providing adequate public outreach to solicit review and comment of its environmental review documents in this matter. We learned of the Water Transfer Program on January 14th more than halfway through the review period set by the Bureau. Bureau staff rejected our request for additional time to review the documents, much to our disappointment. Please add our names and email addresses to all future environmental review news releases.

Sincerely,

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References Cited

Bureau of Reclamation 2006. Sacramento Valley Regional Water Management Plan. p. 5-8 to 5-10.

Butte Basin Water Users Association 2007. *2007 Butte Basin Groundwater Status Report* p. 23 and 30.

Butte Basin Water Users Association 2008. *2008 Butte Basin Groundwater Status Report*

Butte County 2007. Summary of Spring 07 Levels.

Butte County Department and Resource Conservation 2003. *Urban Water Demand Forecast*.

Butte County DWRC June 2007. *Tuscan Aquifer Monitoring, Recharge, and Data Management Project*, Draft.

California State Water Resources Control Board 2009. *GAMA Domestic Well Project, Tehama County Focus Area*.

California Water Impact Network, et al 2008. Complaint for Declaratory and Injunctive Relief.

CH2Mhill 2006, *Sacramento Valley Regional Water Management Plan*, Figure 1-4.

Dudley, Toccoy et al. 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update.*

Dudley, Toccoy 2007. Letter to Lester Snow as presented to the Butte County Board of Supervisors as part of agenda item 4.05.

DWR 2006. *California's Groundwater – Bulletin 118*.

DWR 2008. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

DWR 2009. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

Fleckenstein, Jan; Anderson, Michael; Fogg, Graham; and Mount, Jeffrey 2004. *Managing Surface Water-Groundwater to Restore Fall Flows in the Cosumnes River*, Journal of Water Resources Planning and management, opening page of article.

Friend, Scott 2008. *City of Chico General Plan Update Existing Conditions Report;* Pacific

Municiple Consulting.

Glenn County. Board of Supervisors. California Ordinance No. 1115, Ordinance Amending the County Code, Adding Chapter 20.03, Groundwater Management.

Glenn County. Management Plan: Development of a Locally Driven Groundwater Management Plan Ordinance #1115. Accessed January 18, 2010 at: http://www.glenncountywater.org/management_plan.aspx.

Glenn-Colusa Irrigation District 2008-2009. *Initial Study And Proposed Negative Declaration Landowner Groundwater Well Program*.

Governor's Advisory Drought Planning Panel 2000. *Critical Water Shortage Contingency Plan*.

Hennigan, Barbara 2007. Testimony, Monterey Agreement hearing in Quincy, California. (http://www.water.ca.gov/environmentalservices/docs/mntry_plus/comments/Quincy.txt).

Hennigan, Robert 2010. Personal communication with Barbara Vlamis on January 17, 2010.

Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

Maslin, Paul E., et. al, 1996. *Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon: 1996 Update*.

McManus, Dan; Senior Engineering Geologist, DWR Northern District on August 27, 2007, Personal communication with Jim Brobeck.

Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.

Msangi, Siwa and Howit, Richard E. 2006. *Third Party Effects and Asymmetric Externalities in Groundwater Extraction: The Case of Cherokee Strip in Butte County, California.* International Association of Agricultural Economists Conference, Gold Coast, Australia.

Scalmanini, Joseph C. 1995. *VWPA Substatiation of Damages*. Memo. Luhdorff and Scalmanini Consulting Engineers.

Shutes, Chris et al. 2009. *Draft Environmental Assessment DeSabla – Centerville Project (FERC No. 803)*. Comments. California Sportfishing Protection Alliance.

Spangler, Deborah L. 2002. *The Characterization of the Butte Basin Aquifer System, Butte County, California*. Thesis submitted to California State University, Chico.

Staton, Kelly 2007. *Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California*. California Department of Water Resources.

USFWS 1999. Draft Recovery Plan for the Giant Garter Snake.

USFWS 2006. Giant Garter Snake Five Year Review: Summary and Evaluation.

USFWS 2008 Biological Opinion for Conway Ranch.

USFWS 2009 Biological Opinion for the Drought Water Bank.

california water impact network

California Sportfishing Protection Alliance
"An Advocate for Fisheries, Habitat and Water Quality"

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BEC
32 YEARS OF SERVICE

March 19, 2009

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Subject: Comments on Environmental Reviews for the *2009 Drought Water Bank.*

Dear Ms. Victorine and Mr. Hendrick:

Butte Environmental Council, the California Sportfishing Protection Alliance, the Center for Biological Diversity, and the California Water Impact Network ("the Coalition") submit the following comments and questions for the Draft Environmental Assessment ("EA") and Findings of No Significant Impact ("FONSI"), for the *2009 Drought Water Bank* ("DWB" or "Project"). We also provide comments about the purpose and need for the 2009 Drought Water Bank, the Governor's recent drought emergency declaration, and the CEQA Notice of Exemption to cover this project's implementation with mitigation measures from the 2003 and 2007 Environmental Water Account environmental documents.

The Bureau of Reclamation's draft environmental review of the California Department of Water Resources ("DWR's") DWB does not comply with the requirements of National Environmental Policy Act ("NEPA"), 42 U.S.C. §4321 *et seq*. First, we believe that the Bureau needs to prepare an environmental impact statement ("EIS") on this proposal that could allow up to 600,000 acre-feet (AF) of surface water transfers, up to 340,000 AF of groundwater substitution, and significant crop idling. Bureau reliance on the EA itself violates NEPA requirements because, among other things, the EA fails to provide a reasoned analysis and explanation to support the Bureau's proposed finding of no significant impact. The EA contains a fundamentally flawed alternatives analysis, and treatment of the chain of cause and effect extending from project implementation leading to inadequate analyses of nearly every resource and cumulative impacts.

An EIS would afford the Bureau, DWR, the State Water Resources Control Board, and the California public far clearer insight into how, where, and why the DWB might or might not be needed. The draft EA/FONSI as released this month fails to provide adequate disclosure of these impacts.

Second, exemption of the 2009 DWB from the requirements of the California Environmental Quality Act (CEQA) does not reflect the actual environmental effects of the proposal—which are similar to the proposed 1994 Drought Water Banks and for which a final Program Environmental Impact Report was completed in November 1993. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken. Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate. So, DWR's Notice of Exemption reflects an end-run around established water law through the use of water transfers, and is therefore vulnerable to legal challenge under the California Environmental Quality Act.

Finally, we also question the merits of and need for the DWB project itself. The existence of drought conditions at this point in time is highly questionable and reflects the state's abandonment of a sensible water policy framework given our state and national economic recession and tattered public budgets. Our organizations believe the Governor's drought emergency declaration goes too far to help a few junior water right holders, and that at bottom, the 2009 Drought Water Bank is not needed. The DWB will directly benefit the areas of California whose water supplies are the least reliable by operation of state water law. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The proposed DWB will have significant effects on the environment—both standing alone and when reviewed in conjunction with the multitude of other plans that incorporate and are dependent on Sacramento Valley water. Ironically, the Bureau appears to recognize in its cumulative impacts discussion that there is potential for significant adverse impacts associated with the DWB, but instead of conducting an EIS as required, attempts to assure the public that the 2009 DWB will be deferred to the "willing sellers" through individual "monitoring and mitigation programs" as well as through constraining actions taken by both DWR and Bureau professional staff whose criteria ought instead be incorporated into the Proposed Action Alternative. EA at p. 37, FONSI at p. 3, 4, 5, 6, 7. Of course, this is not a permissible approach under NEPA; significant adverse impacts should be mitigated—or avoided altogether as CEQA normally requires.[1] Moreover, in light of the wholly inadequate monitoring planned for the 2009

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[1] Perhaps even more telling, the Bureau actually began its own Programmatic EIS to facilitate water transfers from the Sacramento Valley and the interconnected actions that are integrally related to it, but never completed that EIS and now has impermissibly broken out this current segment of the overall Program for piecemeal review in the present draft EA. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "include[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater

DWB's extensive water transfer program, the suggestion that the public should be required to depend on that insufficient monitoring to provide the necessary advance notice of "significant adverse impacts" is an unacceptable position.

We incorporate by reference the following documents:

- Butte Environmental Council's comments on the Supplemental Environmental Water Account EIR/EIR, 2006.
- Butte Environmental Council's letter to DWR regarding the Drought Water Bank Addendum from Lippe Gaffney Wagner LLP, 2009.
- Butte Environmental Council's letter to DWR regarding the Drought Water Bank Addendum.
- Multi-Signatories letter regarding the Drought Water Bank, 2008.
- Professor Kyran Mish's White Paper, 2008.
- Professor Kyran Mish's comments on the 2009 DWB EA/FONSI
- Professor Karin Hoover's Declaration, 2008.

I. The Bureau and DWR Must Prepare an Environmental Impact Statement/ Environmental Impact Report on the Proposed 2009 Drought Water Bank

We strongly urge the Bureau and DWR to withdraw these inadequate environmental documents and instead prepare a joint EIR/S on the 2009 DWB, before approval by the State Water Resources Control Board (SWRCB), in order to comply with both NEPA and CEQA requirements for full disclosure of human and natural environmental effects.

NEPA requires federal agencies to prepare a detailed environmental impact statement on all "major Federal actions significantly affecting the quality of the human environment . . . ." 42 U.S.C. §4332(2)(C). This requirement is to ensure that detailed information concerning potential environmental impacts is made available to agency decision makers and the public before the agency makes a decision. *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 349 (1989). CEQA has similar requirements and criteria.

Under NEPA's procedures, an agency may prepare an EA in order to decide whether the environmental impacts of a proposed agency action are significant enough to warrant preparation of an EIS. 40 C.F.R. §1508.9. An EA must "provide sufficient evidence and analysis for determining whether to prepare an [EIS]" (*id.*), and must demonstrate that it has taken a "'hard look' at the potential environmental impact of a project." *Blue Mountains Biodiversity Project v. Blackwood*, 161 F.3d 1208, 1212 (9th Cir. 1998) (internal quotation marks omitted). However, the U.S. Court of Appeals for the Ninth Circuit has cautioned that "[i]f an agency decides not to

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and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" *Id.* At 46219. See also http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").

prepare an EIS, it must supply a convincing statement of reasons to explain why a project's impacts are insignificant." *Id.* (internal quotation marks omitted). The Bureau has not provided a convincing statement of reasons explaining why the DWB's impacts are not significant. So long as there are "substantial questions whether a project *may* have a significant effect on the environment," an EIS must be prepared. *Id.* (emphasis added and internal quotation marks omitted). Thus, "the threshold for requiring an EIS is quite low." *NRDC v. Duvall*, 777 F. Supp. 1533, 1538 (E.D. Cal. 1991). Put another way, as will be shown through our comments, the bar for sustaining an EA/FONSI under NEPA procedures is set quite high, and the Bureau fails to surmount it with its report on the 2009 DWB.

NEPA regulations promulgated by the Council on Environmental Quality identify factors that the Bureau must consider in assessing whether a project may have significant environmental effects, including:

(1) "The degree to which the possible effects on the human environment are highly uncertain or involve unique or unknown risks." 40 C.F.R. §1508.27(b)(5).
(2) "The degree to which the effects on the quality of the human environment are likely to be highly controversial." *Id.* §1508.27(b)(4).
(3) "Whether the action is related to other actions with individually insignificant but cumulatively significant impacts. Significance exists if it is reasonable to anticipate on a cumulatively significant impact on the environment. Significance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).
(4) "The degree to which the action may establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration." *Id.* §1508.27(b)(6).
(5) "The degree to which the action may adversely affect an endangered or threatened species or its habitat that has been determined to be critical under the Endangered Species Act of 1973." *Id.* §1508.27(b)(9).

Here, the Bureau has failed to take a hard look at the environmental impacts of the DWB. As detailed below, there are substantial questions about whether the 2009 DWB's proposed water transfers will have significant effects on the region's environmental and hydrological conditions especially the interactions between groundwater and surface streams of interest in the Sacramento Valley region. There are also substantial questions about whether the 2009 DWB will have significant adverse environmental impacts when considered in conjunction with the other related water projects underway and proposed in the region. The Bureau simply cannot rely on the EA/FONSI for the foreseeable environmental impacts of the proposed 2009 DWB and still comply with NEPA's requirements.

A. The Proposed Action Alternative is poorly specified making it difficult to identify chains of cause and effect necessary to analyze adequately the alternative's environmental effects.

The Proposed Action Alternative is poorly specified and needs additional clarity before decision makers and the public can understand the human and environmental consequences of the 2009 Drought Water Bank. The EA describes the Proposed Action Alternative as one reflecting the Bureau's intention to approve transfers of Central Valley Project water from willing sellers who contract with the Bureau ordinarily to use surface water on their croplands. Up to 208,000 AF of CVP water are on offer from these sellers, according to Table 1 of the EA. "Priority criteria" are described in the EA indicating that sales will be prioritized for water-short public health, urban, and then agricultural uses, in that order. Table 2 of the EA indicates that as much as 839,117 AF has been requested.

The EA/FONSI's statement of purpose and need states specifically that "the purpose of the proposed action is to help facilitate the transfer of water throughout the State from willing sellers of CVP water upstream of the Delta to buyers that are at risk of experiencing water shortage in 2009." This paragraph omits coherent discussion of need. The purpose and need should also state that this transfer program would be subject to specific criteria for prioritizing transfers, as described on page 6: "It is anticipated that water made available to [potential buyers] from the DWB would be prioritized as flows: existing health and safety domestic needs, municipal supply subject to water shortage contingency plan measures, and agricultural irrigation for existing crops and livestock subject to water shortage contingency plan measures."

The EA's description of the proposed action alternative needs to make clear what would occur if the sale criteria are in fact applied. Are both project agencies applying them, or just one and not the other? What is the legal or policy basis authorizing use of these criteria? Will exceptions be provided, and if so, by what criteria would exceptions be made?

Taken together with DWR's March 4th Addendum to the EWA EIS/R, there is considerable ambiguity over just how many potential sellers there are and how much water they would make available to the DWB. This is reflected in different numbers in the two environmental documents justifying the DWB. The following table shows the discrepancies across these uncoordinated environmental reviews:

Comparison of Environmental Review Parameters for the 2009 Drought Water Bank	**DWR Addendum, March 4th**	**Bureau EA, March 4th**
Narrative project description present in document?	No	Yes
DWB sale criteria discussed?	No	Yes
Total potential water for sale (AF)	533,435	389,328
Total potential water requests (AF)	818,905	839,117
Total potential water sales covered by environmental compliance with the EWA EIS/R (AF)	600,000	Not described.

Absence of agreement among these documents on basic facts of the 2009 DWB signals that neither the Bureau nor DWR have a clear idea what the DWB is. This problem contributes greatly to and helps explain the poorly rendered treatment of causes and effects that permeate the Bureau's EA. The project agencies, decision-makers, and the public all face a moving target with the 2009 Drought Water Bank. Such discrepancies reflect hasty consideration and poor planning by project proponents. Nor can the agencies reasonably attribute their inadequate environmental reviews on lack of warning. The Governor has made fear of drought a centerpiece of his recent water statements since at least last June. Yet DWR and the Bureau apparently have not agreed on these basic facts making up the DWB.

From data available in the EA and the Addendum, it is not possible to determine with confidence just how much water is requested by potential urban and agricultural buyers. There is no attempt to describe how firmly tendered are offers of water to sell or requests to purchase. With between 400,000 and 500,000 AF of presumably urban buyer requests[2] (which have priority over agricultural purchases, according to the DWB priorities) and a cumulative total of less than 400 TAF from willing sellers (with just over half that coming from CVP water), it would appear that many agricultural buyers are not likely to have their needs addressed by the 2009 DWB? If so, the Bureau and DWR should state the likelihood that all urban requests and perhaps no agricultural requests will be fulfilled in order to achieve a full and correct environmental compliance treatment of the proposed action. Such an estimate is necessary for accurate explication of the chains of cause and effect associated with the 2009 DWB—and which must propagate throughout a NEPA document for it to be adequate as an analysis of potential natural and human environmental effects of the proposed project. We have additional specific questions:

- Within the request of the San Luis and Delta Mendota Water Authority (SLDMWA), its requesters include SCVWD in Table 2 of the EA/FONSI. Is this request for an agricultural use or an urban use of DWB water? At 30,000 acre-feet, it represents one-sixth of SLDMWA's 180,000 acre-feet request. If it is entirely for agricultural uses, how likely is it to be fulfilled under DWB priorities for water sales?
- What are the specific urban requests for water made by Avenal State Prison, and the cities of Avenal, Huron, and Coalinga, nested within the SLDMWA request?
- Sale criteria should be premised on full compliance with all applicable environmental and water rights laws.

Application of DWB priority criteria will depend on intervening economic factors beyond the control of the DWB. Given this uncertainty, an EIS should be prepared to provide the agencies with advance information and insight into what the sensitivity of the program's sellers and buyers are to the influences of prices—prices for water as well as crops such as rice, orchard and vineyard commodities, and other field crops. It is plausible that crop idling will occur more in field crops, while groundwater substitution would be more likely for orchard and vineyard crops. However, high prices for rice—the Sacramento Valley's largest field crop—would undermine

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[2] Neither DWR's Addendum nor the Bureau's EA specify numerical requests for the cities of Huron, Avenal, Coalinga, and the Avenal State Prison making it impossible to have a firmer number for the amount of urban request for water. Our estimate assumes SCVWD's 30,000 AF and MWD's 300,000 AF requests are for entirely urban uses of DWB-purchased water.

this logic, and could lead to substantial groundwater substitution. We have further extensive concerns about this, described below.

On page 96, the EA finally acknowledges this reality of crop prices:

> *"Hydrologic conditions change the supply of water available for transfers, which would shift the price of water. The difference in supply of water in a wet and dry year amounts to millions of acre-feet. The regional source of the water plays a role in pricing as well. Also, agricultural prices could also affect supply of water transfers. Small changes in agricultural prices can have a large effect on water transfer supply because net returns in farming are very responsive to agricultural prices. These factors are not controlled by participants in the market."*

This statement is actually not a matter of cumulative effects, but an integral part of the chains of cause and effect that affect how the DWB would unfold in the human and natural environments. It should be recognized as part of the 2009 DWB description and should directly apply to the Agriculture and Land Use, and Socioeconomic sections of the EA, because crop prices are key factors in choices potential water sellers would weigh in deciding whether to idle crops, substitute groundwater, or decline to participate in the DWB altogether. The EA and Addendum are inadequate because they fail to identify and analyze the market context for crops as well as water that would ultimately influence the size and scope of the DWB in 2009.

Rice prices are high because of conditions for the grain in the world market. Drought elsewhere is a factor in reduced yields, but growing populations in south and east Asia demand more rice and the rice industry has struggled to meet that demand.[3]

This is very important. The Bureau tacitly admits that the Bureau—and by logical extension, DWR—has no idea how many sales of what type (public health, urban, agricultural) can be expected to occur. Put another way, there is a range of potential outcomes for the 2009 DWB, and yet the Bureau has failed utterly to use the EA to examine a reasonable and representative range of alternatives as it concerns how the priority criteria would affect DWB transfers. And DWR did not bother to conduct an appropriate level of review under the California Environmental Quality Act.

Nor does the 2009 DWB prevent rice growers (or other farmers) from "double-dipping." It appears to us they could opt to turn back their surface supplies from the CVP and the State Water Project and substitute groundwater to cultivate their rice crop—thereby receiving premiums on both their CVP contract surface water as well as their rice crop this fall when it goes to market. There appear to be no caps on water sale prices to prevent windfall profits to sellers of Sacramento Valley water in the event that groundwater is substituted in producing crops—

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[3] "Panic over rice prices hits California," *AZCentral.com*, April 24, 2008; UN News Service, "Bumper rice harvests could bring down prices but poor may not benefit, warns UN," 25 February 2009; "Era of cheap rice at an end in Taiwan: COA," *The China Post*, March 5, 2009; Jim Downing, "Sacramento Valley growers se rice prices soar," *Sacramento Bee*, 18 January 2009.

especially for crops where market prices are high, such as in rice. The DWB in the 1990s capped water prices at $125/acre-foot, much to the disappointment of some water sellers at that time. Why are the state and federal projects encouraging such potential windfall profits at a time when many others suffer through this recession?

As stated, neither the Bureau nor DWR state how much of these transfers would go to public health, urban or agricultural buyers. The EA must also (but fails to) address the ability and willingness of potential buyers to pay for DWB water given the supplies that may be available. Historically, complaints from agricultural water districts were registered in the comments on the Draft EWA EIS/R and reported in the Final EIS/R in January 2004 indicating that they could not compete on price with urban areas buying water from the EWA. Given the DWB's priority criteria, will agricultural water buyers identified in Table 2 of the EA be able to buy water when competing with the likes of the Santa Clara Valley Water District and the Metropolitan Water District, representing two of the wealthiest regions of California? As a matter of statewide water, infrastructure, and economic policy, is it wise to foment urban versus agricultural sector competition for water based solely on price? Shouldn't other factors be considered in allocating water among our state's regions? This fails dramatically to encourage regions to develop their own water supplies more efficiently and cost-effectively without damage to resources of other regions.

Full disclosure of each offer of and each request for DWB water should be provided as part of the EA. This is necessary so the public can understand and have confidence in the efficacy of the DWB, benefit from full disclosure of who requests how much DWB water and for what uses, and so that the public may easily verify chains of cause and effect. Urban application of transferred surface water is not examined in the EA/FONSI, as though how urban buyers would use their purchased water had no environmental effects. Since the dry period could last beyond 2009, how will purchased water be used and conserved?

Nor is a hierarchy of priority uses among urban users stated in the criteria for purchasing DWB water. Could purchased water be used for any kind of landscaping, rather than clearly domestic purposes or strictly for drought-tolerant landscaping? We cannot tell from the EA/FONSI narrative. How can the citizens of California be assured that water purchased through the DWB will not be used wastefully, in violation of the California Constitution, Article X, Section 2?

Will urban users need their DWB purchased water only in July through September, or is that the delivery period preferred in the DWB because of ecological and fishery impact constraints on conveyance of purchased water?

Should agricultural water users be able to buy any DWB water, how will DWR and the Bureau assure that transferred water for irrigation is used efficiently? Many questions are embedded within these concerns that DWR and the Bureau should address, especially when they approach the State Water Resources Control Board to justify consolidating their places of use in their respective water rights permits:

- How much can be expected to be purchased by agricultural water users, given the priority criteria of the 2009 Drought Water Bank?
- How much can be expected to be consumptively used by agricultural water buyers?
- How much can be expected to result in tailwater and ag drainage?
- How much can be expected to add to the already high water table in the western San Joaquin Valley?
- What selenium and boron loads in Mud Slough and other tributaries to the San Joaquin River may be expected from application of this water to WSJ lands?
- What mitigation measures are needed to limit such impacts consistent with the public trust doctrine, Article X, Section 2 of the California Constitution, the Porter-Cologne Water Quality Control Act, and California Fish and Game Code Section 5937?

In other words, the most important chains of cause and effect—extending from the potential for groundwater resource impacts in the Sacramento Valley to potential for contaminated drainage water from farm lands in the western San Joaquin Valley where much of the agricultural buyers are located—are ignored in the Bureau's EA and DWR's Notice of Exemption based upon its EWA EIS/R Addendum.

Will more of surface water transfers go to urban users than to ag users given the 2009 DWB priority criteria? The EA's silence on this is disturbing, and suggests that the DWB's priority criteria may not be that important to the actual functioning of the DWB. What assurances will the Bureau and DWR provide that these criteria will be closely followed?

- The more that goes to urban water agencies the less environmental impacts there would be on drainage impaired lands of the San Joaquin Valley, a neutral to beneficial impact of the DWB's operation on high groundwater and drainage to the SJR.
- However, the more DWB water goes to agricultural users than to urban users, the higher would be groundwater levels, and more contaminated the groundwater would be in the western San Joaquin Valley and the more the San Joaquin River would be negatively affected from contaminated seepage and tailwater by operation of the DWB.

The EA fails to provide a map indicating where the sources of the DWB are located, and where the service areas are to which water would be transferred under the DWB.

Two issues concerning water rights are raised by this EA/FONSI:

- **Consolidated Place of Use.** Full disclosure of what the consolidated places of use for DWR and USBR would be, since the permit request to SWRCB will need NEPA coverage. Why is this consolidated place of use sought by the project agencies? Does consolidation mean that each project agency has the other's place of use, effectively a merger of the permits for DWB purposes? If so, the EA should state so. Will the consolidation be a permanent or temporary request be limited to the duration of the governor's emergency declaration or of just the 2009 DWB? When is the 2009 DWB scheduled to sunset? How do the consolidated place of use permit amendments to the

SWP and CVP permits relate to their joint point of diversion? Why doesn't simply having the joint point of diversion in place under D-1641 suffice for the purpose of the DWB?

- **Description of the water rights of both sellers and buyers.** This would necessarily show that buyers clearly possess junior water rights as compared with those of willing sellers. Lack of full disclosure of these disparate rights is needed to help explain the actions and motivations of buyers and sellers in the DWB, otherwise the public and decision makers have insufficient information on which to support and make informed choices.
    - **Sacramento Valley water rights –** correlative groundwater rights, riparian rights and CVP settlement contract rights
    - **San Joaquin Valley water rights –** CVP contract rights only, junior-most contractors within the CVP priority system (especially Westlands Water District).
    - **Priority of allocations among water contractors within the CVP and SWP.**

To establish a proper legal context for these water rights, the Project Action Alternative section of the EA/FONSI should also describe the applicable California Water Code sections about the treatment of water rights involved in water transfers.

Thus, there are many avenues by which the 2009 DWB is a poorly specified program for NEPA and CEQA purposes, leaving assessment of its environmental effects at best murky, and at worst, risky to all involved, especially users of Sacramento Valley groundwater resources.

B. Correcting the EA's poorly specified chains of cause and effect forces consideration of an expanded range of alternatives.

The Proposed Action Alternative need not have sophisticated forecasts of prices for rice and other commodities. Instead, for an adequate treatment of alternatives, the EA should have examined several reasonable scenarios beyond simply the 2009 DWB and a "no action" alternative. Three reasonable permutations would have considered relative proportions of crop idling versus groundwater substitution (e.g., high/low, low/high, and equal proportions of crop idled water and groundwater substitution). Other reasonable drought response alternatives that can meet operational and physical concerns merit consideration and analysis by the Bureau include:

- Planned permanent retirement of upslope lands in the western San Joaquin Valley where CVP-delivered irrigation water is applied to lands contaminated with high concentrations of selenium, boron and mercury, and which contribute to high water table and drainage problems for lowland farmers, wetlands and tributaries of the San Joaquin River. Retirement of these lands would permanently free up an estimated 3 million acre-feet of state and federal water during non-critical water years. Ending irrigation of these lands would also result in substantial human environmental benefits for the San Joaquin River, the Bay-Delta Estuary, and the Suisun Marsh from removal of selenium, boron, and salt contamination. Having such reasonable and pragmatic practices in place would go a long way to eliminate the need for drought water banks in the foreseeable future.

- More aggressive investment in agricultural and urban water conservation and demand management among CVP and SWP contractors even on good agricultural lands, including metering of all water supply hook-ups by all municipal contractors, statewide investment in low-flush toilets and other household and other buildings' plumbing fixtures, and increased capture and reuse of recycled water. Jobs created from such savings and investments would represent an economic stimulus that would have lasting job and community stability benefits as well as lasting benefits for water supply reliability and environmental stabilization.

C. The 2009 DWB EA fails to specify adequate environmental baselines, or existing conditions, against which impacts would be assessed and mitigation measures designed to reduce or avoid impacts.

The 2009 DWB environmental reviews by DWR and the Bureau incorporate by reference for specific facets of their review the 2003 and 2007 Environmental Water Account EIS/R documents. In both cases, these environmental reviews were conducted on a program whose essential purpose is to "provide protection to at-risk native fish species of the Bay-Delta estuary through environmental beneficial changes in State Water Project/Central Valley Project operations at no uncompensated water cost to the Projects' water users. This approach to fish protection involves changing Project operations to benefit fish and the acquisition of alternative sources of project water supply, called the 'EWA assets,' which the EWA agencies use to replace the regular Project water supply lost by pumping reductions."

The two basic sets of actions of the EWA were to:

- Implement fish actions that protect species of concern (e.g., reduction of export pumping at the CVP and SWP pumps in the Delta); and
- Increase water supply reliability by acquiring and managing assets to compensate for the effects of the fish actions (such as by purchasing water from willing sellers for instream flows that compensates the sellers for foregone consumptive use of water).

Without going into further detail on the EWA program, there is no attempt by the EWA agencies to characterize its environmental review as reflective of water transfer programs generally; the EWA was a specific set of strategies whose purpose was protection of fish species of concern in the Delta, not drought aid for junior water right-holding areas of California. One consequence of this attempt to rely on the EWA EIS/R is that it makes the public's ability to understand the environmental baseline of the 2009 Drought Water Bank impossible, because environmental baselines, differing purpose and need for the project, and many relevant mitigation measures are not readily available to the public. This mocks NEPA and CEQA missions to inform the public adequately about the environmental setting and potential impacts of the proposed project's actions. Moreover, a Drought Water Bank is plainly not the same thing as an Environmental Water Account.

Another consequence is that the chains of cause and effect of an EWA versus a DWB are entirely different because of their different purposes. While the presence of water purchases, willing sellers, and requesting buyers is similar, the timing of EWA water flows are geared to enhancing and protecting fish populations; the water was to flow in Delta channels to San Francisco Bay and the Pacific Ocean. In stark contrast, the DWB's water flows focus water releases from the SWP and CVP reservoirs to be exported for deliveries in the July through September period, whereas EWA assets would be "spent" year-round depending on the specific need to protect fish. EWA was about purchasing water to provide instream flows in the Delta, while the DWB is to acquire water to serve consumptive uses outside of the Delta.

Furthermore, to tease out the various ways in which the EWA review—itself a two-binder document consisting of well over 1,000 pages—could be used to provide appropriate environmental compliance for the DWB is not even attempted by DWR and the Bureau which at least has staff that could have been assigned to undertake it; yet they do not. It is therefore well beyond the reach of non-expert decision-makers and the public, and the use of the EWA EIS/R as the basic environmental review for the DWB therefore violates both NEPA and CEQA.

Nor is any attempt made in the EWA EIS/R to characterize the EWA as a "program level" environmental review off of which a DWB-like project could perhaps legitimately tier. In our view, this reliance on the EWA EIS/R obscures the environmental baselines of the DWB from public view, inappropriately conflates the purposes of two distinct environmental reviews, and flagrantly violates of NEPA and CEQA. This could only be redressed by preparation of an EIS/R on the 2009 DWB.

Finally, the most significant baseline condition omitted in the Bureau and DWR's inadequate reporting relates to Sacramento Valley groundwater resources, discussed in the next section.

D. Scientific uncertainties and controversy about Sacramento Valley groundwater resources merit consideration that only an EIS can provide.

There is substantial evidence that the 2009 DWB may have significant impacts on the aquifer system underlying the project and the adjacent region that overlies the Tuscan Formation. This alone warrants the preparation of an EIS.

Additionally, an EIS is necessary where "[a] project['s] … effects are 'highly uncertain or involve unique or unknown risks.'" *Blue Mountains Biodiversity Project*, 161 F.3d at 1213 (quoting 40 C.F.R. §1508.27(b)(5)). Here, the draft EA/FONSI fails to adequately address gaps in existing scientific research on the hydrology of the aquifer system and the extent to which these gaps affect the Bureau's ability—and by logical extension, DWR's ability—to assess accurately the Project's environmental impacts.

1. Existing research on groundwater conditions indicates that the 2009 DWB may have significant impacts on the aquifer system.

The EA fails to describe significant characteristics of the aquifers that the 2009 DWB proposes to exploit. These characteristics are relevant to an understanding of the potential environmental effects associated with the 2009 DWB's potential extraction of up to 340,000 acre feet ("af") of groundwater. Environmental Water Account 2003 EIS/EIR Record of Decision at p. 11; Draft Supplemental Environmental Water Account 2007 EIS/EIR at p. ES-6; 2009 Drought Water Bank addendum 12/17/08 at p. 2, 3, 9; 2009 Drought Water Bank addendum 3/4/09 at p. 2, 3, 9. First, the draft EA/FONSI fails to describe a significant saline portion of the aquifer stratigraphy of the 2009 DWB area. According to Toccoy Dudley, former Groundwater Geologist with the Department of Water Resources and former director of the Butte County Water and Resources Department, saline groundwater aquifer systems of marine origin underlie the various freshwater strata in the northern counties of Butte, Colusa, Glenn, and Tehama ("northern counties"). The approximate contact between fresh and saline groundwater occurs at a depth ranging from 1500 to 3000 feet. (Dudley 2005) (A list of all references cited in these comments can be found at the end of this letter.)

Second, the EA fails to discuss the pressurized condition of the down-gradient portion of the Tuscan formation, which underlies the northern counties Project area. Dudley finds that the lower Tuscan aquifer located in the Butte Basin is under pressure. "It is interesting to note that groundwater elevations up gradient of the Butte Basin, in the lower Tuscan aquifer system, are higher than the ground surface elevations in the south-central portion of Butte Basin. This creates an artesian flow condition when wells in the central Butte Basin are drilled into the lower Tuscan aquifer." (Dudley 2005). The artesian pressure indicates recharge is occurring in the up-gradient portions of the aquifer located along the eastern margin of the Sacramento Valley.

Third, the EA fails to describe the direction of movement of water through the Lower Tuscan Formation that underlies the northern counties. According to Dudley: "From Tehama County south to the city of Chico, the groundwater flow direction in the lower Tuscan is westerly toward the Sacramento River. South of Chico, the groundwater flow changes to a southwesterly direction along the eastern margin of the valley and to a southerly direction in the central portion of the Butte Basin." (Dudley 2005).

Fourth, the draft EA fails disclose that the majority of wells used in the Sacramento Valley are individual wells that pump from varying strata in the aquifers. The draft EA incorrectly asserts that, "Groundwater users in the basin pump primarily from deeper continental deposits." EA at p. 24. Contradicting this assertion, the EA later states that, "Fifty percent of the domestic wells are 150 feet deep or less," for the Natomas Central Mutual Water Company. (EA at p. 30) Why is the information not provided for other areas of the Sacramento Valley? The thousands of domestic wells in the northern counties are as susceptible as the wells in the Natomas Central MWC. The EA expands the discussion regarding Natomas Central MWC on page 39 stating that, "Shallow domestic wells would be most susceptible to adverse effects. Fifty percent of the domestic wells are 150 feet deep or less. Increased groundwater pumping could cause localized declines of groundwater levels, or cones of depression, near pumping wells, possibly causing effects to wells within the cone of depression. As previously described, the well review data, mitigation and monitoring plans that will be required from sellers during the transfer approval process will reduce the potential for this effect." As the latter statement makes clear, the Bureau hopes that the individual mitigation and monitoring plans will reduce the potential for impact, but there is no assurance in the EA to the thousands of well owners in the Sacramento Valley that it will reduce it to a level of insignificance. The Coalition questions the adequacy of individual mitigation and monitoring plans and suggests that an independent third party, such as USGS, oversee the mitigation and monitoring program. After the fiasco in Butte County during the 1994 Drought Water Bank and with the flimsy, imprecise proposal for mitigation and monitoring in the 2009 DWB, the agencies lack credibility as oversight agencies.

Fifth, the draft EA fails to provide recharge data for the aquifers. Professor Karin Hoover, Assistant Professor of hydrology, hydrogeology, and surficial processes from CSU Chico, finds that, "Although regional measured groundwater levels are purported to 'recover' during the winter months (Technical Memorandum 3), data from Spangler (2002) indicate that recovery levels are somewhat less than levels of drawdown, suggesting that, in general, water levels are declining." According to Dudley, "Test results indicate that the 'age' of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the Lower Tuscan Formation along the eastern margin of the valley have the 'youngest' water and the deeper wells in the western and southern portions of the valley have the 'oldest' water," adding that "the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas." (Dudley 2005). "This implies that there is currently no active recharge to the Lower Tuscan aquifer system (M.D. Sullivan, personal communication, 2004)," explains Dr. Hoover. "If this is the case, then water in the Lower Tuscan system may constitute fossil water with no known modern recharge mechanism, and, once it is extracted, it is gone as a resource," (Hoover 2008).

All of these aquifer characteristics are important to a full understanding of the environmental impacts of the 2009 DWB because there are numerous indications that other aquifer strata associated with the Lower Tuscan Formation are being operated near the limit of overdraft and could be affected by the 2009 DWB. (Butte County 2007). The Bureau has not considered this important historic information in the draft EA. According to Dudley, the Chico area has a "*long term average decline in the static groundwater level of about 0.35 feet-per-year*." (Dudley 2007) (Emphasis added.) Declining aquifer levels are not limited to the Chico Municipal area. This trend of declining aquifer levels in Chico, Durham and the Cherokee Strip is illustrated in a map submitted with this comment letter. (CH2M Hill 2006).

Declining groundwater elevations have been observed specifically in Butte County. A 2007 Butte Basin Groundwater Status Report describes the "historical trend" in the Esquon Ranch area as showing "seasonal fluctuation (spring to fall) in groundwater levels of about 10 to 15 feet during years of normal precipitation and less than 5 feet during years of drought." The report further notes: "Long-term comparison of spring-to-spring groundwater levels shows a decline of approximately 15 feet associated with the 1976-77 and 1986-94 droughts. (Butte Basin Water

Users Association, 2007.) The 2008 report indicates that, “The spring 2008 groundwater level measurement was approximately three feet higher than the 2007 measurement, however it was still four feet lower than the average of the previous ten spring measurements. Fall groundwater levels are approximately nine feet lower than the averages of those measured during either of the previous drought periods on the hydrograph. At this time it appears that there may be a downward trend in groundwater levels in this well.” (Butte Basin Water Users Association, 2008.) Thus, “*it appears that there may be a downward trend in groundwater levels in this well*.” *Id.* (emphasis added).

Groundwater elevations in the Pentz sub-area in Butte County also reveal significant historical declines. The historical trend for this sub-area “…shows that the average seasonal fluctuation (spring to fall) in groundwater levels averages about 3 to 10 feet during years of normal precipitation and approximately 3 to 5 feet during years of drought. Long-term comparison of spring-to-spring groundwater levels shows a decline in groundwater levels during the period of 1971-1981, perhaps associated with the 1976-77 drought. Since a groundwater elevation high of approximately 145 feet in 1985 the measured groundwater levels in this well have continued to decline. Recent groundwater level measurements indicate that the groundwater elevation in this well is approximately 15-25 feet lower than the historical high in 1985. *Id.* Water elevations at the Pentz sub-area well have been monitored since 1967. “Since 1985 spring groundwater levels in this well have been declining, and the spring 2008 measurement remained ten feet below historical high levels and continues the downward trend on the hydrograph.” *Id.* (Emphasis added.)

Both the Pentz and Esquon Ranch areas are located east of U.S. 99, in the eastern portion of the Tuscan aquifer.

In light of this downward trend in regional groundwater levels, the Bureau’s EA should closely analyze replenishment of the aquifers affected by the proposed 2009 DWB. The draft EA fails to provide any in-depth assessment of these issues. For example, the EA fails to discuss the best available estimates of where groundwater replenishment occurs. Lawrence Livermore National Laboratory analyzed the age of the groundwater in the northern counties to shed light on this process: “Utilizing the Tritium (H3) Helium-3 (He3) ratio, the age of each sample was estimated. Test results indicate that the “age” of the groundwater samples ranges from less than 100 years to tens of thousands of years,: (Dudley et al. 2005). As mentioned above, Dudley opines that the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas. (2005).

Are isotopic groundwater data available for other regions in the Sacramento Valley? If so, they would be crucial for all concerned to understand the potential impacts from the proposed 2009 DWB. For example, the EA states, “The WFA area that could be affected by the proposed action includes only the ‘North Area’ bounded on the north and east by the Sacramento County line, by the Sacramento River on the west, and by the American River on the south.” EA at p. 34. If this is the area in Sacramento County that is identified as most vulnerable to groundwater impacts, yet two major rivers surround it, shouldn't the Bureau understand the hydrologic relationship between the groundwater basin and the rivers? If that understanding exists, where is it presented in the EA? It is well known that the Sacramento River is already a losing river south of Princeton.

The Bureau should prepare an EIS that considers this and other existing research to evaluate the 2009 DWB's anticipated effect on regional hydrology.

2. The 2009 DWB proposes to rely on inadequate monitoring to avoid the acknowledged possibility of significant adverse environmental impacts.

The draft EA relies deflects responsibility of the Bureua and DWR for monitoring to individual "willing sellers." EA at p. 21. This fails to provide the most basic framework for governmental authority to enforce the state's role as trustee of the public's water in California, let alone a comprehensive and coordinated structure, for a very significant program that could transfer up to 389,328 af of water from the Sacramento Valley. (Recall that DWR suggests potential sale of water up to 533,000 AF, and believes it has environmental compliance coverage for up to 600,000 AF of water sales from the Sacramento Valley, including 340,000 AF in groundwater substitution alone.) The draft EA further defers responsibility to local groundwater management plans and ordinances to determine when the effects of the proposed extraction become "adverse." EA at p. 22. "As described in Section 3.2, well reviews and monitoring and mitigation plans will be implemented under the proposed action to minimize potential effects of groundwater substitution. Well reviews, monitoring and mitigation plans will be coordinated and implemented in conjunction with local ordinances, basin management objectives, and all other applicable regulations." EA at p. 10. The draft EA merely provides monitoring direction to "willing sellers" without identifying specific actions, responsible agencies, or funding that will be necessary for this oversight. This is unacceptable.

We propose instead that the Bureau and DWR require at a minimum that local governments select independent third-party monitors, who are funded by surcharges on DWB transfers paid by the buyers, to oversee the monitoring that is proposed in lieu of Bureaus and DWR staff. EA at p. 41-45.

Otherwise, the DWB's proposed monitoring is insufficient and cannot justify the significant risk of adverse environmental impacts. For example, the EA fails to identify standards that would be used to monitor the 2009 DWB's impacts. It fails to identify any specific monitoring protocols, locations (particularly in up-gradient recharge portions of the groundwater basins), and why chosen locations should be deemed effective for monitoring the effects of the proposed groundwater extraction. It also fails to describe how the objectives in the Drought Water Transfer White Paper will be met and by whom. EA at p.43. Moreover, it fails to provide a mitigation strategy for review and comment by the public, but defers this vital mitigation planning effort. EA at p.43. Another example of the inadequacy of the proposed monitoring is that the draft EA fails to include any plan to monitor stream flow of creeks located in the presumed recharge area for the Lower Tuscan Formation located on the eastern edge of the Sacramento Valley.

Adequate monitoring is vital to limit the significant risks posed by the DWB to the health of the region's groundwater, streams, and fisheries, as discussed below. Moreover, to the extent this Project is conceived as a one-year drought program that will provide knowledge for future groundwater extraction, its failure to include adequate monitoring protocols is even more disturbing and creates the risk of significant long-term and even irreversible impacts from the DWB.

a. The Bureau's assertion that the DWB will be modified or halted in the event of significant adverse impacts to hydrologic resources is an empty promise in light of the wholly inadequate monitoring provided for in the DWB. Knowing that the Bureau and DWR knowingly violated the X2 standard in the Delta in February 2009 does little to instill confidence from the Coalition in non-specific program and mitigation criteria.

The EA repeatedly illustrates that there is potential for significant injury to other groundwater users, water quality, streams, flora and fauna, and the soil profile, EA at p. 36-41. Page 36 alone has numerous examples that illustrate the need for an EIS since there is insufficient, comprehensive planning for, let alone preparation to mitigate, adverse environmental impacts:

- *Crop idling and groundwater substitution transfers under the proposed action could affect groundwater resources. Changes in groundwater levels could cause secondary effects. Declining groundwater levels could result in: 1) increased groundwater pumping cost due to increased pumping depth, 2) decreased yield from groundwater wells due to reduction in the saturated thickness of the aquifer, 3) reduced groundwater in storage, and 4) decrease of the groundwater table to a level below the vegetative root zone, which could result in environmental effects.*
- *Groundwater pumping within the vicinity of a surface water body could change the existing interactions between surface and groundwater, potentially resulting in decreased stream flows and levels, with potential adverse effects to the riparian habitat and downstream users. The pumping of groundwater near wetland habitats could also result in adverse environmental effects.*
- *Excessive groundwater extraction from confined and unconfined aquifers could result in a lowering of groundwater levels and, in confined aquifers, a decline in water pressure. The reduction in water pressure results in a loss of support for clay and silt beds, which subsequently compress, causing a lowering of the ground surface (land subsidence). The compaction of fine-grained deposits, such as clay and silt, is permanent. The possible consequences of land subsidence are 1) infrastructure damage and 2) alteration of drainage pattern.*
- *Changes in groundwater levels or in the prevailing groundwater flow regime could cause a change in groundwater quality through a number of mechanisms. One mechanism is the potential mobilization of areas of poorer quality water, drawn down from shallow*

> *zones, or drawn up into previously unaffected areas. Changes in groundwater gradients and flow directions could also cause (or speed) the lateral migration of poorer quality water. Artificial or enhanced recharge of the aquifer with water of poorer quality, or even different geochemical constituents, could also have an adverse effect on existing conditions. Geochemical differences between the recharged water and groundwater could affect resultant groundwater quality through geochemical processes such as precipitation, bacterial activity, ion exchange, and adsorption.*

The Bureau thus recognizes the potential for significant decline in groundwater levels as a result of the proposed activity. EA at p. 36, 37. This acknowledgement alone is sufficient to require a full EIS. Moreover, as detailed below, the monitoring proposed by the 2009 DWB is so inadequate that there can be no guarantee that adverse impacts will be discovered, or that they will be discovered in time to avoid significant environmental impacts.

Glenn County is noticeably omitted from the list of counties with some local regulatory authority. EA at p. 28-29. Glenn County does have a Groundwater Management Plan (adopted in August 2001), albeit inadequate. The Bureau's own 2008 EA for the GCID Seven Wells Project cautioned that "[s]ince the groundwater management plan is relatively new and not fully implemented, the enforcement and conflict resolution process has not been vigorously tested." Moreover, the Glenn County Groundwater Management Plan does not have any provisions to monitor or protect the environment. The 2009 DWB EA fails to explain why this management plan, as inadequate as it is, is not discussed nor is the absence of local protection mentioned.

b. Monitoring based on the Glenn County Groundwater Management Plan is inadequate. Since the Bureau omitted discussion of the Glenn County Groundwater Management Plan in the 2009 DWB, we refer to the language used in the 2008 Stony Creek Fan EA/FONSI that explained that the existing Glenn County groundwater management plan will ensure the testing project will have no significant adverse effects on groundwater levels: "This Finding of No Significant Impact (FONSI) is based upon the following: … Implementation of the Glenn County Groundwater Management Plan during the aquifer performance testing plan will ensure that the proposed action will not result in any significant adverse effect to existing groundwater levels." Stony Creek Fan EA/FONSI at p. 2.

But the Butte County Department of Water and Resource Conservation explains that local plans are simply not up to the task of managing a regional resource:

> *Glenn County does not have an export ordinance because it relies on Basin Management Objectives (BMO) to manage the groundwater resource, and subsequently to protect third parties from transfer related impacts. Recently, Butte County also adopted a BMO type of groundwater management ordinance. Butte County, Tehama County and several irrigation districts in each of the four counties have adopted AB3030 groundwater management plans. All of these groundwater management activities were initiated prior to recognizing that a regional aquifer system exists that extends over more than one*

> *county and that certain activities in one county could adversely impact another. Clearly the current ordinances, AB3030 plans, and local BMO activities, which were intended for localized groundwater management, are not well suited for management of a regional groundwater resource like that theorized of the Lower Tuscan aquifer system.*

(Butte County DWRC 2007).[4]

c. The EA fails to propose real time monitoring for land subsidence. Third-party independent verification, perhaps by scientists from the U.S. Geological Survey, should be incorporated by DWR and the Bureau into the project description of the 2009 DWB. The draft EA/FONSI relies on very few existing extensometers in the Sacramento Valley that measure land subsidence, and a Global Positioning System land subsidence network established by one county. EA/FONSI at p. 26 and 32. The remaining responsibility is again deferred to the "willing sellers." Unfortunately, voluntary monitoring by pumpers does not strike us as a responsible assurance given the substantial uncertainties involved in regional aquifer responses to extensive groundwater pumping in the Sacramento Valley.

Not only is there a failure to discuss real time monitoring for subsidence, there also is no discussion regarding delayed subsidence that should also be monitored according to the findings of Dr. Kyran Mish, Presidential Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma. Dr. Mish notes: "It is important to understand that *all* pumping operations have the potential to produce such settlement, and when it occurs with a settlement magnitude sufficient enough for us to notice at the surface, we call it *subsidence,* and we recognize that it is a serious problem (since such settlements can wreak havoc on roads, rivers, canals, pipelines, and other critical infrastructure)." (Mish 2008). Dr. Mish further explains that "[b]ecause the clay soils that tend to contribute the most to ground settlement are highly impermeable, their subsidence behavior can continue well into the future, as the rate at which they settle is governed by their low permeability." *Id.* "Thus simple real-time monitoring of ground settlement can be viewed as an *unconservative* measure of the potential for subsidence, as it will generally tend to underestimate the long-term settlement of the ground surface." *Id.* (emphasis added).

d. The 2009 DWB EA fails to require stream flow monitoring, choosing to defer the monitoring and mitigation planning to "willing sellers." We also urge incorporation of frequent and regular streamflow monitoring by either staff of the project agencies or a third, independent party such as the USGS, paid for by DWB transfer surcharges mentioned above. It is clear from existing scientific studies and the EA that the DWB may have significant impacts on the aquifers replenishment and recharging of the aquifers, and the 2009 DWB should therefore require extensive monitoring of regional streams. The radius for monitoring should be large, not the typical two to three miles as usually used by DWR and the Bureau. Though not presented for the

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DWB, the *Stony Creek Fan Aquifer Performance Testing Plan, which is a much smaller project,* recognized that there may be a drawdown effect on the aquifer by considering results from a DWR Northern District spring 2007 production well test (EA/FONSI p. 28). However, it did not assess the anticipated scope of that effect—or even what level of effect would be considered acceptable. Moreover, the results from that test well indicate that the recharge source for the solitary production well "is most likely from the foothills and mountains, to the east and north"—which at a minimum is more than fifteen miles away. (DWR, Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California).

The Butte County Department of Water and Resource Conservation has identified streams that must be monitored to determine impacts to stream flows that would be associated with pumping the Lower Tuscan Aquifer. These "[s]treams of interest" are located on the eastern edge of the Sacramento Valley and include: Mill Creek, Deer Creek, Big Chico Creek, Butte Creek, and Little Dry Creek. (The Butte County DWRC 2007). The department described the need and methodology for stream flow gaging:

> *The objective of the stream flow gaging is to determine the volume of surface water entering into or exiting the Lower Tuscan Aquifer along perennial streams that transect the aquifer formation outcropping for characterization of stream-aquifer interactions and monitoring of riparian habitat. Measurement of water movement into or out of the aquifer will allow for testing of the accuracy of the Integrated Water Flow Model, an integrated surface water-groundwater finite differential model developed for the eastern extent of the Lower Tuscan aquifer.*
>
> *Two stream gages will be installed on each of five perennial streams crossing the Lower Tuscan Formation to establish baseline stream flow and infiltration information. The differences between stream flow measurements taking upstream and downstream of the Lower Tuscan Formation are indications of the stream-aquifer behavior. Losses or gains in stream volume can indicate aquifer recharge or discharge to or from the surface waters.*

Id.

As evident in the following conclusory assertions, the draft EA/FONSI narrowly defines the radius of influence associated with the aquifer testing and thus entirely fails to identify potential significant impacts to salmon:

> "Interaction with Surface Water - Pumping close to the Sacramento River, and close to tributaries could reduce channel flows. This reduction in channel flows could adversely affect riparian and aquatic habitats, including wildlife refuge habitat, as well as downstream water users… Groundwater pumping for groundwater substitution transfers could reduce flows in nearby surface water bodies. (EA at p. 38)

Monitoring of flow on streams associated with the Lower Tuscan Formation is particularly important to the survival of Chinook salmon which use these “streams of interest” to spawn and where salmon fry rear. Intensive groundwater pumping would likely lower water table elevations near these streams of interest, decreasing surface flows, and therefore reducing salmon spawning and rearing habitat through dewatering of stream channels in these northern counties. This would be a significant adverse impact of the DWB and is ignored by the EA.

A similar effect has been observed in the Cosumnes River, where “[d]eclining fall flows are limiting the ability of the Cosumnes River to support large fall runs of Chinook salmon.” This is a river that historically supported a large fall run of Chinook Salmon. *Id.* Indeed, “[a]n early study by the California Department of Fish and Game . . . estimated that the river could support up to 17,000 returning salmon under suitable flow conditions.” *Id.*, citing CDFG 1957 & USFWS 1995. But “[o]ver the past 40 years fall runs ranged from 0 to 5,000 fish according to fish counts by the CDFG (USFWS 1995),” and “[i]n recent years, estimated fall runs have consistently been below 600 fish, according to Keith Whitener.” (Fleckenstein, *et al*. 2004). Indeed, “[f]all flows in the Cosumnes have been so low in recent years that the entire lower river has frequently been completely dry throughout most of the salmon migration period (October to December).” *Id.*

Research indicates that “groundwater overdraft in the basin has converted the [Cosumnes River] to a predominantly losing stream, practically eliminating base flows….” (Fleckenstein, *et al*. 2004). And “investigations of stream-aquifer interactions along the lower Cosumnes River suggest that loss of base flow support as a result of groundwater overdraft is at least partly responsible for the decline in fall flows.” *Id.* Increased groundwater withdrawals in the Sacramento basin since the 1950s have substantially lowered groundwater levels throughout the county.” *Id.*

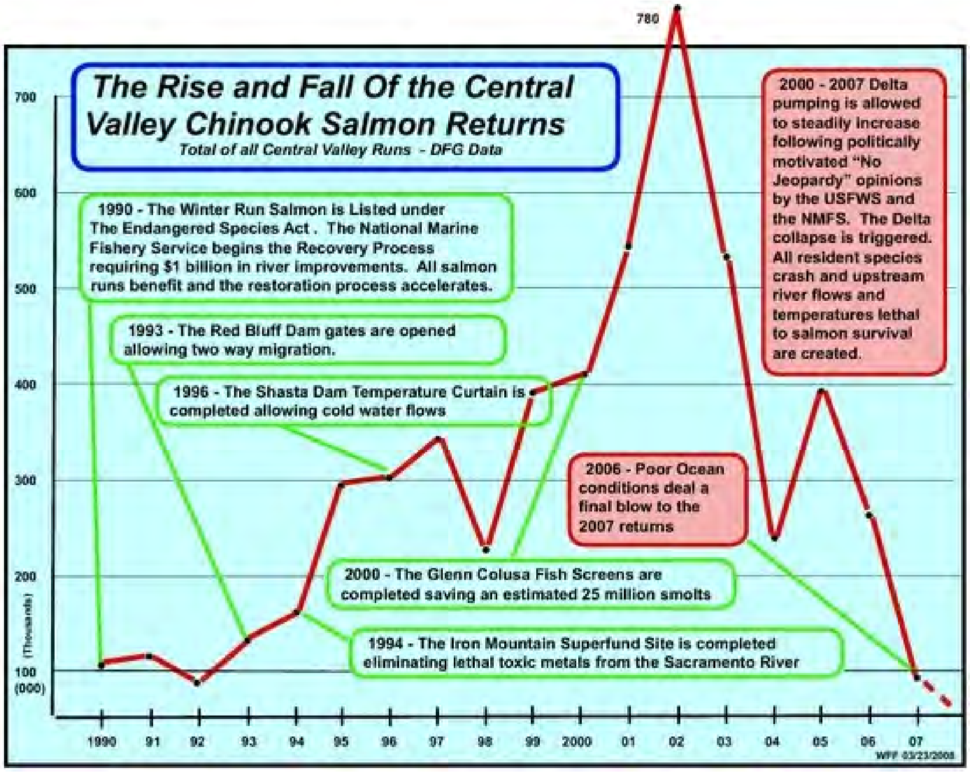
The draft EA acknowledges the potential for impacts to special status fish species from altered river flows and commits to maintaining flow and temperature requirements already in place. (EA at p. 70) The coalition would like to have greater assurance of this commitment after the Bureau and DWR’s failure in February 2009 to meet the X2 standard. The Bureau and DWR should make X2 compliance and streams of interest monitoring in real time part of their permit amendment applications to the SWRCB this spring. If stream levels are affected by groundwater pumping, then pumping would cease.

Unfortunately, the draft EA fails to anticipate possible stream flow declines in important salmon rearing habitat in the 2009 DWB area. Mud Creek is located within the 2009 DWB and flows through probable Tuscan recharge zones. While a charged aquifer is likely to add to base flow of this stream, a de-watered aquifer would pull water from the stream. According to research conducted by Dr. Paul Maslin, Mud Creek provides advantageous rearing habitat for out-migrating Chinook salmon. (Maslin 1996). Salmon fry feeding in Mud Creek grew at over twice the rate by length as did fry feeding in the main stem of the Sacramento River. *Id.*

Another tributary to the Sacramento River, Butte Creek, hosts spring-run Chinook salmon, a threatened species under the Endangered Species Act. 64 Fed. Reg. 50,394 (Sept. 16, 1999). Butte Creek contains the largest remaining population of the spring-run Chinook and is designated as critical habitat for the species. *Id*. at 50,399; 70 Fed. Reg. 52,488, 52,590-91 (Sept. 2, 2005). Additionally, Butte Creek provides habitat for the threatened Central Valley steelhead. *See* 63 Fed. Reg. 13,347 (Mar. 19, 1998); 70 Fed. Reg. at 52,518. The Bureau should not overlook the importance of rearing streams, and should not proceed with this Project unless and until adequate monitoring and mitigation protocols are established.

Existing mismanagement of water in California's rivers, creeks, and groundwater has already caused a precipitous decline in salmon abundance. There is no mention of the fall-run salmon numbers in the main stem Sacramento River or its essential tributaries despite the fact that their numbers dropped precipitously in 2007 (see graphic) and 2008. For the second year in a row, the commercial salmon fishery is closed for fear of pushing these fish to extinction. As noted above, the EA casually asserts that maintaining flow and temperature requirements in the main stem will be sufficient to protect aquatic species, but it fails to consider the impacts of up to 600,000 af of water transfers, fallowing, and groundwater substitution on the tributaries. How much additional pumping does the DWB represent, given CVP and SWP contractual commitments, available reservoir supplies, and other environmental restrictions south of the Delta? The EA and DWR's Addendum are silent on this.

Where are the data to support assertions that impacts to aquatic species will be below a level of significance? Habitat values are also essential to many other special status species that utilize the aquatic and/or riparian landscape including, but not limited to, giant garter snake, bank swallow, greater sandhill crane, American shad, etc. Where is the documentation of the potential impacts to these species?



Graphic is courtesy of Dick Pool.

In addition to the direct decline in the salmon populations is the food chain affect that will influence species such as killer whales.

3. The EA fails to address the significant unknown risks raised by the 2009 DWB's proposed groundwater extraction.

The EA fails to identify and address the significant unknown risks associated with this Project. There are substantial gaps in scientists' understanding of how the aquifer system recharges.

While the EA asserts that the Lower Tuscan is an isolated layer in the aquifer, expert opinion and experience suggest otherwise. Professor Karin Hoover from CSU Chico asserts that: "[T]o date there exists no detailed hydrostratigraphic analysis capable of distinguishing the permeable (water-bearing) units from the less permeable units within the subsurface of the Northern Sacramento Valley. In essence, the thickness and extent of the water-bearing units has not been adequately characterized." (p. 1)

Though the Projects fails to disclose the limitations in knowledge of the geology and hydrology of the northern counties, it was disclosed in 2008 in the EA for the *Stony Creek Fan Aquifer Performance Testing Plan* (Testing Plan EA). It revealed that there is also limited understanding of the interaction between the affected aquifers, and how that interaction will affect the ability of the aquifers to recharge. The Testing Plan EA provides:

> *The Pliocene Tuscan Formation lies beneath the Tehama Formation in places in the eastern portion of the SCF Program Study Area, although its extent is not well defined. Based on best available information, it is believed to occur at depths ranging between approximately 300 and 1,000 feet below ground surface. It is thought to extend and slope upward toward the east and north, and to outcrop in the Sierra Nevada foothills. The Tuscan Formation is comprised of four distinct units: A, B C and D (although Unit D is not present within the general project area). Unit A, or Upper Tuscan Formation, is composed of mudflow deposits with very low permeability and therefore is not important as a water source. Units B and C together are referred to as the Lower Tuscan Formation. Very few wells penetrate the Lower Tuscan Formation within the SCF Program study area.*

The Testing Plan EA/FONSI at p. 23 (emphasis added). The Tehama Formation, however, generally behaves as a semi-confined aquifer system and the EA contains no discussion of its relationship with the adjoining formations. Nor is there any discussion of the role of the Pliocene Tehama Formation as "the primary source of groundwater produced in the area." (DWR 2003).

The EA fails to offer any in-depth analysis of which strata in the aquifers will be most likely affected by the 2009 DWB's proposed extraction of groundwater. The EA incorrectly states that, "Groundwater users in the basin pump primarily from deeper continental deposits." EA at p. 24. The majority of wells are in the upper layers of the aquifers since they are for domestic use, which is not even considered in the EA. In addition, the EA provides no assessment of the interrelationship of varying strata in the aquifers in the Sacramento Valley or between the aquifers themselves.

The EA fails to provide basic background information regarding the recharge of groundwater. The documents states, "Groundwater is recharged by deep percolation of applied water and rainfall infiltration from streambeds and lateral inflow along the basin boundaries." EA at p. 24. How was the conclusion reached that applied water leads to recharge of the aquifer? Where are the supporting data? This claim is unsubstantiated by any of the work that has been performed to date. For example, the RootZone water balance model used by a consultant with Glenn Colusa Irrigation District, Davids Engineering, was designed to simulate root zone soil moisture. It balances incoming precipitation and irrigation against crop water usage and evaporation, and whatever is left over is assigned to "deep percolation." Deep percolation in this case means below the root zone, which is anywhere from a few inches to several feet below the surface, depending on the crop. There is absolutely no analysis that has been performed to insure that applied water does, indeed, recharge the aquifer. For example, if the surface soils were to dry out, water that had previously migrated below the root zone might be pulled back up to the surface by capillary forces. In any case, the most likely target of the "deep percolation" water in the Sacramento Valley is the unconfined aquifer and possibly the Sacramento River. The EA has not demonstrated otherwise.

E. Other resource impacts flowing from corrected chains of cause and effect are unrecognized in the EA and should be considered in an EIS instead.

Regarding surface water reservoir operations in support of the 2009 DWB, we have several questions and concerns:

- We do not understand from the EA/FONSI which BiOps will govern the DWB's environmental compliance with the Endangered Species Act. The Bureau's EA is confusing at best on this point. Compare pages 8, 9, 22, and 70. We note that reliance on the 2004 OCAP biological opinions on Delta smelt and anadromous fisheries were declared unlawful by a federal judge in 2008 and should not be relied on.
- CVPIA water transfer rules should be stated as part of the "affected environment." Do they permit transfers to non-CVP urban water districts?

Regarding fisheries, we note that the Bureau intends to comply with the State Water Resources Control Board's Water Rights Orders 90-05 and 91-01 in order to provide temperature control at or below 56 degrees Fahrenheit for anadromous fish, their redds, and hatching wild salmonid fry, and to provide minimum instream flows of 3,250 cubic feet per second (cfs) between September

1 and February 28, and 2,300 cfs between March 1 and August 31. How will the Bureau and DWR comply with Fish and Game Code Section 5937—to keep fish populations below and above their dams in good condition, as they approves transfers of CVP water from willing CVP contractors to willing buyers? We urge this compliance effort be integrated with the streams of interest and groundwater monitoring programs we recommended above.

We also find confusing the EA's treatment of instream flows for fisheries. On one hand, minimum flows and temperature criteria established in the above-mentioned water rights orders is to be adhered to by the Bureau for the Sacramento River. The necessity for April and May storage is not well explained as well as the reasons that surface water releases from Shasta would occur in the July through September period. Why?

Concerning the social and economic effects of the proposed 2009 DWB, we note that UC Davis researcher Richard Howitt and his colleagues predict loss of 60,000 to 80,000 farm-related jobs in the Central Valley due to crop idling from drought effects and curtailed project deliveries for irrigation (though not specifically attributable to EA/FONSI activities). The EA neither identifies nor comments on this seemingly credible finding. Howitt, et al, do reasonably conclude that the bulk of these potential impacts are in the western San Joaquin and Tulare and Kern County areas where water rights for imported supplies are the most unreliable.

(Given the facts that DWB buyer requests exceed water supplies offered by potential sellers, and that the DWB priority criteria favor public health and municipal buyers over agricultural buyers, it does seem to us that the state and federal government should identify and commit to permanent mitigations for these acute economic dislocations resulting from drought. However, we would dispute, as discussed below, that this year's hydrologic conditions constitute a drought.)

On its own terms, the Bureau's EA makes no attempt to establish baseline agricultural crop acreages for each agricultural county offering or seeking DWB water in order to calculate and apply its 20 percent threshold for limiting economic impacts to agriculture in selling counties. Moreover, this 20 percent threshold needs to be incorporated into the description of the Proposed Action Alternative, since it appears to be an integral part of DWB actions.

In general, the 2009 DWB EA/FONSI—and by logical implication, DWR's Addendum—consistently avoids full disclosure of existing conditions and baseline data, rendering their justifications for the 2009 DWB at best incoherent, and at worst, dangerous to groundwater users and resources, and to vulnerable fisheries in tributary streams of the Sacramento River.

F. The 2009 DWB is likely to have a cumulatively significant impact on the environment.

The draft EA/FONSI does not reveal that the current Project is part of a much larger set of plans to develop groundwater in the region, to develop a "conjunctive" system for the region, and to integrate northern California's groundwater into the state's water supply. These are plans that the

Bureau, together with DWR and others, have pursued and developed for many years. Indeed, one of the plans—the short-term phase of the Sacramento Valley Water Management Program—is the subject of an ongoing scoping process for a Programmatic EIS that has not yet been completed.

In assessing the significance of a project's impact, the Bureau must consider "[c]umulative actions, which when viewed with other proposed actions have cumulatively significant impacts and should therefore be discussed in the same impact statement." 40 C.F.R. §1508.25(a)(2). A "cumulative impact" includes "the impact on the environment which results from the incremental impact of the action when added to *other past, present and reasonably foreseeable future actions* regardless of what agency (Federal or non-Federal) or person undertakes such other actions." *Id.* §1508.7. The regulations warn that "[s]ignificance cannot be avoided by terming an action temporary or by breaking it down into small component parts." *Id.* §1508.27(b)(7).

An environmental impact statement should also consider "[c]onnected actions." *Id.* §1508.25(a)(1). Actions are connected where they "[a]re interdependent parts of a larger action and depend on the larger action for their justification." *Id.* §1508.25(a)(1)(iii). Further, an environmental impact statement should consider "[s]imilar actions, which when viewed together with other *reasonably foreseeable or proposed agency actions*, have similarities that provide a basis for evaluating their environmental consequences together, such as common timing or geography." *Id.* §1508.25(a)(3) (emphasis added).

As detailed below, instead of assessing the cumulative impacts of the proposed action as part of the larger program that even the Bureau has recognized should be subject to a programmatic EIS (but for which no programmatic EIS has been completed), the Bureau has attempted to separate this program and approve it through an inadequate EA. Further, the Bureau has failed to take into account the cumulative effects of other groundwater and surface water projects in the region, the development of "conjunctive" water systems, and the anticipated further integration of Sacramento Valley surface and ground water into the state water system.

G. The Environmental Assessment Fails to Meet the Requirements of NEPA.

Even if an EIS were not clearly required here, the draft EA/FONSI prepared by the Bureau violates NEPA on its own. As discussed above, the draft EA does not provide the analysis necessary to meet NEPA's requirements and to support its proposed finding of no significant impact. Further, as outlined above, the draft document fails to provide a full and accurate description of the proposed Project, its relationship to myriad other water transfer and groundwater extraction projects, its potentially significant adverse effects on salmon critical habitat in streams of interest tributary to the Sacramento River, and an assessment of the cumulative environmental impacts of the 2009 DWB when considered together with other existing and proposed water programs.

Additionally, the draft EA/FONSI fails to provide sufficient evidence to support its assertions that the 2009 DWB would have no significant impacts on the human or natural environments, neither decision makers nor the public are fully able to evaluate the significance of the 2009 DWB's impacts. These informational failures complicate the Coalition's efforts to provide meaningful comments on the full extent of the potential environmental impacts of the DWB and appropriate mitigation measures. Accordingly, many of the Coalition's comments include requests for additional information.

1. The EA Fails to Consider a Reasonable Range of Alternatives.

NEPA's implementing regulations call analysis of alternatives "the heart of the environmental impact statement," 40 C.F.R. §1502.14, and they require an analysis of alternatives within an EA. *Id.* §1408.9. The statute itself specifically requires federal agencies to:

> *study, develop, and describe appropriate alternatives to recommended courses of action in any proposal which involves unresolved conflicts concerning available uses of resources.*

42 U.S.C. §4332(2)(E). Here, because the Bureau's EA considers only the proposed Project and a "No Action" alternative, the EA violates NEPA.

The case law makes clear that an adequate analysis of alternatives is an essential element of an EA, and is designed to allow the decision maker and the public to compare the environmental consequences of the proposed action with the environmental effects of other options for accomplishing the agency's purpose. The Ninth Circuit has explained that "[i]nformed and meaningful consideration of alternatives … is … an integral part of the statutory scheme." *Bob Marshall Alliance v. Hodel*, 852 F.2d 1223, 1228 (9th Cir. 1988) (holding that EA was flawed where it failed adequately to consider alternatives). An EA must consider a reasonable range of alternatives, and courts have not hesitated to overturn EAs that omit consideration of a reasonable and feasible alternative. *See People ex rel. Van de Kamp v. Marsh*, 687 F.Supp. 495, 499 (N.D. Cal. 1988); *Sierra Club v. Watkins*, 808 F.Supp. 852, 870-75 (D.D.C. 1991).

Here, there are only two alternatives presented: the No Action and the Proposed Action. The lack of *any* alternative action proposal is unreasonable and is by itself a violation of NEPA's requirement to consider a reasonable range of alternatives.

Even more significantly, there are numerous other alternative ways to ensure water is allocated reliably when California experiences dry hydrologic years. We described several elements of reasonable alternatives above. These are the alternatives that should have been presented for the Bureau's draft EA/FONSI on the 2009 DWB to comply with NEPA. 42 U.S.C. § 4332(2)(E).

2. The EA Fails to Disclose and Analyze Adequately the Environmental Impacts of the Proposed Action

The discussion and analysis of environmental impacts contained in the EA is cursory and falls short of NEPA's requirements and stems from having an unclear and poorly described narrative for the proposed 2009 DWB. It obscures realistic chains of cause and effect, which in turn prevent accurate and comprehensive accounting of environmental baselines and measurement of the DWB's potential impacts. NEPA's implementing regulations require that an EA "provide sufficient evidence and analysis for determining whether to prepare an [EIS]." 40 C.F.R. §1508.9(a). For the reasons discussed above, the EA fails to discuss and analyze the environmental effects of the water transfers, crop idling, and groundwater substitution proposed by the 2009 DWB. The Bureau must consider and address the myriad of environmental consequences that are likely to flow from this proposed agency action.

Along with our significant concerns about the adequacy of the proposed monitoring, the draft EA/FONSI also fails to explain what standards will be used to evaluate the monitoring data, and on what basis a decision to modify or terminate the pumping would be made. In light of the document's silence on these crucial issues, the draft EA/FONSI's conclusion that there will not be significant adverse impacts withers quickly under scrutiny.

3. The EA Fails to Analyze Cumulative Impacts Adequately.

The Ninth Circuit Court makes clear that NEPA mandates "a useful analysis of the cumulative impacts of past, present and future projects." *Muckleshoot Indian Tribe v. U.S. Forest Service*, 177 F.3d 800, 810 (9th Cir. 1999). Indeed, "[d]etail is required in describing the cumulative effects of a proposed action with other proposed actions." *Id.* The very cursory cumulative effects discussion contained in the EA plainly fails to meet this standard.

As discussed in Part I.C. above, the proposed DWB does not exist in a vacuum, and is in addition to a broader program to develop regional groundwater resources and a conjunctive use system. The 2009 DWB is also only one of several proposed and existing projects that affect the regional aquifers. The existence of these numerous related projects make an adequate analysis of cumulative impacts especially important.

4. The Bureau Has Failed to Consider the Cumulative Impact of Other Groundwater Development and Surface Water Diversions Affecting the Region

In addition to the improper segmentation evident in the draft EA/FONSI, the assessment of environmental impacts is further deficient because the Bureau has failed to consider the cumulative impacts of the proposed groundwater extraction when taken in conjunction with other projects proposed for the development of groundwater and surface water.

The Bureau and its contractors are party to numerous current and reasonably foreseeable water programs that are related to the water transfers contemplated in the DWB including the following:

- Sacramento Valley Integrated Regional Water Management Plan (2006)
- Sacramento Valley Regional Water Management Plan (January 2006)
- Stony Creek Fan Conjunctive Water Management Program
- Sacramento Valley Water Management Agreement (Phase 8, October 2001)
- Draft Initial Study for 2008-2009 Glenn-Colusa Irrigation District Landowner Groundwater Well Program
- Regional Integration of the Lower Tuscan Groundwater Formation into the Sacramento Valley Surface Water System Through Conjunctive Water Management (June 2005)
- Stony Creek Fan Aquifer Performance Testing Plan for 2008-09
- Lower Tuscan Integrated Planning Program, a program funded by the Bureau that will “integrate the Lower Tuscan formation aquifer system into the management of regional water supplies.”
- Annual forbearance agreements (2008 had an estimated 160,00 acre feet proposed).

We briefly describe some of their key elements here.

<u>Stony Creek Fan Conjunctive Water Management Program.</u> The SCF Aquifer Plan is part of and in furtherance of the Stony Creek Fan Conjunctive Water Management Program (“SCF Program”). This program is being carried out by GCID, Orland-Artois and Orland Unit Water Association.

The long-term objective of the SCF Program is the development of a “regional conjunctive water management program consisting of a direct and in-lieu recharge component, a groundwater production component, and supporting elements.…” (SVWMA: Project 8A Stony Creek Fan Conjunctive Water Management Program
(“SVWMA Project 8A”), at 8A-1). The potential supply from such a program was estimated at 50,000 af per year to 100,000 af per year. *Id.*

The SCF Program has 3 Phases: (1) a feasibility study; (2) a demonstration project; and (3) project implementation. Phase I of the SCF Program has already been completed. The SCF Aquifer Plan described in a draft EA/FONSI is part of Phase II of the larger SCF Program. Phase III of the SCF Program will implement the program’s goal of integrating test and operational production wells into the water supply systems for GCID, Orland-Artois, and Orland Unit Water Association for long-term groundwater production in conjunction with surface water diversions.

The Bureau is well aware of the SCF Program, but declined to analyze the environmental effects of the program as a whole, and not simply considered the effects of an isolated component of the larger program. Indeed, the Bureau recently awarded a grant to GCID to fund the SCF Program. The Bureau’s grant agreement states that the SCF Program “target[s] the Lower Tuscan

Formation and possibly other deep aquifers in the west-central portion of the Sacramento Valley … as the source for all or a portion of the additional groundwater production needed to meet [the SCF Partners'] respective integrated water management objectives." BOR Assistance Agreement No. 06FG202103 at p. 2. The agreement further provides that provides that "[a]dditional test wells and production wells will be installed within the Project Area." *Id.*

Moreover, the Bureau's own description of the reasons for not choosing the "No Action" alternative indicate the Bureau's recognition that the primary goal of the SCF Aquifer Plan is to realize the objectives of the SCF Program – "increas[ing] reliable water supplies through conjunctive management of groundwater and surface water" at a fast pace. *See* EA/FONSI at p. 5. The Bureau was obligated to assess the potentially significant environmental impacts associated with such conjunctive management of groundwater and surface water, and wholly failed to do so.

There are serious concerns raised by the proposal to engage in conjunctive management of groundwater and surface water that are not addressed in the EA. For example, in 1994, following seven years of low annual precipitation, Western Canal Water District and other irrigation districts in Butte, Glenn and Colusa counties exported 105,000 af of water extracted from the Tuscan aquifers to buyers outside of the area. This early experiment in the *conjunctive use* of the groundwater resources – conducted without the benefit of environmental review – caused a significant and immediate adverse impact on the environment. (Msangi 2006). Until the time of the water transfers, groundwater levels had dropped but the aquifers had sustained the normal demands of domestic and agricultural users. The water districts' extractions, however, lowered groundwater levels throughout the Durham and Cherokee areas of eastern Butte County. (Msangi 2006). The water level fell and the water quality deteriorated in the wells serving the City of Durham. (Scalmanini 1995). Irrigation wells failed on several orchards in the Durham area. One farm never recovered from the loss of its crop and later entered into bankruptcy. Residential wells dried up in the upper-gradient areas of the aquifers as far north as Durham (.

<u>The SCF Program is a Component of the Sacramento Valley Water Management Program.</u> The Sacramento Valley Water Management Program (Phase 8) ("SVWMP") also includes the SCF Program as one of its elements. (SVWMA Project 8A at pp. 8A-1 to 8A-13).

The SVWMP recognizes that the SCF Program "has the potential to improve operational flexibility on a regional basis resulting in measurable benefits locally in the form of predictable, sustainable supplies, *and improved reliability for water users' elsewhere in the state*." *Id.* at p. 8A-2 (emphasis added). By piecemealing this program improperly and analyzing only the small component of the SCF Program, the Bureau has failed to assess the environmental impacts associated not just with the anticipated conjunctive use of the groundwater, but also the effect of the anticipated export of water to other regions of the state.

Additionally, approximately five years ago, on August 5, 2003, the Bureau published a notice in the Federal Register announcing its intention to prepare a programmatic EIS to analyze the short-term phase of the SVWMP. 68 Fed. Reg. 46218, 46219 (Aug. 5, 2003). Like the SVWMP, this "Short-term Program" for which the Bureau stated its intent to conduct a programmatic EIS included implementation of the SCF Program. *Id.* at 46219, 46220.

The SCF Program is Also a Component of the Sacramento Valley Integrated Regional Water Management Program. The Bureau has been working with GCID and others to realize the Sacramento Valley Integrated Regional Water Management Program ("SVIRWMP"). SVIRWMP is comprised of a number of sub-regional projects, including the SCF Program. *See* SVIRWMP, Appendix A at A-5; BOR Assistance Agreement No. 06FG202103. Here again, even though the SCF Aquifer Plan is clearly a necessary component of the SCF Program – which is in turn a component of the SVIRWMP – the draft EA/FONSI failed to even acknowledge, let alone assess, the cumulative impacts of these related projects.

Most obviously, the draft EA wholly fails to assess the impact of the Bureau's *Sacramento Valley Regional Water Management Plan (2006)* (SVRWMP) and the forbearance water transfer program that the Bureau and DWR facilitate jointly. As noted above, the Programmatic EIS for the 2002 Sacramento Valley Water Management Agreement or Phase 8 Settlement was initiated, but never completed, so the SVRWMP was the next federal product moving the Phase 8 Settlement forward. The stated purpose of the Phase 8 Settlement and the SVRWMP are to improve water quality standards in the Bay-Delta and local, regional, and statewide water supply reliability. In the 2008 forbearance program, 160,000 af was proposed for transfer to points south of the Delta. To illustrate the ongoing significance of the demand on Sacramento Valley water, we understand that GCID alone entered into "forbearance agreements" to provide 65,000 af of water to the San Luis and Delta Mendota Water Association in 2008, 80,000 af to State Water Project contractors in 2005, and 60,000 af to the Metropolitan Water District of Southern California in 2003.

> Less obvious, but certainly available to the Bureau, are the numerous implementation projects that Phase 8 signatories are pursuing, such as Glenn Colusa Irrigation District's (GCID) proposed to divert groundwater pumped from private wells to agricultural interests in the District. *See* Attach. (GCID Proposed Negative Declaration, GCID Landowner Groundwater Well Program for 2008-09). Additionally, the draft EA does not consider the cumulative effect of the Lower Tuscan Integrated Planning Program, a program funded by the Bureau that will "integrate the Lower Tuscan formation aquifer system into the management of regional water supplies." Grant Agreement at 4. This program, as described by the Bureau, will culminate in the presentation of a proposed water management program for the Lower Tuscan Formation for approval and implementation by the appropriate authorities. Clearly, the cumulative impact of this program and the 2009 DWB's proposed groundwater extraction should have been assessed.

Finally, with the myriad projects and programs that are ignored in the EA and have never been analyzed cumulatively, the EA finally discloses that there could be a devastating impact to groundwater: "The recent reduction in recharge (due to the decrease in precipitation and runoff) in addition to the increase in groundwater transfers would lower groundwater levels. Multi-year groundwater acquisition for other programs in areas that have repeatedly transferred groundwater may also be more susceptible to adverse effects. In these areas groundwater levels may not fully recover following a transfer and may experience a substantial net decline in groundwater levels over several years." (EA at p. 94) While the honesty is refreshing, the lack of comprehensive monitoring, mitigation, and project cessation mechanisms is starling. This alone warrants the preparation of an EIS.

Here again, the document does not discuss or analyze these potential impacts, their potential scope or severity, or potential mitigation efforts. Instead, it relies on the existence of local ordinances, plans, and oversight with the monitoring and mitigation efforts of individual "willing sellers" to cope with any adverse environmental effects. However, as we have shown above, for example, the Glenn County management plan is untested and does not provide adequate protection and monitoring of the region's important groundwater resources. To further clarify the inadequacy of relying on local plans and ordinances, Butte County's Basin Management Objectives have no enforcement mechanism and Chapter 33 requires CEQA review for transfers that include groundwater in Butte County. As one can see, there is very limited local protection for groundwater and no authority to influence pumping that is occurring in a different county.

5. The 2009 DWB is likely to serve as precedent for future actions with significant environmental effects.

As set forth above, this Project is part of a broader effort by the Bureau and DWR to develop groundwater resources and to integrate GCID's water into the state system. For these reasons, the 2009 DWB is likely to "establish a precedent for future actions with significant effects or represents a decision in principle about a future consideration" (40 C.F.R. §1508.27(b)(6)), and should be analyzed in an EIS.

6. The 2009 DWB has potential adverse impacts for a threatened species.

As the Bureau of Reclamation is well aware, the purpose of the ESA is to conserve the ecosystems on which endangered and threatened species depend and to conserve and recover those species so that they no longer require the protections of the Act. 16 U.S.C. § 1531(b), ESA § 2(b); 16 U.S.C. § 1532(3), ESA §3(3) (defining "conservation" as "the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this chapter are no longer necessary"). "[T]he ESA was enacted not merely to forestall the extinction of species (i.e., promote species survival), but to allow a species to recover to the point where it may be delisted." *Gifford Pinchot Task Force v. U.S. Fish & Wildlife Service*, 378 F3d 1059, 1069 (9th Cir. 2004). To ensure that the statutory purpose will be carried out, the ESA imposes both substantive and procedural requirements on all federal agencies to carry out programs for the conservation of listed species and to insure that their actions are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. 16 U.S.C. § 1536. *See NRDC v. Houston*, 146 F.3d 1118, 1127 (9th Cir. 1998) (action agencies have an "affirmative duty" to ensure that their actions do not jeopardize listed species and "independent obligations" to ensure that proposed actions are not likely to adversely affect listed species). To accomplish this goal, agencies must consult with the Fish and Wildlife Service whenever their actions "may affect" a listed species. 16 U.S.C. § 1536(a)(2); 50 C.F.R. § 402.14(a). Section 7 consultation is required for "any action [that] may affect listed species or critical habitat." 50 C.F.R. § 402.14. Agency "action" is defined in the ESA's implementing regulations to "mean all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies in the United States." 50 C.F.R. § 402.02.

The giant garter snake ("GGS") is an endemic species to Central Valley California wetlands. (Draft Recovery Plan for the Giant Garter Snake ("DRP") 1). The giant garter snake, as its name suggests, is the largest of all garter snake species, not to mention one of North America's largest native snakes, reaching a length of up to 64 inches. Female GGS tend to be larger than males. GGS vary in color, especially depending on the region, from brown to olive, with white, yellow, or orange stripes. The GGS can be distinguished from the common garter snake by its lack of red markings and its larger size. GGS feed primarily on aquatic fish and specialize in ambushing small fish underwater, making aquatic habitat essential to their survival. Females give birth to live young from late July to early September, and brood size can vary from 10 to up to 46 young. Some studies have suggested that the GGS is sensitive to habitat change in that it prefers areas that are familiar and will not typically travel far distances. The EA discloses that one GGS study in Colusa County revealed the "longest average movement distances of 0.62 miles, with the longest being 1.7 miles, for sixteen snakes in 2006, and an average of 0.32 miles, with the longest being 0.6 miles for eight snakes in 2007. However, in response to droughts and other changes in water availability, the GGS has been known to travel up to 5 miles in only a few days, but the impacts on GGS survival and reproduction from such extreme conditions are unknown due to the deficiency in data and analysis.

Flooded rice fields, irrigation canals, and wetlands in the Sacramento Valley can be used by the giant garter snake for foraging, cover and dispersal purposes. The draft EA fails to comprehensively analyze the movements and habitat requirements for the federal and state-threatened giant garter snake and yet again defers responsibility to a future time. The Biological Assessment acknowledges the failure of Bureau and DWR to complete the Conservation Strategy that was a requirement of the 2004 Biological Opinion. (BA at p. 19-20) [The BA appears to have no page numbers] What possible excuse delayed this essential planning effort?

The 2009 DWB also proposes to delete or modify other mitigation measures previously adopted as a result of the EWA EIR process to substantially reduce significant impacts, but without showing they are infeasible. For example, the Bureau and DWR propose to delete the 160 acre maximum for "idled block sizes" for rice fields left fallow rather than flooded and to substitute for it a 320 acre maximum. (See 2003 Draft EWA EIS/EIR, p. 10-55; 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 4.) There is no evidence to support this change. In light of the agencies failure to complete the required Conservation Strategy mentioned above and the data gathered in the Colusa County study, how can the EA suggest that doubling the fallowing acreage is in any way biologically defensible? The agencies additionally propose to delete the mitigation measure excluding Yolo County east of Highway 113 from the areas where rice fields may be left fallow rather than flooded, except in three specific areas. (See 2004 Final EWA EIS/EIR, Appendix B, p. 18, Conservation Measure # 2.) What is the explanation for this change? What are the impacts from this change?

Deleting these mitigation measures required by the EWA approval would violate NEPA and CEQA's requirements that govern whether, when, and how agencies may eliminate mitigation measures previously adopted under NEPA and CEQA. (See *Napa Citizens for Honest Government v. Napa County Board.*

The 2009 DWB fails to include sufficient safeguards to protect the giant garter snake and its habitat. In order to avoid potentially significant adverse impacts for the snake, additional surveys should be conducted prior to any alteration in water regime or landscape. (Addendum March 4, 2009 at p. 8)

It is conspicuously noticeable that there isn't a claim of a less-than-significant impact for the Giant Garter Snake (*Thamnophis gigas*), in the EA and the BA. There is really no conclusion reached due to the fundamental absence of science for the species. The Bureau should also prepare an EIS because the 2009 DWB will likely have significant environmental effects on the Giant Garter Snake, a listed threatened species under the federal Endangered Species Act and California Endangered Species Act. 40 C.F.R. §1508.27(b)(9).

II. Purpose and Need Issues of the 2009 Drought Water Bank

A. The Purpose and Need Section of the EA/FONSI fails to specify the policy framework upon which the 2009 Drought Water Bank is based.

Exemption of the 2009 DWB from the requirements of the California Environmental Quality Act (CEQA) does not reflect the actual environmental effects of the proposal—which are similar to the proposed 1994 Drought Water Banks and for which a final Program Environmental Impact Report was completed in November 1993. In 2000, the Governor's Advisory Drought Planning Panel report, *Critical Water Shortage Contingency Plan* promised a program EIR on a drought-response water transfer program, but was never undertaken. Twice in recent history, the state readily acknowledged that CEQA review for a major drought water banking program was appropriate. So, this Notice of Exemption reflects an end-run around established water law through the use of water transfers, and is therefore vulnerable to legal challenge under the California Environmental Quality Act.

We question the merits of and need for the 2009 DWB itself. The existence of drought conditions at this point in time is highly questionable and reflects the state's abandonment of a sensible water policy framework given our state and national economic recession and tattered public budgets. Our organizations believe the Governor's drought emergency declaration goes too far to help a few junior water right holders, and that at bottom the 2009 Drought Water Bank is not needed. The DWB is to directly benefit the areas of California whose water supplies are the least reliable by operation of state water law. Though their unreliable supplies have long been public knowledge, local, state, and federal agencies in these areas have failed to stop blatantly wasteful uses and diversions of water and to pursue aggressive planning for regional water self-sufficiency.

The EA/FONSI's statement of purpose and need states specifically that "the purpose of the proposed action is to help facilitate the transfer of water throughout the State from willing sellers of CVP water upstream of the Delta to buyers that are at risk of experiencing water shortage in 2009." This paragraph omits coherent discussion of need. The purpose and need should also state that this transfer program would be subject to specific criteria for prioritizing transfers, as described on page 6: "It is anticipated that water made available to [potential buyers] from the DWB would be prioritized as flows: existing health and safety domestic needs, municipal supply subject to water shortage contingency plan measures, and agricultural irrigation for existing crops and livestock subject to water shortage contingency plan measures."

The EA/FONSI makes no attempt to place the 2009 Drought Water Bank into the context of the 2005 California Water Plan that the state recently completed. It appears to us that this plan is largely on the shelf now, perhaps because of the state's dire fiscal problems. It does contain many good recommendations concerning increasing regional water self-sufficiency. However, our review of the 2005 California Water Plan reveals no mention of the 2000 Critical Water Shortage Reduction Marketing Program or any overarching drought response plan that the state could have planned for in 2005, but did not. We sadly conclude that the state of California has no meaningful adopted drought response policy, save for gubernatorial emergency declarations to suspend protective environmental regulations. This is not a sustainable water policy for California.

The purpose and need section of the EA/FONSI *and the Governor's own drought emergency declaration* cry out for placing the 2009 Drought Water Bank into a policy framework. What is the state doing otherwise to facilitate regional water self-sufficiency for these areas with the least reliable water rights? How does the 2009 DWB fit into the state and federal government's water and drought policy framework? Instead, the state and federal response to this third consecutive dry year falls back on simply the Drought Water Bank model that ran into environmental and water users' opposition in 1991 and 1992. Is anybody home at our water agencies?

B. The 2009 Drought Water Bank is not needed because the state's current allocation system—in which the federal Bureau of Reclamation participates—wastes water profligately.

The incentive from the state's lax system of regulation of California's State Water Project and Central Valley projects is to deliver the water now, and worry about tomorrow later. Indeed, the State Water Resources Control Board (SWRCB) has been AWOL for decades. In response to inquiries from the Governor's Delta Vision Task Force last fall, the SWRCB acknowledged that while average runoff in the Delta watershed between 1921 and 2003 was 29 million acre-feet annually, the 6,300 active water right permits issued by the SWRCB is approximately 245 million acre-feet. In other words, **water rights on paper are 8.4 times greater than the real water in California streams diverted to supply those rights on an average annual basis.** *And the SWRCB acknowledges that this "water bubble" does not even take account of the higher priority rights to divert held by pre-1914 appropriators and riparian water right holders, of which there are another 10,110 disclosed right holders.* Many more remain undisclosed.

Like federal financial regulators failing to regulate the shadow financial sector, subprime mortgages, Ponzi schemes, and toxic assets of our recent economic history, the state of California has been derelict in its management of scarce water resources here. This in no way justifies suspension of environmental and water quality regulations, for which the Governor's drought emergency declaration calls. We supplement our comments on this matter of wasteful use and diversion of water by incorporating by reference the joint complaint to the State Water Resources Control Board of the California Water Impact Network and the California Sportfishing Protection Alliance on public trust, waste and unreasonable use and method of diversion as additional evidence of a systematic failure of governance by the State Water Resources Control Board, the Department of Water Resources and the U.S. Bureau of Reclamation, filed with the Board on March 18, 2008 (attached).

We question the Governor's contention of continued dry conditions, since the storms of early March have greatly increased reservoir levels throughout California. The Climate Prediction Center of the National Oceanographic and Atmospheric Administration believes the drought will ease by May 2009. Non-state and non-federal reservoirs indicate conditions fast approaching normal for their facilities: Bullard's Bar in Yuba County is at 107 percent of the 15-year average for this time of year, EBMUD's Pardee Lake is at 98 percent of normal, San Francisco's Hetch Hetchy Reservoir on the Tuolumne River is at 169 percent of normal, while Don Pedro Reservoir on the same river is at 90 percent. The CVP's Millerton (101 percent of normal) and Folsom reservoirs (112 percent) exceed the normal storage for this time of year. These two reservoirs must provide water to the agricultural San Joaquin River Exchange Contractors, and who have among the most senior rights on that river. Rice growers in the Sacramento Valley are generally expecting close to full deliveries from the CVP and Yuba River water supplies. The CVP's own New Melones Reservoir on the Stanislaus River, which contributes to Delta water quality as well as to meeting eastern San Joaquin Valley irrigation demands, is at 87 percent of normal for this time of year.

Moreover, the SWP's terminal reservoirs at Pyramid (102 percent of average) and Castaic (99 percent of average) Lakes are right at about normal storage levels for this time of year, presumably because DWR has been releasing water from Oroville for delivery to these reservoirs.

The fact that reservoirs of the CVP with more senior responsibilities in the water rights hierarchy do well with storage for this time of year suggests that at worst this will be a year of below normal runoff in 2009—hardly a drought scenario. Low storage levels at Oroville, Shasta and San Luis may easily be attributed to redirected releases to terminal reservoirs or groundwater banks in the San Joaquin Valley and Tulare Lake Basin—these latter storage venues and their current performance are not disclosed on DWR’s Daily Reservoir Storage levels web site. Still, given what is known, from what these reservoir levels indicate many major cities and most Central Valley farmers are very likely will have enough water for this year.

The ones expecting to receive little water this year do so because of the normal functioning of their water rights—their imported surface supplies are therefore less reliable in dry times. It is the normal and appropriate functioning of California’s system of water rights law that makes it so. Among those with more junior water rights, the Metropolitan Water District and the Santa Clara Valley Water District are the wealthiest regions and the agencies most capable of undertaking aggressive regional water self-sufficiency actions. They should be further encouraged and assisted to do so through coherently formulated state and federal water policies and programs.

On the agricultural side, the drought emergency declaration appears to benefit mainly the few western San Joaquin Valley farmers whose contractual surface water rights have always been less reliable than most—and whose lands are the most problematic for irrigation. In excess of 1 million acres of irrigated land in the San Joaquin Valley and the Tulare Lake Basin are contaminated with salts and trace metals like selenium, boron, arsenic, and mercury. These lands should be retired from irrigation to stop wasteful use of precious fresh water resources. This water drains back—after leaching from these soils the salts and trace metals—into sloughs and wetlands and the San Joaquin River carrying along these pollutants. Retirement of these lands from irrigation usage would help stem further bioaccumulation of these toxins that have settled in the sediments of these water bodies.

The 2009 DWB would exacerbate pumping of fresh water from the Delta, which has already suffered from excessive pumping in earlier years of this decade. Pumped exports cause reverse flows to occur in Old and Middle Rivers and can result in entrainment of fish and other organisms in the pumps. Our organizations share the widely held view that operation of the Delta export pumps is the major factor causing the Pelagic Organism Decline (POD) and in the deteriorating populations of fall-run Chinook salmon. 2009 will be the second consecutive year where no commercial fishing of fall-run Chinook fish will be allowed because of this species’ population decline. Operation of the DWB at a time when others refrain from taking these fish and other organisms strikes us as a consummate unwillingness on the part of the State of California and the U.S. Bureau of Reclamation to share in the sacrifices needed to help aquatic ecosystems and anadromous fisheries of the Bay-Delta Estuary recover.

New capital facilities should be avoided to save on costly, unreliable, and destructive water supplies that new dams and canals represent. Moreover, these facilities would need new water rights; yet the most reliable rights in California are always the ones that already exist—and of those, they are the ones that predate the California State Water Project and the federal Central Valley Project. We should be applying our current rights far more efficiently—and realistically—than we do now. California should instead pursue a “no-regrets” policy incorporating aggressive water conservation strategies, careful accounting of water use, research and technological innovation, and pro-active investments.[5]

III. Conclusion

The Bureau’s EA/FONSI states on page 9:

> *California laws contain numerous protections that apply to water transfers. However, there are three fundamental principles that apply: no injury to other legal users of water, no unreasonable effects to fish, wildlife, or other instream beneficial uses of water, and no unreasonable effects on the overall economy or the environment in the counties from which the water is transferred.*

We unreservedly state to you that the draft EA/FONSI on the proposed 2009 Drought Water Bank appears to describe a project that would fail all three of these tests as currently described. The 2009 Drought Water Bank clearly has the potential to affect the human and natural environments, both within the Sacramento Valley as well as in the areas of conveyance and delivery. It is entirely likely that injuries to other legal users of water, including those entirely dependent on groundwater in the Sacramento Valley, will occur if this project is approved. Groundwater, fishery and wildlife resources are likely also to suffer harm as instream users of water in the Sacramento Valley. And the economic effects of the proposed DWB are at best poorly understood through the EA/FONSI. To its credit, at least the Bureau studied the proposed project, while DWR, with the Governor’s assistance, went the route of exempting it from CEQA, thereby enabling the agency to ignore these potential effects.

Taken together, the Bureau and DWR treat these serious issues carelessly in the EA/FONSI, and in DWR’s specious reliance for environmental compliance on an emergency exemption and the Environmental Water Account EIS/R of 2003 and 2007. In so doing, they deprive decision makers and the public of their ability to evaluate the potential environmental effects of this Project, and violate the full-disclosure purposes and methods of both the National Environmental Policy Act and the California Environmental Quality Act.

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[5] See especially, Pacific Institute, *More with Less: Agricultural Water Conservation and Efficiency in California, A Special Focus on the Delta,* September 2008; Los Angeles Economic Development Corporation, *Where Will We ?Get the Water? Assessing Southern California’s Future Water Strategies*, August 2008, and Lisa Kresge and Katy Mamen, *California Water Stewards: Innovative On-farm Water Management Practices*, California Institute for Rural Studies, January 2009.

Our organizations request advance notification of any meetings that address this proposed Project or any other BOR projects in Butte, Colusa, Glenn, or Tehama counties that require consideration of NEPA/CEQA as well as water rights applications that will be needed as the 2009 DWB moves forward. Please add C-WIN, CSPA, BEC, and the Center for Biological Diversity to your basic public notice list on this Project, and send us each any additional documents that pertain to this particular Project.

Sincerely,

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References Cited

Bureau of Reclamation 2006. Sacramento Valley Regional Water Management Plan. p. 5-8 to 5-10.

Bureau of Reclamation 2008. Draft Environmental Assessment and Finding of No Significant Impact. Stony Creek Fan Aquifer Performance Testing Plan. Glenn-Colusa Irrigation District.

Butte Basin Water Users Association 2007. *2007 Butte Basin Groundwater Status Report* p. 23 and 30.

Butte Basin Water Users Association 2008. *2008 Butte Basin Groundwater Status Report* p. 26-27 and 32-33.

Butte County 2007. Summary of Spring 07 Levels.

Butte County Department and Resource Conservation 2003. Urban Water Demand Forecast.

Butte County DWRC June 2007. *Tuscan Aquifer Monitoring, Recharge, and Data Management Project*, Draft.

CH2Mhill 2006, *Sacramento Valley Regional Water Management Plan*, Figure 1-4.

Dudley, Toccoy et al. 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update.*

Dudley, Toccoy 2007. Letter to Lester Snow as presented to the Butte County Board of Supervisors as part of agenda item 4.05.

DWR 2006. *California's Groundwater* – Bulletin 118.

DWR 2008. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

DWR 2009. Addendum to the Environmental Water Account Environmental Impact Statement/Environmental Impact Report

Fleckenstein, Jan; Anderson, Michael; Fogg, Graham; and Mount, Jeffrey 2004. Managing Surface Water-Groundwater to Restore Fall Flows in the Cosumnes River, *Journal of Water Resources Planning and management*, opening page of article.

Friend, Scott 2008. *City of Chico General Plan Update Existing Conditions Report;* Pacific

Municiple Consulting.

Glenn County. Board of Supervisors. California Ordinance No. 1115, Ordinance Amending the County Code, Adding Chapter 20.03, Groundwater Management.

Glenn-Colusa Irrigation District 2008-2009. Initial Study And Proposed Negative Declaration Landowner Groundwater Well Program

Governor's Advisory Drought Planning Panel 2000. Critical Water Shortage Contingency Plan

Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

Maslin, Paul E., et. al, 1996. *Intermittent Streams as Rearing Habitat for Sacramento River Chinook Salmon: 1996 Update*.

McManus, Dan; Senior Engineering Geologist, DWR Northern District on August 27, 2007, Personal communication with Jim Brobeck.

Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.

Msangi, Siwa and Howit, Richard E. 2006. *Third Party Effects and Asymmetric Externalities in Groundwater Extraction: The Case of Cherokee Strip in Butte County, California*. International Association of Agricultural Economists Conference, Gold Coast, Australia.

Scalmanini, Joseph C. 1995. *VWPA Substatiation of Damages*. Memo. Luhdorff and Scalmanini Consulting Engineers.

Shutes, Chris et al. 2009. *Draft Environmental Assessment DeSabla – Centerville Project (FERC No. 803)*. Comments. California Sportfishing Protection Alliance.

Spangler, Deborah L. 2002. *The Characterization of the Butte Basin Aquifer System, Butte County, California*. Thesis submitted to California State University, Chico.

Staton, Kelly 2007. *Glenn-Colusa Irrigation District Aquifer Performance Testing Glenn County, California*. California Department of Water Resources.

USFWS. 1999. Draft Recovery Plan for the Giant Garter Snake.

USFWS. 2006. Giant Garter Snake Five Year Review: Summary and Evaluation.

USFWS. 2008 Biological Opinion for Conway Ranch.

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28 July 2014

Mr. Ryan Wulff
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VIA: Electronic Submission
Hardcopy if Requested

RE: Comment Letter No. 1: Bay Delta Conservation Plan and Associated EIR/EIS Related to Habitat Restoration and Conservation Measures

Dear Mr. Wulff,

The California Sportfishing Protection Alliance (CSPA) has reviewed the proposed Bay Delta Conservation Plan and associated Environmental Impact Report/Environmental Impact Statement (hereinafter, BDCP) submits the following comments. Comment Letter No. 1 relates to habitat restoration and conservation measures intended to important habitat. This Comment Letter includes an attached report titled *Overview of Delta Habitat Restoration*, which analyzes recent Delta habitat restoration projects and includes an appendix that compares the "Overview" with the habitat assessment in BDCP Appendix 5E and identifies major flaws in the proposed native fish habitat restoration program. We request that both documents be considered and responded to as a single submittal.

CSPA worked closely with the Environmental Water Caucus (EWC) in developing their comments and incorporates by reference into these comments both submittals by the EWC on all issues related to BDCP. We also incorporate by reference the submittal by Michael Jackson on behalf of CSPA, California Water Impact Network and AquAlliance, as well as the individual comments submitted by AquAlliance. We further incorporate by reference the submittals by the County of San Joaquin, South Delta Water Agency, Central Delta Water Agency, Restore the Delta, Earth Law Center and Friends of the River, insofar as they are consistent with these comments.

Summary Overview

As discussed more fully below, the BDCP conservation measures to improve important aquatic communities and habitats in the Delta Plan Area are wholly inadequate to mitigate for the expected effects of the BDCP. BDCP and its associated EIR/EIS fail because they are predicated upon a series of monstrous and demonstrably false premises. Based upon these premises, they serve up a many-thousand page omelet of distortion and half-truth in order to reach their predetermined conclusion.

BDCP peddles a revisionist thesis that the Delta's fisheries collapsed because of the historical loss of the pre-reclamation mosaic of Delta habitat. It asserts that severely degraded fisheries can be significantly improved by simply restoring habitat. It claims that restoration of physical habitat can successfully serve in lieu of flow and does so based upon a conceptual programmatic level document. It asks one to believe that you can deprive an estuary of more than half of its flow, turn its hydrograph on its head and expect that fisheries that evolved over millennia, under the historical flow regime, will prosper. The stark reality is that no estuarine ecosystem in the world has survived such insult.

The facts are: 1) reclamation of Delta islands was completed by the second-to-third decade of the last century; 2) Delta fisheries remained relatively stable until the advent of the state and federal export projects; 3) there is now more habitat in the Delta than existed eighty years ago; 4) physical habitat restoration projects in the Delta have largely failed; and 5) the estuary's ecological collapse and one-to-two magnitude declines in anadromous and pelagic fisheries and lower trophic communities occurred after the projects began exporting millions of acre-feet of water yearly.

Habitat is more than the spatial extent of acreage: an increase in habitat area doesn't ensure increases in habitat quality or functionality. The amount of freshwater inflow to an estuary is a physical and ecological driver that defines the quality and quantity of estuarine habitat. As the U.S. Fish & Wildlife Service testified during the State Water Resources Control Board's 2010 flow hearing, "flow in the Delta is one of the most important components of ecosystem function."

Habitat requires adequate physical (flow, residence time, variability, etc.) and chemical parameters (salinity, temperature, turbidity, chemical constituents, etc.), as well as the nutrients necessary for primary production to support renewable fisheries. The export projects have radically altered the Delta's hydrodynamics, which has resulted in a loss of critical flows, degraded water quality and reduced primary productivity. The yearly export of phytoplankton biomass is equivalent to more than 30% of net primary production. This altered hydrology has allowed myriad invasive non-native species to become entrenched to the detriment of native communities.

BDCP proponents confidently assume that proposed habitat restoration projects will be successful. The fact is the majority of restoration projects in the more than 222,902 acres of existing "conservation lands" scattered throughout the Delta have failed to achieve their forecasted goals. Many of these project areas are now habitat dominated by assemblages of invasive species that compete with and prey upon native species, including those listed pursuant to state and federal endangered species acts. Proposed restoration projects are unlikely to provide anticipated benefits unless the physical and chemical parameters approximating historical levels (i.e., mid-20th Century conditions) necessary for native species are also reestablished.

The consistent flaw of previous restoration efforts in the Delta has been a failure to adequately meet the habit requirements of native fish. The estuary's native species evolved over many thousands of years in response to prevailing habitat conditions. Successful restoration of native species requires restoring the conditions under which they evolved and prospered. This entails increasing outflows, mimicking the natural hydrograph, improving water quality, protecting the critical low salinity zone (LSZ) and reducing export of primary productivity. However, these are the essential elements BDCP cannot and will not provide.

The critical need for significantly increased Delta outflow is beyond scientific doubt. The State Water Resources Control Board, in its legislatively mandated 2010 report on needed Delta flows declared, “the best available science suggests that current flows are insufficient to protect public trust resources.” Substantial increases in Delta outflow were recommended. The California Department of Fish and Wildlife, in a similar legislatively mandated report on necessary biological objectives and flow criteria, found, “recent Delta flows are insufficient to support native Delta fishes in habitats that now exist in the Delta.” The San Francisco Estuary Partnership’s 2011 State of San Francisco Bay report observed, “scientists now consider poor freshwater inflow conditions to be one of the major causes for the ongoing declines of fish populations observed in the upper Estuary.”

Conservation measure CM1 is essentially a water conveyance project masquerading as a conservation measure. It will reduce outflow and exacerbate already poor Delta hydrological habitat that is essential for key fish species and their critical habitats. While presented as a project level analysis, less than ten percent of engineering and even less of the geotechnical investigation has been completed. Yet project proponents brazenly claim that all potential adverse impacts have been identified.

Conservation measures CM 2-21 are only presented and analyzed at a programmatic level, lack assured funding and are highly unlikely to achieve the predicted results. There are no assurances that proposed habitat protections and enhancements will be able to overcome the long-term detrimental effects of excessive Delta water diversions or the proposed new North Delta conveyance facilities with experimental fish screens. Indeed, the programmatic nature of the conservation measures precludes anyone from identifying the number and extent of impacts to biological resources, water quality, and other beneficial uses; let alone determining whether the conservation measures will effectively mitigate impacts.

The conservation measures applicable to securing a take permit for CM-1 (Water facilities and Operation) include: CM-2 (Yolo Bypass Enhancement), CM-3 (Natural Communities Enhancement), CM-4 (Tidal Marsh Creation/Restoration), CM-5 (Seasonal Floodplain Creation/restoration), CM-6 (Channel Margin Enhancement), CM-7 (Riparian Restoration), CM-10 Non-tidal Marsh Restoration), CM-11 (Natural Community Enhancement) and possibly CM-16 (Non-Physical Fish Barriers). Many of these measures were included as Stage 1 Action Items in the 2000 CalFed Record of Decision but were never implemented or were partially and/or unsuccessfully implemented with unintended adverse consequences. Funding is highly speculative, subject to congressional or legislative authorization or bond passage. Implementation can proceed with or without BDCP and these measures should have been required mitigation for adverse impacts created by operation of the present export facilities.

Conservation measure CM-2 (Yolo Bypass Enhancement), and conservation measures CM-12 (Mercury Enhancement), CM-13 (Invasive Vegetation), CM-14 (Stockton Ship Channel O2), CM-15 (Predatory Fish), CM-16 (Non-Physical Fish Barriers), CM-17 (Illegal Harvest Reduction), CM-18 (Hatchery Management), CM-19 (Urban Stormwater), CM-20 (Invasive Species), CM-21 (Non-Project Diversions) are, for the most part, not dependent on BDCP. In varying degrees, these measures have long been necessary, are already underway, being approved, financed and managed by others. They will likely proceed regardless of whether BDCP's conservation measures are approved. BDCP should not be seeking credit for these ongoing activities.

A number of critically important conservation measures are conspicuously absent in BDCP. While CM-1 focuses on experimental fish screens at the north Delta diversions, it ignores requirements in the CalFed Record of Decision to upgrade the existing inadequate 1950s-era fish screens in the south Delta to current screening criteria. The South Delta Fish Facilities Forum ceased development of the new screens in 2005 after the state and federal contractors said they wouldn't pay for them. Between 2000 and 2011, more than 130 million fish were salvaged at project facilities, many of which were lost during collection, handling, trucking and post-release predation, and more than a billion fish were estimated lost due to high predation in and around the export facilities.

There are no conservation measures proposed for San Pablo and San Francisco Bays despite the massive impacts the export projects have had and will have on the Bays. A median of 39% of the estuary's unimpaired runoff is already consumed upstream or diverted. Exports sometimes exceed 50% of inflow. Shifts in the seasonal hydrograph and movement of the low salinity zone (LSZ) upstream have been marked by major declines of native phytoplankton, zooplankton and pelagic fish and huge shifts in biological communities. Construction and operation of CM-1 will intensify these problems. Yet BDCP continues to deny that it has any role in creating or mitigating these impacts.

There are no conservation measures proposed for impacts upstream of the Delta. Despite repeated denials by proponents, construction and operation of CM-1 will necessitate reoperation of upstream reservoirs, with resulting instream impacts. Increased total export capacity, especially in drier years at the north Delta diversion point, opens the door to myriad opportunities to significantly increase water transfers. Water transfers are generally authorized under temporary transfer rules or emergency proclamations and receive little or no environmental analysis. BDCP severs the Delta from the upper and lower segments of the watershed to avoid having to acknowledge or mitigate impacts.

Nor are there any conservation measures proposed for the largest source of pollutant loading to the Delta: discharges from irrigated agriculture. The entire Delta is identified on the 2010 Clean Water Act 303(d) List as impaired and incapable of supporting beneficial uses because of agricultural pollutants. A 2007 Regional Board survey of monitoring data from 313 agricultural sites in the Delta and Central Valley revealed that; toxicity to aquatic life was present at 63% of the sites (50% were toxic to more than one species); pesticides criteria were exceeded at 54% of sites (many for multiple pesticides); metal criteria was violated at 66% of sites; human health standards for bacteria were violated at 87% of sites while more than 87% of the sites exceeded general parameters (dissolved oxygen, pH, salt, TSS, etc.). By reducing inflow of relatively good quality water (i.e., reducing dilution) and increasing the time for pollutants to interact with the ecosystem, CM-1 will exacerbate existing impacts.

Perhaps the most flagrant omission is the fact that proposed conservation measures do not include protection and enhancement of the most important and affected habitat in the Delta: the low salinity zone (LSZ) and freshwater pelagic habitats of the Delta on which many Delta native fishes including Delta Smelt depend. These habitats are unproductive because they are entrained and exported in drier years and summers of most years at the existing south Delta export facilities and thus lack the necessary residence time, nutrients, and water quality to sustain pelagic fish production.

The West Delta Restoration Opportunity Area (ROA) especially lacks measures to protect important tidal marsh, aquatic shoreline (channel margin), riparian and pelagic open water habitats despite its overall importance and sensitivity to Delta exports. There is no Central Delta ROA and this Delta region’s habitat appears to have been largely ignored by BDCP planners for restoration, despite its central location in the area most affected by the North and South Delta exports. Conservation Zone 1 and 2, the center and northern Yolo Bypass, also lack needed measures on non-tidal marsh, riparian, seasonally inundated floodplain and channel margin habitats and are not included in any ROA.

If BDCP proposes to continue massive water supply exports from the Delta, it must propose meaningful measures to replace the millions of acre-feet of pelagic habitat lost each year to the export pumps and prevent native species that depend on that habitat from going extinct. CM1 fails to provide the enhanced outflow that fish agencies, regulators and independent scientists have observed is critical to the restoration of the estuary. Instead BDCP offers less outflow in order to enhance water supply benefits.

Other Summary Points

1. Potential export capacity under CM-1 would increase from the present 11,400 cfs to 15,000 cfs, with the existing array of pumps and the new, “isolated” forebay at Clifton Court. There are no credible measures offered to reduce the millions of acre-feet of pelagic habitat that will be exported from the North and South Delta each year under the BDCP. Increased export of pelagic habitat will exacerbate recent population declines and prevent recovery of pelagic species because of further habitat degradation.
2. CM-1’s north Delta fish screens are experimental and will require variances from present fish screen criteria. Screen design was based on laboratory studies and it is unknown if the laboratory studies are representative. Consequently, a number of studies are required to see if the proposed screen design concept will work, will be protective or if the screens can be legally permitted. Half of these studies are proposed post-construction. BDCP rejected requests by NOAA Fisheries and recommendations by the BDCP Fish Facilities Technical Team that construction be phased to see if the first one works before constructing the rest. Delta smelt are present at the diversion point February through June and no screens can prevent

entrainment of eggs and larval Delta smelt, longfin smelt, splittail, striped bass American shad or smaller lamprey ammocoetes.

3. Tidal wetlands are proposed under CM-4 for five ROAs. Three of the five proposed wetlands are Suisun Marsh ROA, Cosumnes/Mokelumne ROA, and Cache Slough ROA. These wetlands will have marginal benefit to key Delta food webs because of isolation from the LSZ and key pelagic habitats. Invasive overbite clams limit food-web production in Suisun Bay and Marsh. Reductions in North and East Delta inflows from proposed North Delta exports would reduce net transport of water and food web contributors from Cache Slough and East Delta. The Cosumnes/Mokelumne ROA will become more isolated from Delta inflows than under present conditions.
4. Suisun Bay LSZ habitat will further deteriorate, as the LSZ moves into the Delta and becomes less productive due to lower Delta outflows predicted under CM-1, especially in drier years. Delta outflow remains the most critical factor in Suisun Bay and the Delta portions of the LSZ nursery areas that are critical to smelt and other pelagic species.
5. CM2 focuses on the Yolo Bypass, Cache Slough, and Sacramento Ship Canal habitats but offers little potential improvement to existing poor water quality conditions (mainly high water temperature and low dissolved oxygen) in these areas, especially during spring and summer when these areas are important salmon and smelt nursery areas. In drier years, spring-summer habitats will suffer from reduced freshwater inflow to Cache Slough from its primary freshwater sources (Miner, Steamboat and Sutter Sloughs) because of the proposed North Delta exports.
6. CM3 lacks focus and actions on West and Central Delta tidal wetland improvements, as large areas of the West Delta tidal wetlands (i.e., West Sherman Island and Big Break) suffer from extensive invasion of non-native submerged aquatic vegetation and deteriorating channel margin habitat (Figure 3.4-27).
7. There is a general lack of focus on the linear shoreline habitats throughout the Delta. Smelt and salmon rearing are far more concentrated in shoreline and nearby open-water habitats than in tidal marshes. CM-6 proposes to restore less than 2% or only twenty of more than seven hundred miles of channel habitat over a thirty-year period.
8. There is a lack of specific restoration strategies regarding habitats, locations, and timing of habitat improvements relative to the needs of each of the listed and soon-to-be-listed native fishes in the Delta
9. There are no credible measures offered to reduce the millions of acre-feet of pelagic habitat that will be exported from the North and South Delta each year under the BDCP.
10. There is no mention of the detailed habitat improvement actions presented in the smelt, salmon, and steelhead state and federal recovery plans.
11. There are repeated references to adaptive management actions that will adjust habitat improvement actions of the BDCP but virtually no details on how adaptive management will actually be implemented or funded. Adaptive management programs have frequently failed throughout the nation, as have decades of adaptive management actions on dozens of failed habitat mitigation projects that were constructed in the Delta.

12. Many of the proposed habitat actions already exist and/or will likely be implemented in the future without the BDCP. These actions should be considered part of the baseline or no-action alternative in the EIR/EIS and not included in BDCP's portfolio of habitat mitigation measures.
13. The proposed restoration projects are insufficient in amount and quality of aquatic habitat to meet the goals and objectives of the BDCP. There is a high degree of uncertainty they will be able to achieve expected goals. Yet, there is no discussion of historical habitat restoration projects, analysis of the results of implementation or why the proposed habitat projects will have different outcomes.
14. CM-1 proposes to operate pursuant to requirements in D-1641 and existing biological opinions. These standards are seriously inadequate as evidenced by the continuing collapse of Delta fisheries. Additionally, the State Water Resources Control Board has failed to take enforcement action against the state and federal projects for thousands of documented violations of D-1641 standards and the fishery agencies have demonstrated a willingness to weaken requirements in the biological opinions at the request of project operators.

The assumptions and conclusions that buttress the BDCP and EIR/EIS conservation strategy and goals are egregiously flawed and technically invalid. Consequently, the analysis of impacts regarding CM1-22 and likelihood of success of the various conservation mitigation measures are seriously deficient and fail to meet minimum CEQA or NEPA standards for environmental review. BDCP must be returned to the drafting table and a new EIR/EIS should be circulated for public review and comment.

Development of the Broad Conservation Goals, Types of Restoration Action Evaluated and Specific Conservation Measures

The BDCP Introduction, Chapter 1, pages 1-2 and 1-3, identifies the broad conservation goals of BDCP's conservancy strategy. The goals are repeated in Chapter 3, Conservation Strategy (3A-2 and 3A-3), which also describes the strategy as being built upon *scientific tenets that reflects the current state of available science* (3A-2, lines 38, 39). Chapter 3, Appendix 3A, page 3A-13, lines 19-32), describes the types of habitat restoration and enhancement actions that were evaluated for inclusion in the conservation strategy. Based upon the evaluation of the *types of habitat restoration and enhancement actions that were evaluated for inclusion in the conservation strategy* and development of the *broad conservation goals*, BDCP offers 22 specific conservation measures to advance the goal of restoring the Delta's ecological functions (Chapter 3, Part 2, Conservation Strategy, 3.4, pages 40-353).

Below are our specific comments on: A) the *broad conservation goals* of BDCP's conservancy strategy; B) the *types of habitat restoration and enhancement actions that were evaluated for inclusion in the conservation strategy* and C) the specific *conservation measures CM 1-21*.

A. Broad Conservation Goals and Strategy

The Broad Conservation Goals and Strategy are discussed in Chapter 1, pages 1-2 and 1-3; and Appendix 3A, pages 3A-2, lines 38-42 and 3A-3, lines 1-21. Goals 1 through 8 and 11 are applicable to fisheries. They include:

1. ***Increase the quality, availability, spatial diversity, and complexity of aquatic habitat in the Delta.***

   CM1-11, if implemented as proposed, would not lead to increased habitat quality and complexity in a timely manner. The main limitation is the lack of potential improvement to pelagic open water habitat under CM1 and lack of the indirect benefits of the other conservation measures to key LSZ pelagic habitats of the West and Central Delta.

2. ***Create new opportunities to restore the ecological health of the Delta by modifying the water conveyance infrastructure.***

   The potential restore ecological health to the Delta is severely restricted by retention of the south Delta export facilities, especially without upgrading them to state-of-the-art standards and current criteria fish screen criteria. The potential for Delta pelagic and shoreline habitats to improve is restricted by the proposed large fine mesh passive screen intake infrastructure in the North Delta.

3. ***Directly address key ecosystem drivers in addition to freshwater flow patterns rather than manipulation of Delta flow patterns alone.***

   Freshwater flow patterns in the Delta under CM1 remain the critical ecosystem driver in the Delta. Enhanced ecosystem inputs from new margin wetland and floodplain habitats will not be of benefit if they cannot contribute to the pelagic habitats of the West and Central Delta. Under the BDCP proposal both Suisun Marsh and Cache Slough Complex would be more isolated from contributing to the LSZ than under present conditions.

4. ***Improve connectivity among aquatic habitats, facilitate migration and movement of covered fish among habitats, and provide transport flows for the dispersal of planktonic material (organic carbon), phytoplankton, zooplankton, macroinvertebrates, and fish eggs and larvae.***

   The proposed North Delta exports will reduce connectivity and create a serious impediment to migration and movement of salmon, smelt, steelhead, sturgeon, and many other important fish of the Central Valley. The North Delta diversions and continuation of South Delta diversions will entrain vast amounts of biological organisms, nutrients, and other essential elements of Bay-Delta productivity.

5. ***Improve synchrony between environmental cues and conditions and the life history of covered fish and their food resources in the upstream rivers, Delta, and Suisun Bay, including seasonal water temperature gradients, salinity gradients, turbidity, and other environmental cues.***

The proposed North Delta exports and continued significant reliance on South Delta exports will further add to reduced synchrony of natural environmental cues to which native fishes are adapted. Food sources will be reduced, water temperatures will increase, salinities will increase, turbidity will be further reduced, and environmental cues will be further disrupted.

6. ***Reduce sources of mortality, and other stressors, on the covered fish and the aquatic ecosystem in the Delta.***

   Delta smelt have suffered relentlessly from the direct and indirect effects of past and present levels of exports from the Delta. A switch of exports to the North Delta upstream of the main pelagic habitats of the smelt will simply increase the risk of smelt to South Delta exports and further degrade smelt critical habitat in the West, Central, and North Delta, as well as Suisun Bay. The North Delta intakes will add a significant source of mortality to Sacramento Valley listed salmon and steelhead that does not exist today. Continuation of South Delta exports does little to alleviate existing stressors that are related to fish growth, survival, and reproduction. Freshwater Delta inflow from the Sacramento River will decrease and inflow from the San Joaquin River will increase, thus contributing to even warmer water in the Delta from spring through summer and early fall. LSZ pelagic habitat of Delta Smelt would be drawn upstream into the influence of north Delta diversions and screening systems (which do not protect smelt). Pelagic low-salinity cool water Delta habitat would also suffer under new North Delta exports and continuing South Delta exports to the point where at a minimum no benefits would accrue. (Appendix 5B forecasts little if any benefits from reduced entrainment to Delta Smelt from the BDCP.) As for salmon, there will be more opportunity for the populations from the Sacramento River system to interact with the project screen systems than under the present configuration. Finally, continuation of the south Delta exports will maintain most of the present risks to these populations.

7. ***Improve habitat conditions for covered fish in the Delta and downstream in the low salinity zone of the estuary in Suisun Bay through the integration of water operations with physical habitat enhancement and restoration.***

   Major habitat enhancements of the proposed conservation measures are isolated from the LSZ of the estuary. Proposed water operations and infrastructure (including the proposed North Delta export facilities) would further isolate, not integrate, proposed habitat improvements.

11. ***Emphasize natural physical habitat and biological processes to support and maintain species covered by the Plan (i.e., covered species) and their habitat.***

    The biological processes and habitats of the LSZ in the West and Central Delta are virtually ignored in the conservation measures. The natural pelagic habitats so important to Delta fishes are virtually ignored in the BDCP.

B. Types of Habitat Restoration and Enhancement Actions That Were Evaluated for Inclusion in the Conservation Strategy

Appendix 3A, page 3A-13, lines 19-32, identifies the types of habitat restoration and enhancement actions that were evaluated for inclusion in the conservation strategy. They include:

1. ***Restoring intertidal habitat to establish vegetated marshes and associated sloughs to increase habitat diversity and complexity, food production, and in-Delta productivity, and rearing habitat for covered species.***

   Most of the tidal marsh restoration proposed is in Suisun Marsh and Cache Slough/Yolo Bypass. Suisun Marsh restoration will be isolated from the low salinity zone upstream in Delta, and subject to modification by invasive clams found in brackish Bay waters. Much of Suisun Marsh ROA is already restored or in managed freshwater marshes (duck clubs and state wildlife areas). Large areas of the Cache Slough ROA are existing functional pelagic habitats adjoining extensive tidal marshes (e.g., Liberty Island, Little Holland Tract, Prospect Island, Sacramento Ship Channel). The Cache Slough ROA is also largely isolated from the LSZ in the Delta in drier years. Furthermore, tidal marshes contribute little productivity to open water pelagic habitats. Special status fish are far more apt to select shoreline habitats adjacent to pelagic waters than tidal marshes.

2. ***Increasing hydraulic residence time and tidal exchange in the Delta sloughs and channels by changing circulation patterns to increase primary productivity and foodweb support and improve turbidity conditions for delta smelt and longfin smelt.***

   Continued reliance on south Delta exports in drier years and late spring and summer of wetter years will continue stressors on pelagic species and their tidal aquatic habitats. LSZ Any shift in the LSZ upstream toward the North Delta intakes could put added pressures on the smelt populations because the screens will not protect larvae and early juvenile smelt whose habitat includes freshwater tidal pelagic habitats.

3. ***Increasing the amount of functional floodplain habitat to increase the quantity and quality of rearing habitat for salmonids and sturgeon and spawning habitat for Sacramento splittail, and generate food resources for pelagic species.***

   The BDCP holds little promise in providing more floodplain habitats that would be inundated by tidal or flood flows especially in the Yolo Bypass (CM2). More floodplain inundation in the East Delta and Yolo Bypass without improved access in CM2 would not significantly benefit salmon growth, survival, and production from the Delta.

4. ***Providing adequate water quality and quantity within the Delta at appropriate times to help conserve resident native fishes and improve rearing and migration habitats***

for salmon moving through the Delta.

Target water quality objectives in the Delta include cooler waters, keeping the LSZ to the west away from the export facilities in both the North and South Delta, increasing the area of the LSZ, keeping the low-productivity reservoir water out of the Delta, and retention of the higher turbidity, higher productivity, low salinity water within the Delta's pelagic habitat. Retaining a salinity gradient and positive downstream flow through the Delta in winter and spring are necessary to improve salmon survival through the Delta. Such conditions are not provided under CM1 or other conservation measures.

C. Specific BDCP Conservation Measures CM 1-22

The specific BDCP conservation measures are proposed at Chapter 3, Part 2, Conservation Strategy, 3.4, pages 40-353 and include: CM1 (Water Facilities and Operation), CM2 (Yolo Bypass Enhancement), CM3 (Natural Communities Enhancement), CM4 (Tidal Marsh Creation/Restoration), CM5 (Seasonal Floodplain Creation/Restoration), CM-6 (Channel Margin Enhancement), CM7 (Riparian Restoration), CM8 (Grassland Restoration), CM9 (Vernal Pool and Alkali Wetland Restoration), CM10 (Non-Tidal Marsh Restoration), CM11 (Natural Community Enhancement), CM12 (Mercury Enhancement), CM13 (Invasive Vegetation), CM14 (Stockton Ship Channel O2), CM15 (Predatory Fish), CM16 (Non-Physical Fish Barriers), CM17 (Illegal Harvest Reduction), CM18 (Hatchery Management), CM19 (Urban Stormwater), CM20 (Invasive Species), CM21 (Non-Project Diversions), CM22 (Avoidance and Minimization Measures).

General Overview of Conservation Measures

The amount of freshwater inflow to an estuary is a physical and ecological driver that defines the quality and quantity of estuarine habitat (Jassby et al. 1995; Kimmerer 2002; 2004 Feyrer et al. 2008, 2010; Moyle and Bennett, 2008; Moyle et al., 2010).

Before construction of most of the major dams on the estuary's tributary rivers (1930-43) an average of 82% of estimated unimpaired flow reached San Francisco Bay. By the 1980's, the percentage had decreased significantly to 60%. The averaged for the 2000s is 49%.

BDCP conservation measures applicable to securing a take permit for CM1 (Water facilities and Operation) include CM2 (Yolo Bypass Enhancement), CM3 (Natural Communities Enhancement), CM4 (Tidal Marsh Creation/Restoration), CM5 (Seasonal Floodplain Creation/restoration), CM6 (Channel Margin Enhancement), CM7 (Riparian Restoration), CM10 Non-Tidal Marsh Restoration) and CM11 (Natural Community Enhancement).

Salmon, steelhead, sturgeon, splittail, striped bass, and other important native and non-native migratory Central Valley fishes significantly depend on the Delta for spawning, young rearing, or residence during all or parts of their life cycles. Altered habitats and hydrology have greatly hindered native fish communities and favored non-native invasive plants, clams and less nutritional primary producers and predatory and competitive fishes.

Unfortunately, only CM1 has received a project level evaluation and even that evaluation is sadly lacking in specific and necessary details. The lack of project level analysis and disclosure in the other conservation measures effectively piecemeals the project and defers mitigation and assurances in violation of HCP/NCCP permitting requirements. All components should receive the same level of detail.

Of these, CM1 is misleadingly described as a conservation measure. CM1 provides for the construction and operation of new north Delta water conveyance facilities to bring water from the Sacramento River to the existing water export pumping plants in the south Delta, as well as for the operation of the existing south Delta export facilities. Diversion of Sacramento River inflow under the Delta to facilitate the increased export of water cannot be justified as a conservation measure. Nor can it qualify as a HCP or NCCP conservation measure addressing compliance with state and federal endangered species acts.

Further, there is no discussion in either the BDCP or EIR/S as to how conservation measures CM 2-21, which are predicated on uncertain public funding, which may or may not be implemented, which are unlikely to be fully successful and which are only analyzed to a programmatic level of analysis can be employed to mitigate for the impacts of a massive water diversion project that has been analyzed (if inadequately) to a project level of detail. Conservation measures CM 2-21 will need to be analyzed to a project level of detail and funding and implementation will need to be assured in order to qualify for consideration in an HCP or NCCP.

Conservation measures CM 2-21 together comprise a stand-alone publicly funded project to restore the Delta’s ecosystem and is not dependent on CM1. In fact, conservation measure CM2 and conservation measures CM 12-21 are not dependent on BDCP and are already underway and, in varying degrees, being approved, financed and managed by others. They will proceed regardless of whether BDCP is approved or not. BDCP should not be seeking credit for these ongoing activities that are not dependent on BDCP or CM1. That said, it should be noted that historical efforts similar to CM 12-21 have already failed to achieve their envisioned or desired results. For that matter, BDCP should not be seeking credit for conservation measures CM 3-11, which will be funded by the public purse and are also not dependent on BDCP or CM1.

Most importantly, none of the conservation measures CM 2-21 are will be as successful as predicted in the BDCP and EIR/S. For example, historical habitat restoration efforts in the Delta have had questionable benefits and frequently provided habitat for undesirable non-native species, predators and noxious vegetation. Numerous commentators have remarked that excessive diversions of water have changed the hydrology of the estuary into something resembling an Arkansas lake. Creating more “Arkansas lake” habitat will not restore the natural ecological processes that supported myriad native species over millennia. Flow and appropriate salinity levels are major components of pelagic estuarine habitat.

None of the conservation measures address the effects of increased Delta exports on the habitat and aquatic species of San Francisco or San Pablo Bays. This is a glaring omission, as numerous studies have documented the effects of Delta outflow on the circulation, water quality and productivity of San Francisco and San Pablo Bays and further reductions in outflow will exacerbate present adverse impacts caused by excessive upstream diversions.[1] Overall net outflow to San Francisco and San Pablo Bays will decrease under BDCP. The major water supply benefits of the tunnels come in wetter years when freshwater flushes the Bays.

The uncertainty of success of proposed habitat restoration efforts are lavishly documented in comments by the Delta Science Program's Independent Review Panel report on the BDCP Effects Analysis, the Delta Independent Science Board's review of the draft EIR/EIS for BDCP, the Independent Panel Review of BDCP sponsored by American Rivers and the Nature Conservancy, the March 2014 comments submitted by the Pacific Fishery Management Council, the February 2014 comments by the California Advisory Committee on Salmon and Steelhead Trout, as well as numerous earlier comments by the National Research Council on adaptive management and the effects analysis, the red flag and progress comments by the National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. EPA, U.S. Corps of Engineers and comments on the EIR/EIS by the State Water Resources Control Board.

The underlying assumptions of habitat restoration are further brought into question by the evaluation of BDCP modeling by MBK Engineers in their presentation before the Delta Stewardship Council, which identified a number of flaws including the use of outdated models, the failure to accurately model climate change, the faulty assumptions of actual reservoir operations, the overrepresentation of outflow and underrepresentation of exports. The failure of BDCP models to accurately reflect anticipated changes in CVP and SWP operations with BDCP bring into serious question the assumptions of habitat restoration.

BDCP modeling demonstrates that, under the proposed alternative, Delta outflow will decrease, exports will increase, X2 will migrate eastward, residence time and pollutant concentration will increase throughout the Delta, salinity levels and violations of present fish and agricultural salinity standards will increase, survival rates of winter-run, spring-run and Sacramento and San Joaquin fall-run salmon smolts will decrease, and concentrations of mercury and selenium in bass and sturgeon will increase.

Comments on Specific Conservation Measures

1. CM1, Water Facilities and Operation, Pages 3.4.1 – 3.4-39.

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[1] Cloern, J. E., and A. D. Jassby (2012), Drivers of change in estuarine-coastal ecosystems: Discoveries from four

CM1 is essentially a water conveyance project masquerading as a conservation measure. It will reduce outflow and exacerbate already poor Delta hydrological habitat that is essential for key fish species and their critical habitats. By reducing outflow to San Francisco and San Pablo Bays and drawing X2 further eastward, CM-1 will increase the habitat expanse of *Potamocorbula amurensis*, the saltwater clam that invaded the estuary in the 1980s to the detriment of primary and secondary productivity and fish production. Higher salinities and reduced outflow will also expand the habitat of an array of invasive aquatic vegetation that has expanded throughout the Delta and established itself in recent habitat restoration areas. Invasive aquatic vegetation has reduced productivity and provided habitat for an assortment of non-native predatory fish species. CM1 will increase residence time and will exacerbate already poor water quality conditions and significantly increase the frequency of violations of water quality standards established to protect fish and other beneficial uses of water.

Existing water exports from the south Delta have altered Delta hydrology, degraded water quality, expanded the range of invasive species, reduced plankton productivity, exported primary production, decreased suspended sediment and entrained vast numbers of fish. According to the California Department of Fish and Wildlife’s Fall Midwater Trawls, between 1967 (the beginning of SWP exports) and 2013, population abundance indices of striped bass, Delta smelt, longfin smelt, American shad, splittail and threadfin shad have declined 99.6, 95.6, 99.8, 90.9, 98.5 and 97.8%, respectively. During the same period, the Summer Townet Survey reveals that abundance indices for striped bass and Delta smelt declined 98.2 and 94.2%, respectively. Native lower trophic orders and populations of wild winter-run and spring-run Chinook salmon show similar orders of magnitude declines.

The majority of Delta exports will continue to come from the south Delta export facilities. During dry years, south Delta exports will significantly exceed north Delta exports. Yet there is no conservation measure to upgrade the existing 1950s-technology fish screens at south Delta facilities to state-of-the-art screens, as required by the CalFed Record of Decision. It is highly uncertain whether or not the proposed new fish screens in the north Delta will work as envisioned. The new screens will require a variance from present National Marine Fisheries Service (NMFS) and California Department of Fish and Wildlife (DFW) fish screen requirements. BDPC has rejected the recommendations of the NMFS and the Fish Facilities Technical Team to phase in installation of the new screens to see if they work or can be legally permitted.

The assessment models in the CM1 proposed operations include the existing restrictions including operational criteria prescribed in the two OCAP biological opinions and the state’s D-1641 water quality standards. However, these are the same restrictions and operating criteria that contributed to many of the present problems, including the Pelagic Organism Decline (POD).

A fundamental problem with CM1 is that it does not enhance Delta outflow, but rather decreases outflow to enhance exports. Outflow is the common denominator of many intertwined processes and influences distribution, condition and abundance of numerous species.[2] The failure to increase outflow will likely undermine any improvements that may occur with other conservation measures.

BDCP is pregnant with uncertainty, as evidenced by comments by the Delta Science Program's Independent Review Panel report on the BDCP Effects Analysis, the Delta Independent Science Board's review of the draft EIR/EIS for BDCP, the Independent Panel Review of BDCP sponsored by American Rivers and the Nature Conservancy, as well as numerous earlier comments by the National Research Council on adaptive management and the effects analysis, the red flag and progress comments by the National Marine Fisheries Service, U.S. Fish and Wildlife Service, U.S. EPA, U.S. Corps of Engineers and comments on the EIR/EIS by the State Water Resources Control Board.

Failing to acknowledge the enormous uncertainties inherent in CM-1 construction and operation and waiting to address uncertainty until sometime later through a vague undefined decision tree and adaptive management process is unacceptable. If is all the more unacceptable because all four decision tree operational alternatives will lead to reduced outflow in the long-term.

Existing water export operations by BDCP project proponents have frequently violated promulgated water quality and flow standards established to protect fisheries and other beneficial uses. These include, San Joaquin River and south and west Delta salinity objectives protective of agriculture, Delta and Suisun Marsh salinity objectives protective of fish and wildlife, Delta outflow objectives, Sacramento and San Joaquin River flow objectives and objectives limiting exports and establishing inflow/export ratios. The State Water Resources Control Board has never taken enforcement action for thousands of documented violations of these water quality standards. There is no discussion or assurances in BDCP regarding compliance with water quality violations or how or whether CM-1 will comply with water quality standards in the future.

Discharges from irrigated agriculture, the largest source of pollutant loading to the Central Valley, the Delta and critical smelt and salmon habitat areas, are completely ignored. Forty-two years after passage of the federal Clean Water Act and forty-five

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[2] *"Outflow is thus the common denominator among the multitude of intertwined processes. In recognizing this, the Panel is unified in agreeing that the distribution, condition, or abundance of some estuarine organisms are statistically related to outflow and X2 because these two indicators reflect underlying physical and ecological processes that more directly affect the estuarine organisms. In statistical terminology, a number of important ecological factors "co-vary" with outflow and X2 and are more proximal influences on organism distribution, condition, and abundance. For example, some biotic indices may correlate with X2 because their distributions are driven by properties (for example salinity) that co-vary with X2, or because seasonal trends in X2 happen to coincide with inherent reproductive seasonality."* (Workshop on Delta Outflows and Related Stressors Panel Summary Report, May 2014)

years following enactment of California's Porter-Cologne Water Quality Control Act, the State and Regional Water Boards cannot document any reduction in the total mass loading of pollutants from irrigated agriculture and municipal stormwater discharges. For that matter, they cannot document any reduction in the total mass loading of pollutants from municipal and industrial wastewater facilities.

The entire Delta is identified on the 2010 Clean Water Act 303(d) List as impaired and incapable of supporting beneficial uses because of agricultural pollutants. A 2007 Regional Board survey of monitoring data from 313 agricultural sites in the Delta and Central Valley revealed that; toxicity to aquatic life was present at 63% of the sites (50% were toxic to more than one species); pesticides criteria were exceeded at 54% of sites (many for multiple pesticides); metal criteria was violated at 66% of sites; human health standards for bacteria were violated at 87% of sites and more than 87% of the sites exceeded general parameters (dissolved oxygen, pH, salt, TSS, etc.). By reducing inflow of relatively good quality water (i.e., reducing dilution) and increasing the time for pollutants to interact with the ecosystem, CM-1 will exacerbate existing impacts.

Nothing in BDCP and CM1 and associated conservation measures demonstrates or provides assurances that CM1, in conjunction with continued south Delta exports, will alleviate present downward trends, let alone reverse these trends and begin restoration of the Delta ecosystem to meet the requirements of an HCP or NCCP.

2. CM2 Yolo Bypass Fisheries Enhancement, Pages 3.4-40 – 3.4-66.

CM2 is designed to mitigate a long list of identified problems on the Yolo Bypass and Cache Slough that were, in significant measure, created by flood control system projects. The flood control system should mitigate these problems. In any case, a number of these valuable and important activities are already underway, are being financed and managed by others and can move forward with or without CM-1. BDCP should not be latching on to ongoing projects or taking credit for them.

CM-2 is only analyzed at a programmatic level. Many of the proposed projects are highly speculative, may or may not be implemented and have uncertain likelihood of being funded. They cannot comply with HCP or NCCP requirements unless they can demonstrate adequate assurances of funding and implementation.

There is no ROA for 30 miles of the central tidal Bypass and non-tidal northern Bypass where tidal and non-tidal wetlands and seasonal inundated habitat could be added with benefits to young salmon that would be passing into the Bypass via the Fremont Weir. Nor are there proposals to address the many water diversions in the Bypass that entrain salmon and smelt. Many of the diversions in the south end have unscreened tide gates.

The Ship Channel that runs for over 20 miles along the east side of the lower Bypass and the Tule Canal that runs within the east side of the Bypass are important smelt spawning and early rearing habitats, yet they suffer from poor habitat and water quality conditions. The BDCP fails to address these issues. The entire Bypass, Cache Slough, and the Ship Channel suffer poor water quality from stormwater and agricultural return-flow discharges in winter, spring, and summer that degrade the smelt and salmon habitats. The Bypass also receives significant methylmercury loading that bioconcentrates in fish tissue. These issues have long been known and amply documented but existing regulatory programs have failed to achieve anticipated results. Failure to ensure that these problems are adequately addressed increases the likelihood that many of the CM2 improvements may be wasted or may even be detrimental to overall fish survival and production because fish can be diverted from the Sacramento River into marginal habitat in the ROA.

3. CM3, Natural Communities Protection and Restoration, Pages 3.4-66 – 3.4-115.

CM-3 proposes to provide a mechanism and guidance to establish a reserve system by acquiring lands for protection and restoration to meet biological goals and objectives addressed under the BDCP. However, no specific properties have been identified for acquisition in the BDCP, although Restoration Opportunity Areas (ROAs) have been identified. Goals for establishing habitat include: 27,000 acres of tidal perennial aquatic; 932 acres of tidal mudflat; 6,000 acres of tidal brackish emergent wetland; 24,000 acres of tidal freshwater emergent wetland; 4,300 acres of valley/foothill riparian; 100 acres of non-tidal perennial aquatic; 670 acres of non-tidal freshwater perennial emergent wetland; and unknown acres of other seasonal wetland.

CM-3 is essentially a conceptual wish list. It has only been analyzed to a programmatic level. Specific properties have not been identified and specific plans have not been developed. Potential adverse impacts and possible mitigation measures have not been identified or analyzed. If implementation proceeds, it will lag far behind the construction of CM-1. Funding is not assured and is dependent on future state and federal authorizations. Given the lack of success of numerous previous habitat restoration projects in the Delta, implementation is unlikely to achieve the 100% success rate envisioned by BDCP. Examples of previous restoration projects that failed to meet their objectives include: Decker Island, McCormick Williamson Tract, West Sherman Island, Little Holland Tract, Prospect Island, Kimball Island, Winters Island, Chipps Island, Montezuma Island, Mildred Island, Franks Tract, Big Break, Antioch Point, Donlon Island and Hog Island. Many of these projects are already mitigation sites for Corps dredging and levee projects, DWR water projects (Four Pumps Program, Delta Levees Program, Delta Barriers Program, etc.) or required in the various biological opinions.

Habitat restoration is not simply acres of new terrain or physical structure. Habitat is the quantity and quality of water flowing through terrain. Open water habitat is critically important, especially for pelagic species, but largely ignored in BDCP’s conservation measures. It is highly unlikely that conservation measures CM 2-11 can mitigate for the significant reduction in the inflow of relatively good quality water to the estuary caused by the diversion of Sacramento water through tunnels under the

Delta. As previously noted, BDCP modeling demonstrates that those inflow reductions will: decrease outflow; move X2 and the LSZ's crucial habitat for pelagic species eastward; increase the concentration of pollutants and the residence time for pollutants to interact with the ecosystem; reduce smolt survival rates for winter-run, spring-run and Sacramento and San Joaquin fall-run salmon and increase the bioconcentration of mercury and selenium in fish tissue.

Statements of Overriding Consideration for Significant and Adverse Impacts may be approved by a lead agency, pursuant to CEQA. However, such overriding considerations have no place in a Section 7 consultation for an HCP or NCCP, especially when they would not occur in the absence of the project and where adverse impacts affect listed species.

The West Delta ROA contains virtually all the dry year spring-summer-fall critical habitats of the Delta Smelt and much of the winter-spring habitat of rearing salmon in the Delta. These large pelagic habitat units and many miles of shorelines and shoals of the West Delta are critical to the success of these species as well as the BDCP. BDCP documents describe the West Delta as an integral part of the "North Delta Arc of Native Fishes" (Figure 1). Yet, inexplicably, the West Delta ROA is virtually ignored in CM3 and other conservation measures. Over 50 miles of shoreline, half of which is un-leveed and "natural," are completely ignored, as are thousands of acres of important pelagic open-water habitat of the West Delta. These are critical areas heavily used by salmon and smelt in the Delta, especially in dry years when populations are highly stressed by low Delta outflow. In these drier years, the West Delta is especially critical habitat, given the high salinities of Suisun Marsh and the Bay and the fact that the Cache Slough complex in the north Delta is subject to lethal temperatures. At such times the LSZ lies almost entirely within the West Delta. The remaining LSZ habitat is completely ignored, as it is in the Central Delta and does not have an ROA.

The LSZ is supposed to be the most productive and prolific area of an estuary. However, as BDCP acknowledges in Chapter 5 Effects Analysis, primary production in the West Delta ROA is currently the second lowest of the ROAs. BDCP models predict that production will increase but will remain lower than the average of the other ROAs. The BDCP states: "*Tidal habitat restoration in the West Delta ROA could increase local food production for rearing salmonids and splittail*," but virtually no tidal habitat restoration is proposed here. Of course, tidal habitat is already extensive in the western Delta, as virtually the entire area is tidal habitat. Primary productivity does not suffer from lack of tidal habitat. Poor productivity or primary production is a result of the radically altered hydrodynamics, low quality inputs and the export of phytoplankton biomass equivalent to 30% of Delta primary production (Cloern and Jassby, 2012) by the state and federal projects.

Excessive Delta exports literally vacuum the critical LSZ pelagic habitat to the central and south Delta for export to southern California. This important habitat area needs more nutrients, longer residence times, more productive inputs from adjacent ROAs, and, most critically, less export of its primary production to southern California. High inflows of unproductive “blue” reservoir water during the summer from the Sacramento River, coupled with negative flows in the lower San Joaquin River, draw critical habitat toward the South Delta export facilities. This reduces residence time for primary production and exports critical pelagic habitat. Summer temperatures frequently exceed levels lethal to Delta smelt. Pelagic habitat remaining in the western Delta, during the summer, is largely comprised of unproductive reservoir water feeding the exports.

The new North Delta export facility in CM1 will exacerbate these hydrodynamic problems by reducing lower Sacramento River inflows, increasing reverse flow above Georgiana Slough, altering DCC operations and providing another, closer outlet for LSZ export. Enhancing the pelagic habitat and plankton community of the West Delta ROA would require managing and restoring natural Delta hydrodynamics. Because it fails to manage and restore Delta hydrodynamics, CM-3 cannot mitigate the adverse impacts of CM-1.

4. CM4, Tidal Natural Communities Restoration, Pages 3.4-116 – 3.4-144.

Open water or pelagic habitat is largely missing from the tidal habitat discussion in CM4, as it is in CM3. Open water habitat in the Delta is the key habitat of smelt and other pelagic fishes and clearly part of the Tidal Perennial Aquatic Habitat Community. But CM4 ignores open water habitat and primarily focuses on emergent wetland restoration in the Suisun Marsh and Cache Slough areas. It essentially ignores the potential habitat in the west and central Delta that is critical for salmon and pelagic species in drier years, when threats to salmon and smelt are most severe. In these drier years, the Suisun Marsh and Cache Slough ROAs are less important because the LSZ moves into the west Delta away from Suisun Marsh, while high temperatures and low inflow impact Cache Slough. Implementation of CM1 will exacerbate these impacts.

As one example of misplaced priorities, the entire six miles of shoreline along the north shore of the lower Sacramento River from Collinsville to Rio Vista is un-leveed and bordered by major smelt spawning shoal habitats. Salmon, smelt, splittail and other native fishes often dominate fish catches in this area and smelt surveys have their highest catches in these areas. Unfortunately, adjacent pastures, non-native Arundo riparian shoreline communities and dredging are adversely impacting this area.

Other locations identified in the west Delta ROA for restoration include relatively small acreage in Seventeen Mile Slough, Decker Island, areas around Three-Mile Slough and Big Break. However, potential benefits are undermined by continuation of south Delta exports, which draw water from these areas.

CM4 should serve as a cautionary tale concerning expectations of habitat restoration. This area abounds in failed habitat projects including Decker Island, Big Break, Kimble Island, PG&E mitigation project near Collinsville, Chips Island, Winter Island and areas of Sherman Island. These areas have become prime habitat for invasive species, noxious weeds and predators. As previously observed, restoring habitat is more than merely acquiring acreage: it requires meeting the physical and chemical parameters under which native species evolved for millennia.

Implementation of CM1 will likely adversely impact the time and space array of quality pelagic habitat in the Delta. In other words, it will likely decrease the amount of quality Delta smelt habitat.

For climate change and sea-level rise comment, please see ISB comments B-52

5. **CM5, Seasonally Inundated Floodplain Restoration, 3.4-145 – 3.4-154.**

There are several references to seasonal habitat in the Conservation Strategy, Part 1 and 2 of Chapter 3. Other than the potential opportunities for creation and restoration of habitat in the Yolo Bypass/Cache Slough area provide in CM-2, most of which will proceed regardless of CM-1: and in the south Delta, where seasonal floodplain could be incorporated in a bypass on the San Joaquin, there is limited opportunity to enhance floodplain habitat that would seasonally inundate during high flows in most of the Delta. Conceptually, areas such as east-side floodplains and margins of the Delta could provide habitat for salmon rearing and potentially increase Delta productivity. However, with the continued winter-spring closure of the Delta Cross Channel, benefits from the east Delta would likely be minimal, as this water moves directly to the South Delta export pumps when the DCC is closed.

6. **CM6, Channel Margin Enhancement, 3.4-155 – 3.4-161.**

Channel margin enhancement is the poster-child of BDCP's public relations efforts. Parts 1 & 2 of the Conservation Strategy, as well as the Executive Summary, effusively discuss the virtues of channel margin enhancement to benefit a wide variety of species. Indeed, there are hundreds of miles of channel margin habitat that could be enhanced to the benefit of all Delta native fishes including salmon and smelt. While salmon sometimes use tidal marshes for rearing, salmon, smelt, and other native fishes predominantly use the channel shorelines and shoals adjacent to Delta pelagic habitats.

However, under CM6 only twenty miles of channel margin habitat restoration will occur over thirty-year period. Fifteen miles of restoration will be split between the Sacramento River, Steamboat Slough and Sutter Slough and five miles on the San Joaquin River. The west Delta ROA is ignored, although it would greatly benefit from channel margin enhancement. Of course, like all of the proposed habitat restoration proposals in BDCP, channel margin enhancement is a conceptual wish list: there has been no project level analysis. No specific properties have been identified, no specific plans have been developed, no specific mitigation has been proposed and no assured funding has been identified.

7. CM7, Riparian Natural Community Restoration, 3.4-162 – 3.4-175.

In addition to the riparian habitat of CM6 channel margins, there is also a need to restore large-block riparian communities especially in areas subject to seasonal inundation. The best opportunities for these are in the Yolo Bypass, the Cosumnes/Mokelumne floodplain, and the lower San Joaquin floodplains. The BDCP goes far to state that the Yolo Bypass and Cache Slough complexes are precluded from such restoration by flood control needs. However, it was little more than a decade ago that these areas were in agricultural production protected by levees (e.g., Liberty, Little Holland, Prospect, etc.). Riparian floodplain habitats are simply not a threat to the flood control capacity of these areas that were recently not part of the floodplain at all except possibly in very large floods. Riparian floodplain forest habitats were once a major component of the regional Delta habitat array used by native fishes, especially salmon, and should be restored as much as possible.

10. CM-10, Nontidal Marsh Restoration, 3.4-193 – 3.4-201.

Nontidal marsh restoration is primarily for the benefit of the giant garter snake and greater sandhill crane. Nontidal marsh restoration could also be of benefit to salmon and other native fishes in areas upstream of the Delta such as the upper Yolo Bypass. However, fish are virtually ignored in CM10. Such marshes could also potentially contribute to Delta productivity through the transfer of organic carbon in the form of live and dead organisms and detritus, as well as inorganic nutrients and sediment.

Over 20 miles of the upper Yolo Bypass are not included in the proposed BDCP habitat restoration mosaic. Despite providing for annual streamflow and passage at the Fremont Weir, there is no provision for habitat in the entire upper Bypass that could take advantage of inundation with the new flow. It has been clearly demonstrated that such habitat greatly increase the growth and survival of salmon compared to the adjacent leveed Sacramento River. As compared to open agricultural fields, marshes in such nontidal areas offer significant habitat advantages for native fish spawning, rearing, and migrating. These advantages include increased cover from currents and predatory birds. The same potential occurs upstream of the Delta on other Delta tributaries including the San Joaquin River and its tributaries; this potential is not covered in the CM-10.

11. CM11, Natural Community Enhancement and Management, 3.4-202 – 3.4-256.

CM11 is essentially a conceptual hodgepodge of how the conceptual programmatic habitat restoration projects will be managed in accordance to achieve natural community goals and objectives. What is missing is a serious discussion of why previous restoration projects and management of habitat have utterly failed to reverse the downward spiral of native species in the estuary. Nor, is there any discussion of how the implementation of BDCP conservation measures will be different: why BDCP results are likely to be more successful. If the reviewer of these comments disagrees with this observation, he or she should provide specific replies on how these proposed efforts will be different from historical or present programs and why a different outcome can be expected.

12. CM12, Methylmercury Management, 3.4-257 – 3.4-264.

The section on Methylmercury Management was completely rewritten following the November 2010 preliminary administrative draft, because the 2010 draft lacked a lacked a clear statement of the problem and specific actions that would help to alleviate it. Those items remain lacking in substance in the current draft. The section leaves out extensive past and present work of the USGS and universities on methylmercury in the Delta and in upstream watershed habitats and ongoing source control programs. The risks from methylmercury in tidal wetlands by ROA are not assessed in the HCP. Instead CM12, as in other CMs with high uncertainty, only offers adaptive management and monitoring to account for the complexities of the system "to ensure that measures implemented at the project scale through CM12 do not conflict with goals for restoration site ecological function." (P. 3.4-264).

13. CM13, Invasive Aquatic Vegetation Control, 3.4-266 – 3.4-284.

The measure is focused on ongoing and emerging risks posed by invasive aquatic vegetation throughout the Plan Area and builds heavily on the existing state program, managed by the California Department of Boating and Waterways, to continue aquatic vegetation control using chemical methods. Despite the recognized "major concern with the use of herbicides over large areas and the potential for toxic effects" (p. 3.4-273), the program focuses on this costly and ecologically degrading process instead of the root problem. The root of IAV problems are species-and-location specific but have an over-riding theme of disturbed physical habitats and lack of flow.

The huge areas of the West and Central Delta infested with Egeria including Franks Tract, Big Break, and West Sherman are large breached formerly-reclaimed islands that lack circulation and turbidity that normally limit such rooted invasive plants. All the shallow margins of these areas are infested (see Figures 3.4-27, 28) and their adjoining vast pelagic habitats suffer terribly. Rooted invasives like Egeria collect suspended plankton and sediment thus reducing turbidity, and compete for nutrients with pelagic phytoplankton.

The root cause of the predominance of invasive vegetation in these critical areas is lack of primary plankton productivity in the pelagic foodweb; this in turn is caused by exports and high inflows of reservoir water to meet export demand, in combination with the unnatural physical state of deep breached former leveed agricultural islands. Another example of a disturbed habitat is Seventeen Mile Slough (connecting to the San Joaquin River and Three Mile Slough in the Central Delta). It is infested with water hyacinth because its circulation was cut off by a road-crossing blockage at its east end. Boating and Waterway treatments result in seventeen miles of channel clogged with dead water hyacinth (and dead habitat). The appropriate treatment is restoration of tidal circulation by removing the barrier at the east end of the slough and the removal of dead hyacinth. Control of extensive IAV infestations of backwater habitat also requires a reduction in water depth so that native tules can recover.

14. CM14, Stockton Ship Channel Dissolved Oxygen Levels, 3.4-285 – 3.4-292.

Comments regarding CM-14 can be found in CSPA's Comment Letter No. 2: Bay Delta Conservation Plan and Associated EIR/EIS Related to Water Quality and in the technical comments prepared by Dr. G. Fred Lee that are attached to those comments.

15. CM15, Localized Reduction of Predatory Fishes, 3.4-293 – 3.4-312.

Like many of the CMs, CM15 Localized Reduction of Predatory Fishes was completely rewritten following the November 2010 preliminary administrative draft. The current version of this measure claims to have been developed with extensive input from fish agency staff and claims to be focused on research and adaptive management to better understand the role of fish predation as a driver of covered fish species distribution, behavior, survival/abundance, and population status in the Plan Area.

Despite the staff effort to improve this measure, BDCP again proposes to rely on research and monitoring to address this long-standing problem brought about by the associated habitat effects of exports and the high Delta inflows of reservoir water to meet export demand. The real problem is that the state and federal exports have created habitat conditions that favor non-native predators over native species. The Delta is, in many respects, like an "Arkansas lake" full of "Arkansas" predator fish; such as largemouth bass, bluegill, crappie, and channel catfish.

The only control of this problem is to restore and replicate the natural Delta habitats under which native species evolved over thousands years and to remove, alter, or isolate habitats that favor non-native predators. No measure of predator removal will resolve this problem.

The measure proposes a limited suite of initial implementation actions with substantial investments in research prior to developing a full field implementation of the measure. In reality, Delta scientists already know why these species occur and how to control them. Predator removal at "hotspots" has been on-going for decades. However, fishermen and scientists have noted the futility of this approach as a predator removal action.

16. CM-16, Nonphysical Fish Barriers, 3.4-313 – 3.4-317.

The Nonphysical Fish Barriers program is still in the experimental stage after several decades of research, monitoring, and adaptive management. It remains focused on increasing the survival of juvenile covered fishes (primarily salmonids) by discouraging them from entering channels known to result in higher mortality than other viable migration routes. The efforts have focused on prime cross-Delta channels that carry juvenile salmon to South Delta export fish salvage facilities.

Such efforts recognize the serious nature of such non-natural migratory behavior, but ignore the real cause of the problem and past/present lack of treatment. First, exports and associated altered Delta hydrology cause the problem. Ineffective salvage facilities in the South Delta fail to treat the problem. Closure of barriers such as the Delta Cross Channel and Head of Old River Barrier simple make the problem worse. Research has shown such barriers (e.g., bubble "screens") are ineffective and may even attract predators. Even if they were effective, there are presently no accurate methods to quantify improved survival.

17. CM-17, Illegal Harvest Reduction, 3.4-318 – 3.4-321.

CM17 Illegal Harvest Reduction is focused on increasing the enforcement of fishing regulations in the Delta and bays with the goal of reducing illegal harvest of covered salmonids and sturgeon (and non-native predatory sportfish). The CM focuses on the lack of game wardens to "police" the problem. Such harvest is "illegal" under state laws and adequate enforcement should be the responsibility of the State not the BDCP. Furthermore the BDCP should not take credit for any effort for the State policing its problem. There is nothing in the EIR/EIS to indicate that this CM will be different than present programs or be more effective in addressing the issue.

18. CM-18, Conservation Hatcheries, 3.4-322 – 3.4-325.

CM18 Conservation Hatcheries was completely rewritten following the November 2010 preliminary administrative draft. The current version of this measure was developed with extensive input from USFWS staff familiar with the existing and proposed Delta and longfin smelt conservation hatchery programs. The CM is focused on providing refugial hatchery populations and fish suitable for use in research actions. The Delta smelt population is noted as continuing to decline and at high risk of extinction in its present population state, and thus would seem to benefit from a conservation hatchery funded by BDCP. This whole conservation hatchery seems to come from a sense of desperation, yet the BDCP offers no real actions that would improve the plight of the wild Delta smelt population or its critical habitats.

The BDCP admits entrainment and salvage losses would not decline, and that the habitat improvements proposed would provide minimal if any benefit to the smelt population. The BDCP fails to focus on specific improvements to crucial LSZ habitat area and the proposed new North Delta diversion is likely to move it further upstream into more unsuitable areas. What is the point of stocking hatchery smelt if BDCP provides less favorable habitat conditions for them.

The history of trying to maintain or restore salmonid populations with hatcheries is fraught with problems that exemplify problems likely to confront a similar approach to smelt or other species. Stocking smelt not accustomed to natural habitat and predators may cause more predators to seek out wild smelt. Wild smelt may inbreed with inferior hatchery smelt. Key genetic information could be altered or even lost in the wild population from breeding with hatchery smelt. Collecting wild smelt for the conservation hatchery has its own effects. Simply breeding the captive population could have serious consequence to the genetic state of the captive stock that could be a threat to the wild population.

19. CM-19, Urban Stormwater Treatment, 3.4-326 – 3.4-332.

Nearly the entire Delta aquatic habitat array is surrounded by agricultural and urban basins protected by levees. All of these basins route storm and/or agricultural return water back to Delta waters via hundreds of large and small pumping plants. Damage to the water quality of Delta habitats from this process is immense. The Cache Slough, Yolo Bypass, and Ship Channel habitats of the Cache Slough ROA are especially influenced by such blatant water pollution. An argument could be made that some pollution is good and contributes to productivity and high turbidity so much welcomed in the Delta pelagic habitats, but too much pollution is pollution. Many of these “stormwater” inputs are “allowed” under state waiver programs for small stormwater and agricultural systems, and violations of Basin Standards occur. High water temperature, low dissolved oxygen, and excessive salts and chemicals degrade many important rearing habitats including nearly 40 miles of the Tule Canal in the Yolo Bypass and 20 miles of the Ship Channel, areas heavily used by smelt for spawning and early rearing. Warning signs not to eat the fish are found throughout these areas. Heavy spring inputs of such pollution threaten the survival of salmon, smelt, and other Delta native fishes. Water quality protection and enhancement should be an important part of the BDCP habitat restoration program.

21. CM-21, Non-project Diversions, 3.4-339 – 3.4-344.

In fall 2011, DWR directed that the BDCP include screening of non-project water diversions as a conservation measure. There are literally thousands of such diversions in the Delta, with many in prime rearing habitats of Delta smelt. The largest would include Delta power plants owned by Mirant and built by PG&E located at Antioch and Pittsburg right in the heart of the smelt distribution range. (Note: the BDCP attempts to include these plants in the BDCP HCP, despite the projects having their own approved HCP.)

Though technically screened, the screens on these fossil fuel burning plants' cooling water intakes have a mesh too large to keep out larval smelt. Larger smelt are at great risk to screen impingement mortality if caught by inflows. "Remediation of these non-project diversions could eliminate or reduce this entrainment or impingement, and improve Delta ecosystem health by reducing the diversion of plankton and other nutritional resources, thereby benefiting all covered fishes" (p.

3.4-339). (Note: unlike project diversions these power plant diversions are not consumptive and pass water, albeit too warm for smelt, back to the Delta.)

Thousands of smaller agricultural and duck club intakes are unscreened in Suisun Marsh, Delta, and Yolo Bypass. Total Delta unscreened diversion volume likely equals several thousand cfs and potentially causes entrainment and impingement losses. While the CM21 focuses on screening remediation at diversion intakes it includes, "[e]liminating those non-project diversions with the greatest risk of entrainment to delta smelt." This would involve extremely costly land and/or water purchases/leases and involve the loss of high-valued, productive agricultural lands. Such an approach ignores the "…diversions with the greatest risk of entrainment to delta smelt:" the state and federal project pumps.

22. CM-22. Avoidance and Minimization Measures, 3.4-345 – 3.4-353.

CM22 Avoidance and Minimization Measures was not previously identified as a potential conservation measure, but was designated to recognize that there are many avoidance and minimization measures to reduce the risk of incidental take that must be implemented in the course of implementing conservation actions, including construction of water facilities and construction of natural community restoration sites. Of special note is the inclusion of the effects of water facilities (tunnel intakes) and Adaptive Management and Monitoring in this conservation measure. Within the BDCP process these two subjects are far too important to be buried in CM22. These are fundamental elements of the BDCP process that should be assessed and described in detail in their own stand alone sections of the BDCP.

The BDCP conservation measures are essentially the proposed mitigation for the tunnels, continued operation of South Delta exports, and their associated effects on Bay-Delta hydrology. There is little mention in the BDCP plan or EIR/EIS of Avoidance and Minimization Measures for the proposed North Delta tunnel intakes or for the continued operation of South Delta intakes, or for their effects on Bay-Delta hydrology under operating criteria limits of D-1641 water quality standards or present biological opinions. One of the most critical topics that must be addressed is how the two diversions would avoid and minimize effects on Delta smelt in dry and critical years.

Concluding Observations

The Public Policy Institute of California published a June 2012 report titled, *Where the Wild Things Aren't, Making the Delta a Better Place for Native Species.* The report[3] promotes a "*Reconciled Delta - a coherent, robust, and dynamic portfolio of habitats and flows that support desired ecosystem functions and conditions.*"

Despite a relatively negative prognosis for the future of the Delta, these authors state,

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[3] http://www.ppic.org/main/publication.asp?i=1053

> “*physical habitats and flows can be managed, where possible, to provide conditions that native estuarine species need at different stages in their lives…. In our vision for a reconciled Delta ecosystem, habitats in different parts of the Delta would be specialized to foster improved conditions for native fishes. All forms of habitat cannot be at all locations, so we propose a strategy in which different habitat types are available and connected to support each desirable species at the appropriate season, taking advantage of existing ecological differences among different regions of the Delta. Area specialization can provide the ecosystem diversity and variability that native fishes (and other organisms) need, while supporting continued human uses of Delta land and waters.*”

These statements portray the basic problem with the BDCP: it lacks specifics as to habitats, flows, and timing to meet the needs of the target native fishes in the Delta. Specifically BDCP needs to identify the critical areas in the Delta for anadromous and pelagic species and then analyze and discuss the problems with these habitat areas. Only then, can it develop and propose specific, effective and implementable measures to improve habitats and fish populations.

The complete lack of discussion of pelagic habitat and the LSZ of the Delta estuary is an illustrative example of what is missing from BDCP. It is as if BDCP forgot the purpose of habitat conservation plans and why its proponents are proposing one. The purpose of HCPs should be to increase the likelihood that listed species will survive recovery, consistent with the purposes of state and federal endangered species acts.

If BDCP proposes to continue massive water supply exports from the Delta, it must propose meaningful measures to replace the millions of acre-feet of pelagic habitat lost each year to the export pumps and prevent native species that depend on that habitat from going extinct. CM1 fails to provide the enhanced outflow that fish agencies, regulators and independent scientists have observed is critical to the restoration of the estuary. Instead BDCP offers less outflow in order to enhance water supply benefits.

If we have learned one thing, over the past several decades in the Bay-Delta, it is that regime shifts and population crashes occur in drier years. Yet we continue to relax standards in dry years and focus protection in wetter years. The smelt population has yet to recover from 1981. Striped bass have yet to recover from 1987-1992. We killed modest smelt recoveries in 2001-2002, 2007-2009, and 2012-2014. BDCP will increase problems in dry years because the plan retains large south Delta exports during these years. A start toward recovery of Delta smelt would be a realistic plan to save what little habitat occurs in dry years when the LSZ pelagic habitat lies within the west and central Delta. That measure should be addressed in CM1 and not reside in conceptual and uncertain programmatic measures to be implemented sometime in the future. Determining how the system should work after the infrastructure is constructed and operating is a recipe for further disaster.

BDCP highlights the importance of Cache Slough ROA to target species especially delta smelt. It fails to mention the importance of tidal freshwater inputs from the areas major freshwater sources: Sutter and Steamboat sloughs. It fails to mention key stressors like warm water, agricultural diversions and waste discharges, North Bay Aqueduct exports, and lack of dry year flows (importance of Fremont Weir notch), etc. Likewise, it fails to discuss key stressors in the Sacramento Ship Channel, such as, propeller entrainment from cargo ships and how the channel gets its freshwater inflow. The gates at the upper entry to the Sacramento Ship Channel are rusted shut. Consequently, a high percentage of freshwater inflow comes from West Sacramento’s storm-sewer system and local agricultural drainage.

BDCP fails to recognize the importance of outflow in maintaining location, productivity, and water quality of the LSZ, especially through the summer. It retains the illusion, expressed in the USFWS biological opinions that smelt are not in the Delta during summer because they, X2 and the LSZ are in Suisun Bay. The fact is that, under modern hydrodynamic conditions in the Delta, the LSZ and X2 are in the Delta most summers, especially in drier years.

BDCP equally fails to realistically discuss Suisun Marsh and its main channel, Montezuma Slough. Little discussion is provided regarding the role, or potential use, of the Salinity Control Structure at the upper end of Montezuma Slough, how important maintaining freshwater inflow and low salinity is to the ecology of the slough and marsh, or how important this area is, or could be, to the production of nearly all the native Bay-Delta fish. Lack of Delta outflow in spring and summer of drier years results in the loss of this important nursery and the production of many of its native fishes each year. This critical habitat loss, following expansion of Delta exports in the 1970's, was a major factor in the decline of many native and non-native Bay-Delta fish. Coupled with the massive degradation of Delta pelagic habitats, there is little fish production capacity left in the Bay-Delta’s open waters.

BDCP not only fails to address these fundamental problems, it actually proposes to exacerbate these problems with additional outflow reductions, introduction of a massive new diversion on the lower Sacramento River, higher exports, and further degradation of the LSZ pelagic habitats.

In the final analysis, BDCP is not a program intended to restore habitat and fisheries: it is simply a project to maximize the export of water from the Delta. More insidiously, it proposes to do so by diverting 2.5 MAF of freshwater inflow via tunnels under a Delta that is already grievously suffering from a lack of freshwater flow. The other conservation measures are simply window dressing: conceptual in nature, lacking in specific details, analyzed at a programmatic level, facing uncertain public funding, and highly unlikely to achieve the unrealistically predicted results. BDCP is not restoration; it is a death sentence for an estuary.

The assumptions and conclusions that buttress the BDCP and EIR/EIS conservation strategy and goals are egregiously flawed and technically invalid. Consequently, the analysis of impacts regarding CM1-22 and likelihood of success of the various conservation mitigation measures are deficient and fail to meet minimum CEQA or NEPA standards for environmental review. BDCP must be returned to the drafting table and a new EIR/EIS should be circulated for public review and comment.

Thank you for considering these comments. If you have questions or require clarification, please don’t hesitate to contact us.

Sincerely,

Bill Jennings

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Attachment: Overview of Delta Habitat Restoration

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28 July 2014

Mr. Ryan Wulff
National Marine Fisheries Service
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Sacramento, CA 95814
BDCP.Comments@noaa.gov

VIA: Electronic Submission
Hardcopy if Requested

RE: Comment Letter No. 2: Bay Delta Conservation Plan and Associated EIR/EIS Related to Water Quality

Dear Mr. Wulff,

The California Sportfishing Protection Alliance (CSPA) has reviewed the proposed Bay Delta Conservation Plan and associated Environmental Impact Report/Environmental Impact Statement (hereinafter, BDCP or EIR/EIS) and submits the following comments related to water quality. Our comments include the attached review from Dr. G. Fred Lee and Dr. Anne Jones-Lee and we request that both documents be considered and responded to as a single submittal.

CSPA worked closely with the Environmental Water Caucus (EWC) in developing their comments and incorporates by reference into these comments both submittals by the EWC on all issues related to BDCP. We also incorporate by reference the submittal by Michael Jackson on behalf of CSPA, California Water Impact Network and AquAlliance, as well as the individual comments submitted by AquAlliance. We further incorporate by reference the submittals by the County of San Joaquin, South Delta Water Agency, Central Delta Water Agency, Restore the Delta, Earth Law Center and Friends of the River.

CSPA asked Dr. Lee and Dr. Jones-Lee to review Chapter 8 and Chapter 25 of the EIR/EIS and evaluate whether the approach in analyzing potential impacts to water quality and public health was technically valid and reliable. Their assessment of Chapter 8 is that,

> *"The approach used does not adequately or reliably consider the range of water quality impacts caused by the wide variety of potential pollutants present in the various Delta channels, that can be expected to result from the removal of large amounts of high-quality Sacramento River water from the Delta by this project."* and *"As it stands now Chapter 8 of this EIR/EIS does not reliably inform the public or decision-makers about the magnitude of the errors in estimates and conclusions inherent in the BDCP analysis of the impact of the diversions on Delta water quality/beneficial uses."*

Drs. Lee and Jones-Lee's assessment of the technical validity of Chapter 25 is that the,

> *"…approach is not technically valid for identifying all the constituents that need to be considered in evaluating potential water quality and public health impacts of the proposed BDCP."*

Table 31-1, page 31-9, Summary of Significant and Unavoidable Adverse Impacts, identifies six impacts to surface water quality. Three (concentrations of bromide, chloride and electrical conductivity) result from facilities operations and maintenance (CM1) and three (concentrations of mercury, organic carbon and pesticides) result from implementation of CM2-CM22. Perhaps, nothing more graphically illustrates the fundamental inadequacy of the EIR/EIS than the fact that it only identifies three water quality adverse impacts resulting from the diversion of another 2.5 million acre feet of water from an estuary already grievously suffering from lack of flow.

Our specific concerns are enumerated below followed by our comments.

1. A Word of Caution

We offer a word of caution. The Delta is an incredibly complex estuarine ecosystem and only in our hubris do we believe we understand the intricacies of its hydrological, chemical and biological tapestry. Virtually every previous environmental document prepared for hydro-modification projects in this estuary have promised benign or beneficial results. All exacerbated existing conditions. Almost every significant physical change of the environment by humankind has been accompanied by unintended consequences. Adaptive management must be an integral component of any Delta Plan. But, adaptive management is difficult to implement. As the National Research Council put it:[1]

> *"Numerous attempts have been made to develop and implement adaptive management strategies in environmental management, but many of them have not been successful, for a variety of reasons, including lack of resources; unwillingness of decision makers to admit to and embrace uncertainty; institutional, legal, and political preferences for known and predictable outcomes; the inherent uncertainty and variability of natural systems; the high cost of implementation; and the lack of clear mechanisms for incorporating scientific findings into decision making."*

Adaptive management has a long and checkered history in this estuary. Taken together, the suite of water quality control plans and water rights decisions by the State Water Resources Control Board (SWRCB or State Water Board) from D-990 (1961) through D-1641 (2000) to the adoption of the present Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (2006) constitutes adaptive management. The array of biological opinions issued over the years by the U.S. Fish and Wildlife Service and National Marine Fisheries Service comprises adaptive management. CalFed was an elaborate structured water planning and adaptive management program, as is the Long-Term Operational Criteria and Plan (OCAP) for coordination of the State Water Project and Central Valley Project, with its Water Operations Management Team (WOMT) and various technical working groups.

All of the reasons identified by the National Research Council, as to why adaptive management frequently fails, presently exist in this estuary. Managers and decision makers have routinely rejected the "adaptive" recommendations made by scientists, biologists and technical review teams. Resource and regulatory agencies have failed to adopt and implement recommended criteria and failed to enforce existing criteria. Financial resources have been lacking. Adaptive management has not only failed to reverse the downward spiral of native species in the estuary, it has chaperoned them to the brink of extinction. For adaptive management to play a meaningful role, scientists must have the authority to "adapt."

We can find nothing in the thousands of pages of BDCP's plan or EIR/EIS that provides any evidence that adaptive management is likely to succeed. Adaptive management remains subject to political pressure and the approval of the state and federal contractors. If the reviewer of these

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[1] National Research Council, *A Review of the Use of Science and Adaptive Management in California's Draft Bay Delta Conservation Plan*, 2011, p. 6.

comments has a different opinion, please provide some support for the view that “adaptive management” will be different this time.

Over mere decades, construction and operation of the Central Valley and State Water Projects have deprived the Delta estuary of half its flow; turned the natural hydrograph on its head, reduced temporal and spatial variability; eliminated crucial habitat, complexity and diversity and deprived the estuary of dilution necessary to assimilate increased pollutant mass loading. It is not surprising that an ecosystem that developed and prospered under a state of nature has been brought to the brink of destruction. No estuarine ecosystem in the world has survived this level of abuse. If the reviewer can identify an estuary somewhere in the world that is suffering from lack of freshwater flow and that has been restored by depriving it of additional millions of acre-feet of flow, please provide the information to us.

Water quality and quantity are flip sides of the same coin; changes in flow change assimilative capacity, residence time and the fate and transport of contaminants. Hydrologic changes modify constituent concentration and bioavailability, which in turn can adversely impact the aquatic ecosystem and other beneficial uses.

Water from the Sacramento River is significantly less polluted than water flowing into the estuary from other tributaries, especially the San Joaquin River. Sacramento River water drawn across the Delta to the export pumps is a major reason water quality in the South Delta is better than it would otherwise be. Diversion of approximately 2.5 million acre feet (MAF) of this relatively good quality water around the Delta will increase the concentration of existing constituents in the surface water remaining in the Delta. It will also increase the residence time of water in the Delta, thereby enhancing the opportunity for bioaccumulation and oxygen depletion to occur. This is exacerbated in tidal environments where pollutants tend to move back and forth with the tides. The EIR/EIS and Delta Plan fail to contain a technically defensible analysis and discussion of the likelihood and extent of degradation and adverse impacts to Delta water quality caused by alternative conveyance or increased exports.

Previous efforts to evaluate potential water quality impacts from proposed projects to modify the hydrology of the Delta have either ignored water quality, with the exception of salt, or relied upon models that track “particles” to evaluate water quality. However, the majority of pollutants identified as impairing the estuary are non-conservative dissolved forms of pesticides, mercury, nutrients or oxygen demand constituents. Conservative constituents like salt are unacceptable surrogates for the universe of chemical constituents and pathogens degrading and impairing Delta waters.

CalSim II and various particle-tracking models, like DSM2, are unable to model potential impacts to water quality from non-conservative constituents. Different constituents respond differently to changes in flow and residence time. Consequently, any credible environmental review should evaluate the impacts of potential hydrologic modifications on a pollutant-by-pollutant basis. Unfortunately, BDCP fails to avail itself of the many water quality models that are routinely employed in NPDES permitting and expressly designed to address the fate and transport of chemical constituents in the environment.

The pollutants identified as causing impairments on the 303(d) list are only the tip of the iceberg. There are water quality impairments in the Delta attributable to total organic carbon, nutrients and other contaminants for which there are no federal or state water quality criteria. In addition to a lack of promulgated water quality criteria for many common water pollutants, there are situations in which the current water quality criteria/standards are well recognized as not being protective of aquatic life resources. For example, the water quality criterion for selenium in the SJR and Delta is not protective of some aquatic life.[2]

Furthermore, existing water criteria fails to address many issues that must be considered in considering impacts on aquatic life. For example:

- Existing criteria fails to consider additive and synergistic properties of regulated chemicals that occur in concentration below criteria. For example, Delta water frequently contains a cocktail of as many as 15 pesticides, many of which interact additively or synergistically.
- Adverse impacts to sensitive species, such as zooplankton, were not included in the development of many criteria.
- There is limited information on chronic exposure to sublethal impacts of chemicals and mixtures of chemicals. Numerous studies in the scientific literature demonstrate adverse effects of chemical exposure well below water quality criterion.
- Water quality criterion fail to address the chronic effects of multiple stressors acting on an already weakened aquatic ecosystem.
- Chemical degradants (or products of chemical breakdown in the environment) are little understood but frequently are highly toxic.
- Water quality criteria have been developed for only a small subset of the chemicals found in these waters. Of the approximately 100,000 chemicals registered for use in the United States, only about 200 are regulated with respect to water quality. The Priority Pollutant List is an artifact of a legal settlement several decades ago, has never been peer-reviewed and is an inadequate surrogate for the maelstrom of chemicals found in waterways today. These include pharmaceuticals and personal care products, industrial chemicals and other potentially hazardous constituents that have been identified as carcinogens, reproductive toxins, endocrine disruptors and immune suppressors, etc.
- Criteria are frequently insufficiently protective for pollutants that bioconcentrate and/or bioaccumulate in tissue.
- Many drinking water criteria are economically based and not health risk based.

As noted above, relocation of export facilities to the Sacramento River will increase residence time in the Delta. This increased residence time may encourage the growth of toxic blue-green algae, which has become a serious problem in recent years. Bioaccumulating constituents like selenium and methyl-mercury or pollutants like DDT and dioxin will have more opportunity to work their way up the food chain. Increases in the concentration of mercury in fish tissue would

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[2] US EPA, as part of endangered species consultations for the California Toxics Rule, agreed to have the US Geological Survey model the fate and transport of selenium in the Bay-Delta Estuary and the information would serve as the basis for revised water quality criteria. USGS completed the study in December 2010 and it indicated that the Bay-Delta standards should be lowered from 5 ug/l to 1 ug/l or less, depending on the residence time of selenium. The study can be found at: www.epa.gov/region9/water/ctr

further threaten the health of the Delta's large subsistence fishing community. Longer residence times will increase the timeframe for oxygen demanding constituents to reduce oxygen levels in channels already identified as impaired because of low dissolved oxygen.

An alternative conveyance facility and reduction in Sacramento inflow will impact dissolved oxygen levels in the Mokelumne River and Stockton Deep-Water Ship Channel. Presently, flow from the Sacramento is diverted through the cross-channel into the Mokelumne and San Joaquin River as it is drawn to the south Delta pumping facilities. The presence of better quality Sacramento River water in the central Delta and the reverse flows in the San Joaquin at Stockton served to somewhat ameliorate oxygen depletion in the reach below Stockton.

Presently, some part of the pollutant load in the San Joaquin River is drawn to the pumps via Old River, Middle River, Turner Cut and Columbia Cut and exported or "siphoned" south. Any reduction of this "siphon" mechanism would also affect nutrients and numerous other pollutants in the eastern and southeastern Delta. It would likely increase the spatial distribution of water quality impacts into the Central Delta. For example, it could increase nutrient loading to the ship channel exacerbating dissolved oxygen problems. Selenium concentrations might increase in the Delta to levels comparable to those found in wildlife in Suisun Bay. EC impairment might expand into the eastern Delta.

Alternative conveyance and reduction of dilution and outflow will significantly increase the concentration of salt in channels further impacting the yield of Delta agriculture. It will also reduce salinity variability and encourage the spread of certain undesirable invasive species. BDCP has been referred to as a habitat expansion plan for the overbite clam *Potamocorbula amurensis.*

To summarize, the Delta and its tributary streams are formally identified as impaired by a broad suite of pollutants. Water quality criteria have been developed for only a very small subset of the chemicals found in these waters. These criteria fail to adequately consider additive/synergistic, bioaccumulative and chronic/sublethal effects or multiple stressors acting on an already weakened aquatic ecosystem. Increased diversion or routing of good quality dilution flows around the estuary will result in increased concentration and residence time of pollutants. Increased residence time exacerbates the effects of toxic and bioaccumulative pollutants. Reduced diversion and increased Delta flow enhances flushing of pollutants and decreases pollutant concentration.

The BDCP and its EIR/EIS fail to comprehensively analyze and address potential impacts to fish, wildlife and human health from reduced water quality caused by loss of dilution, increased residence time and modified channel hydrology. They also fail to include a comprehensive antidegradation analysis required by the federal Clean Water Act and California's Porter-Cologne Water Quality Control Act.

2. BDCP's Analysis of Water Quality is Technically Invalid and Inconsistent with Prevailing Standards.

"All Models are Wrong, Some are Useful." Statistician E. P. Box

The approach to identifying impacts to water quality is fundamentally and technically flawed. Properly calibrated and verified, comparative models are useful in distinguishing relative differences between alternatives. However, comparative models like CalSim II or DSM2 are not designed and are unable to make credible short-term predictions. There are a number of predictive water quality models that have been designed, peer-reviewed and approved for assessing water quality – but these readily available models were not used.

The BDCP misuses tiered comparative models in an attempt to evaluate potential exceedances of one-hour and four-day water quality criteria that are based upon a not-to-be-exceeded more than once-in-three years standard. More frequent occurrences could, in and of themselves, lead to 303(d) listings of impairment that would be significant impacts. This misuse of modeling appears to be an ill-disguised attempt to minimize and deflect attention from the obvious impacts of diverting 2.5 MAF of freshwater around a severely polluted Delta that is already suffering from a chronic lack of flow. As such, it seriously understates the number and magnitude of adverse impacts.

Models are complex simulations that, at their best, only represent an idealization of actual field conditions. Models can be a black box with a “trust us” outcome. They must be used with extreme caution to ensure that the underlying model assumptions hold for the site-specific situations being modeled. Subtle changes in coefficients, assumptions or input data can dramatically alter output. It is crucial that models be properly calibrated and verified. The design parameters, assumptions, input data, calibration and validation must be transparent in order to be able to meaningfully evaluate the ability to accurately project values.

A critical problem arises when decision makers attribute more precision to modeling results than is warranted and where a model’s output is misused to make definitive comparisons and predictions. While models can be employed to inform analysis, they cannot provide near-certain conclusions that significant environmental effects will or will not occur or will or will not be mitigated, especially where common sense and existing knowledge indicate otherwise.

The EIR/EIS, Table 4-1. Overview of BDCP EIR/EIS Modeling Tools, shows that several models were used to simulate water quality projections for the various project alternatives:

- *Artificial Neural Network (ANN) for CALSIM II An ANN has been developed for CALSIM II that attempts to mimic the flow-salinity relationships in the Delta, as simulated in DSM2. The ANN attempts to statistically correlate the salinity results from a particular DSM2 model run to the various peripheral flows (Delta inflows, exports and diversions), gate operations and an indicator of tidal energy.*
- *CALSIM II simulates operations of the SWP, CVP and areas tributary to the Sacramento-San Joaquin Delta. The model, based on inputted priorities and constraints, determines monthly river flows and diversions, Delta flows and exports, reservoir storage, deliveries to project and non-project users, and controls on project operations. CALSIM II results are used to determine water quality, hydrodynamics, and particle tracking in the DSM2 model.*

- *Delta Simulation Model II (DSM2) DSM2 is a one-dimensional mathematical model that simulates hydrodynamics, water quality, and particle tracking throughout the Delta based on flow data generated from CALSIM II outputs. It describes the existing conditions in the Delta as well as performs simulations for the assessment of incremental environmental effects caused by facilities and operations. The model can be used to calculate stages, flows, velocities, mass transport processes for conservative constituents, and transport of individual particles. HYDRO provides the flow input for QUAL and PTM. QUAL simulates one-dimensional fate and transport of conservative water quality constituents given a flow field simulated by HYDRO. PTM simulates pseudo three-dimensional transport of neutrally buoyant particles based on the flow field simulated by HYDRO.*
- *Particle Tracking Model (PTM) PTM simulates fate and transport of conservative and non-conservative water quality constituents throughout the Sacramento-San Joaquin Delta given a flow field simulated by HYDRO. The model uses velocity, flow, and stage output from DSM2-HYDRO. Outputs are used to estimate the effects of hydrodynamic changes on the fate and transport of larval fish, other covered species, and toxics through the Delta, as well as entrainment of larval fish at various locations. It allows assessment of particle fate, transport, and movement rate from numerous starting points to numerous end points. It provides information on movement of planktonic larval fish, such as delta and longfin smelt, in a tidal environment and is used extensively in Central Valley fishery assessments.*
- *DSM2-HYDRO is a one-dimensional hydraulic model used to predict flow rate, stage, and water velocity in the Delta and Suisun Marsh at a 15-minute timestep.*
- *DSM2-QUAL simulates multiple conservative and non-conservative constituents including dissolved oxygen, carbonaceous BOD, phytoplankton, organic nitrogen, ammonia nitrogen, nitrate nitrogen, organic phosphorus, dissolved phosphorus, TDS and temperature. The model is used to predict water temperature, dissolved oxygen, and salinity in the Delta and Suisun Marsh at a 15-minute timestep.*

All of the DSM2 models require data provided by CalSim II.

The Review of the Draft BDCP EIR/EIS and Draft BDCP conducted by the Delta Independent Science Board (15 May 2014) observed,

> *"As noted for other chapters in the DEIR/DEIS, a concise and informative summary of the chapter would be extremely useful to readers and reviewers. This chapter, covering water quality impacts of the different Alternatives, is not very informative because of its reliance on a few modeling approaches, most notably CALSIM and DSM2, without an explanation of the limitations of these models. There is a noted lack of emphasis on validating model outputs with observational data, as well as a lack of any presentation or discussion of the uncertainties associated with the models."* Page B-22.
>
> *As stated above, there is an over-reliance on model outputs, both to describe existing conditions as well as to project the effects of Alternatives on water*

> *quality constituents. There do not seem to be either a) attempts to compare model outputs for existing conditions to existing water quality data, or b) calls for monitoring of future conditions in order to inform adaptive management of Draft BDCP implementation. Because models will always be incorrect, such observational data are obviously required. Moreover, models were run for only certain constituents and not others; this needs to be clarified and the reasons for selective applications of models should be explained.* Page B-23.

3. BDCP's Inappropriate Use of CalSim II.

CalSim II is like Aladdin's Lamp; it grants wishes to whoever rubs it. CalSim II can be manipulated to produce desired results. Even properly operated it is only as accurate as the data and assumptions that are plugged into the model. It has previously been used to project a false certainty that impacts will be minor. For example, it has been used to show that salmonid mortality will increase by a specific percentage and discussion of possible error or of ranges of possible outcomes has been entirely absent. The model cannot possibly produce such certainty. At best it can predict, given a certain set of data and assumptions, a range of possible outcomes, with some outcomes potentially more probable than other, and with all predictions limited by both known and unknown sources of error.

CalSim II is a highly complex simulation model of a complex system that requires significant expertise to run and understand. Consequently, only a few individuals concentrated in the Department of Water Resources, U.S. Bureau of Reclamation and several consulting firms understand the details and capabilities of the model. State Water Resources Control Board (SWRCB) staff cannot run the model. To the extent CalSim II is relied upon, the EIR/EIS must be transparent and clearly explain and justify all assumptions made in model runs. It must explicitly state when findings are based on post processing and when findings are based on direct model results. And results must include error bars to account for uncertainty and margin of safety.

As an optimization model, CalSim II is hardwired to assume perfect supply and perfect demand. The notion of perfect supply is predicated on the erroneous assumption that groundwater can always be obtained to augment upstream supply. However, the state and federal projects have no right to groundwater in the unadjudicated Sacramento River basin. Operating under this assumption risks causing impacts to ecosystems dependent upon groundwater basins in the areas of origin. The notion of perfect demand is also problematic, as it cannot account for the myriad of flow, habitat and water quality requirements mandated by state and federal statutes. Perfect demand assumes water deliveries constrained only by environmental constraints included in the code. In other words, CalSim II never truly measures environmental harm beyond simply projecting how to maximize deliveries without violating the incorporated environmental constraints.

As a monthly time-step model, CalSim II cannot determine weekly, daily or instantaneous effects; i.e., it cannot accurately simulate actual instantaneous or even weekly flows. It follows that CalSim II cannot identify real-time impacts to objectives or requirements. Indeed, DWR admits, "CalSim II modeling should only be used in 'comparative mode,' that is when comparing the results of alternate CalSim II model runs and that 'great caution should be taken when comparing actual data to modeled data.'"[3] Since CalSim II results are employed as boundary conditions by subsequent water quality models, like DSM2, those limitations undermine efforts by subsequent models to accurately evaluate specific exceedances of water quality criteria or impacts to water quality.

CalSim II assumes foresight and compliance by project operators. However, this cannot satisfy CEQA/NEPA's mandates to analyze and disclose the full spectrum of potential environmental impacts caused by a project vis-à-vis a no-project and other alternatives. A report produced by the National Heritage Institute summarizes this flaw by "call[ing] into question the use of CalSim II as a tool for environmental impact assessment, since it is changes in the environment associated with specific projects and the satisfaction of arbitrary constraints which is the critical focus of environmental review."[4]

A formal peer-review of CalSim II was highly critical and detailed numerous inadequacies in the model. Among these was the opinion that CalSim II "has not yet been calibrated or validated for making absolute prediction values."[5]

The Department of Civil Engineering University of California at Davis conducted a comprehensive survey of members of California's technical and policy-oriented water management community regarding the use and development of CalSim II in California. Detailed interviews were conducted with individuals from California's water community, including staff from both DWR and USBR (the agencies that created, own, and manage the model) and individuals affiliated with consulting firms, water districts, environmental groups, and universities.[6]

The results of the survey, which was funded by the CalFed Science Program and peer-reviewed, should serve as a cautionary note to those who make decisions based on CalSim II. The report cites that in interviewing DWR and USBR management and modeling technical staff: "*Many interviewees acknowledge that <u>using CALSIM II in a predictive manner is risky and/or inappropriate</u>, but without any other agency-supported alternative they have no other option.*" The report continues that: "All users agree that CalSim II needs better documentation of the model, data, inputs, and results. CalSim II is data-driven, and so it requires numerous input files, many of which lack documentation," and "There is considerable debate about the current and desirable state of CalSim II's calibration and verification," and "Its representation of the SWP and CVP includes many simplifications that raise concerns regarding the accuracy of results." It

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[3] Answering Brief for Plaintiff-Intervenor-Appellee California Department of Water Resources, Appeal from the United States District Court for the Eastern District of California, No. 1:09-cv-407, Case: 11-15871, 02/10/2012, ID: 8065113, page 15.

[4] Payne, J. and Purkey, D. 2005. An Environmental Review of CalSim-II: Defining "Full Environmental Compliance" and "Environmentally Preferred" Formulations of the CalSim-II Model." Page 14.

[5] Close, A, et al. 2003. A Strategic Review of CALSIM II and its Use for Water Planning, Management, and Operations in Central California, Submitted to the California Bay Delta Authority Science Program, Association of Bay Governments, Oakland, California. 4 December 2003. Page 9.

[6] Ferreira, Ines C., et al. 2005. Musings on a Model: CalSim II in California's Water Community, published in San Francisco Estuary & Watershed Science. March 2005. 13 Pages.

reported, “Many interviewees are concerned that CalSim II’s monthly time step cannot capture hydrologic variability adequately and thus does not compute water exports and export capacity accurately, both of which are significant factors in system operations,” and, “The model’s inability to capture within-month variations sometimes results in overestimates of the volume of water the projects can export from the Sacramento- San Joaquin Bay-Delta and makes it seem easier to meet environmental standards than it is in real operations.” The study concluded by observing, “CalSim II is being used, and will continue to be used, for many other types of analyses for which it may be ill-suited, including in absolute mode.”

More recently, Walter Bourez of MBK Engineers made a presentation on BDCP operations modeling at the 17 January 2014 meeting of the Delta Independent Science Board.[7] The presentation concluded:

- *Incorporation of climate change contains errors and does not incorporate adaptation measures.*
- *BDCP’s “High Outflow Scenario” is not sufficiently defined for analysis.*
- *BDCPs simulated operation of the dual conveyance, coordinating proposed North Delta diversion facilities with existing South Delta diversion facilities, is inconsistent with the project description.*
- *BDCP models do not accurately reflect anticipated changes in CVP and SWP operations with BDCP.*
- *Independent modeling of the BDCP revealed differences in CVP and SWP operations and water deliveries from the analysis disclosed for the Draft EIR/EIS. Total exports would increase about 200 TAF and Delta outflow would decrease approximately 200 TAF while the North Delta intake would divert 680 TAF more and the South Delta intakes would divert 460 TAF less than projected in BDCP modeling.*

A reduction of Delta outflow coupled with an even larger reduction in the inflow of better quality Sacramento River water into the Central Delta would exacerbate water quality problems. This reduction on outflow and increase in exports, plus the failure to accurately model climate change and CVP and SWP operations, undermines DSM2’s assessment of water quality conditions and resulting impacts from operation of BDCP, since DSM2 relies on modeling results generated by CalSim II.

A consortium of water agencies including Contra Costa Water District, East Bay Municipal Utility District, Friant Water Authority, Northern California Water Association, North Delta Water Agency, San Joaquin River Exchange Contractors Water Authority, San Joaquin Tributaries Authority and Tehama Colusa Canal Authority asked MBK Engineers to review the CalSim II modeling studies performed as part of the BDCP. A 29-page report, supported by a 72 page technical appendix, summarized their analysis of the BDCP model. MBK Engineers found that:

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[7] Can be found at, http://deltacouncil.ca.gov/sites/default/files/documents/files/BDCP_Review_ISB_2014_01_17Final_sent.pdf

> *"There are three basic reasons why the BDCP Model cannot be used to determine the effects of the BDCP: 1) the no action alternatives do not depict reasonable operations due to climate change assumptions, 2) operating criteria used in the BDCP Alternative 4 result in unrealistic operations, and 3) updates to CalSim II since the BDCP modeling was performed almost 4 years ago alter model results."* (P. 3)
>
> *"The CalSim II model is the foundational model for analysis of the BDCP, including the effects analysis in the Draft BDCP and the impacts evaluation in the Draft EIR/EIS. Results from CalSim II are used to examine how water supply and reservoir operations are modified by the BDCP, and the results are also used by subsequent models to determine physical and biological effects, such as water quality, water levels, temperature, Delta flows, and fish response. Any errors and inconsistencies identified in the underlying CalSim II model are therefore present in subsequent models and adversely affect the results of later analyses based on those subsequent models."* (P. 10)
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> *"Hydrologic modeling of BDCP alternatives using CalSim II has not been refined enough to understand how BDCP may affect CVP and SWP operations and changes in Delta flow dynamics. Better defined operating criteria for project alternatives is needed along with adequate modeling rules to analyze how BDCP may affect water operations."* (P. 27)

Flow Science Inc., at the request of the Sacramento Regional County Sanitation District, reviewed documents and model results associated with the BDCP environmental review process in order to determine how the proposed BDCP alternatives might impact Sacramento River temperatures at Freeport. In a 23 April 2014 Technical Memorandum, they stated:

> *"As noted above, the corrections to the DSM2 temperature boundary conditions have a substantial effect on the temperatures at Freeport. In additions, the methodology for determining the temperature boundary conditions (for both the original and corrected boundary conditions) is questionable because the same set of temperature boundary conditions are used for all BDCP alternatives. Changes in boundary conditions between scenarios reflect only climate change effects and not different BDCP or upstream reservoir operations. That is, all ELT simulations used the same temperature boundary conditions for all BDCP alternatives, and all the LLT simulations used the same temperature boundary conditions for all BDCP alternatives. Clearly, with this approach the modeling will predict no (or minimal) impacts of the BDCP on the temperature at Freeport, since Freeport is located close to the boundary. However, the various BDCP alternatives are likely to result in substantially different river flows at different times of the year (e.g., whether or not Fall X2 is implemented may cause substantially different reservoir releases and river flows)."* (P. 2)

Flow Science recommended, *"that SRCSD comment the EIR does not contain information - and the modeling data upon the EIR is based are insufficient – to support any conclusions about how*

Sacramento River temperatures at Freeport may change in the future." (P. 7) The same flaws identified by Flow Science would extend to evaluating the potential impacts resulting from various BDCP temperature scenarios on water quality constituents and fisheries.

The Review of the Draft BDCP EIR/EIS and Draft BDCP conducted by the Delta Independent Science Board (15 May 2014) observed,

> *"The major analytical problem is the gap between CALSIM-II modeling of the water-supply system and actual operations. The State Water Project and Central Valley Project account for only a part of the water management decisions and impacts in this vast system. DWR and USBR modeling has improved considerably in recent decades but remains centered on the SWP and CVP. This limited modeling therefore largely ignores or oversimplifies most water management decisions in California, which are those taken by local and regional governments and water users. The limited modeling thus seems inadequate for impact analysis of a system governed largely by local agencies."* Page A-24.

4. BDCP's Inappropriate Use of DSM2

As described in the BDCP EIR/EIS (5A-A34), DSM2 is a one-dimensional hydrodynamics, water quality and particle tracking simulation model used to simulate hydrodynamics, water quality, and particle tracking in the Sacramento-San Joaquin Delta. It is a data-intensive DWR model that runs for a limited period (only 16 years) and has never been peer-reviewed. Several of its modules have only received limited validation and calibration. For example, its particle tracking module has been severely criticized.[8] The EIR/EIS describes its limitations, at 5A-A49-50, as:

> *DSM2 is a 1D model with inherent limitations in simulating hydrodynamic and transport processes in a complex estuarine environment such as the Sacramento – San Joaquin Delta. DSM2 assumes that velocity in a channel can be adequately represented by a single average velocity over the channel cross-section, meaning that variations both across the width of the channel and through the water column are negligible. DSM2 does not have the ability to model short-circuiting of flow through a reach, where a majority of the flow in a cross-section is confined to a small portion of the cross-section. DSM2 does not conserve momentum at the channel junctions and does not model the secondary currents in a channel. DSM2 also does not explicitly account for dispersion due to flow accelerating through channel bends. It cannot model the vertical salinity stratification in the channels.*
>
> *It has inherent limitations in simulating the hydrodynamics related to the open water areas. Since a reservoir surface area is constant in DSM2, it impacts the stage in the reservoir and thereby impacting the flow exchange with the adjoining channel. Due to the inability to change the cross-sectional area of the reservoir*

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[8] Panel Review of the CA Department of Fish and Game's Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta, A2: Discussion of the DSM2 PTM, 2010, P. 17 - 19.

> *inlets with changing water surface elevation, the final entrance and exit coefficients were fine tuned to match a median flow range. This causes errors in the flow exchange at breaches during the extreme spring and neap tides. Using an arbitrary bottom elevation value for the reservoirs representing the proposed marsh areas to get around the wetting-drying limitation of DSM2 may increase the dilution of salinity in the reservoirs. Accurate representation of RMA's tidal marsh areas, bottom elevations, location of breaches, breach widths, cross-sections, and boundary conditions in DSM2 is critical to the agreement of corroboration results.*
>
> *For open water bodies DSM2 assumes uniform and instantaneous mixing over entire open water area. Thus it does not account for the any salinity gradients that may exist within the open water bodies. Significant uncertainty exists in flow and EC input data related to in-Delta agriculture, which leads to uncertainty in the simulated EC values. Caution needs to be exercised when using EC outputs on a sub-monthly scale. Water quality results inside the water bodies representing the tidal marsh areas were not validated specifically and because of the bottom elevation assumptions, preferably do not use it for analysis.*

The Review of the Draft BDCP EIR/EIS and Draft BDCP conducted by the Delta Independent Science Board (15 May 2014) observed,

> *"DSM2 used for salinity-flow analysis is a one-dimensional model having inherent limitations in simulating open water areas, flow in bends and small channel, inlet/outlets and three-dimensional turbulent mixing, particularly with sea level decimeters higher than today's."* Page A-12

In other words, in an exceedingly complex Delta with myriad meandering small channels and constantly changing flows, DSM2 modeling output inadequately accounts for varying velocities and secondary currents, channel junctions and open waters, stratification, fluctuating channel beds, turbulent mixing, surface waves, sediment resuspension and agricultural inputs and diversions. And, as previously discussed, DSM2 is dependent on flawed CalSim II output data regarding flows and boundary conditions.

For example, fluctuating channel beds directly affect water quality. In the renewal of the NPDES permit for Sacramento Regional County Sanitation District's NPDES permit, it was found that the bed of the Sacramento River fluctuates as much as six feet near the outfall diffuser. Modeling revealed that bottom contours had a direct effect on whether constituent plumes from the diffuser exceeded water quality standards. Discharges from the Stockton Wastewater Treatment facility experienced a somewhat different problem. Because of an abrupt turn in the river below the outfall, pollutants tended to concentrate along one bank and had the potential to exceed water quality standards. Consequently, Stockton was unable to qualify for a mixing zone. Another example is the relatively recent sediment buildup blocking flow into the head of Steamboat Slough, which has reduced the depth of the entrance from approximately nineteen feet to ten feet. While not hindering boating navigation, the underwater barrier certainly affects fish migration, flow and potentially water quality. Sediment buildup and scouring in channels is a constant in the Delta. The failure to continually update information on channel bathymetry undermines DSM2's ability to accurately model hydrology and water quality.

While the EIR/EIS discusses the limitations of DSM2, it fails to account for and disclose the uncertainty of model results There are few, if any, error bars attached to predictions and comparisons to indicate to makers and the general public the relative confidence level in the results. The EIR/EIS is deficient without discussion of the degree of uncertainty in results.

Whatever the merits of DSM2 for comparative analysis, it is fundamentally unable to model or identify specific violations of water quality criteria or other impacts to water quality. The EIR/EIS acknowledges that the North Delta diversion facility will increase the percentage of more polluted San Joaquin River water in the Delta. It also acknowledges that BDCP will increase the residence time of water in the East, South, West and North Delta over existing conditions (Table 5C.5.4-14, p. 5C.5.4-84, BDCP). The diversion of two and a half MAF of Sacramento River water will inevitably change the constituent composition and hydrology of the estuary. Changes in hydrology affect the fate and transport of contaminants, which in turn, affect beneficial uses.

As previously discussed, water quality criteria for aquatic life are established on a one-hour or four-day basis not to be exceeded more than once in three years. Exceedances of these criteria cause direct adverse impacts to listed species and other aquatic life. Exceedances of human health criteria can have direct adverse impacts to people. Exceedances of criteria protecting other identified beneficial uses of water will adversely impact those who rely on the beneficial use. For example, multiple exceedances of a pollutant within a waterway would qualify the waterway for listing as an impaired waterbody on the CWA 303(d) list. Such a listing would have enormous financial implications for the municipalities and business discharging wastewater and stormwater into the Delta. NPDES permits and Waste Discharge Permit requirements would become more stringent entailing expensive facility upgrades and enhanced management practices.

The data and models relied upon by BDCP in this EIR/EIS are incapable of evaluating and predicting the potential adverse impacts by the project on water quality. They may confirm common sense: that the removal of 2.5 MAF of freshwater from the Delta will inevitably increase the concentration and residence time of salinity and a number of conservative constituents in the Delta. However, they cannot credibly predict or quantify exceedances of specific water quality criteria for the universe of constituents, especially non-conservative constituents, which exist and interact in the estuary. Consequently, they are unsuitable for analyzing and unable to make the effects determinations described in Chapter 8, Section 8.4.2.3, pp. 8-75 & 8-76. A vast discretionary project with potential to cause great harm that will certainly have major unintended consequences should not proceed until the significant impacts of that project on water quality can be conclusively identified and addressed.

5. BDCP's Inappropriate Use of "Best" Professional Judgment.

Professional judgment is frequently employed but not defined in the EIR/EIS. Chapter 8, Section 8.4.2.1, Screening Analysis and Results, page 8-173, states:

> *This water quality analysis assessed the potential effects of implementing the various alternatives on 182 constituents (or classes of constituents). The initial analysis of water quality effects, referred to as the "screening analysis" in the Methods of Analysis section (above) resulted in the following findings. Of the 182 constituents, 110 were determined to have no potential to be adversely affected by the alternatives to an extent to which adverse environmental effects would be expected. Historical data for these constituents showed no exceedances of water quality objectives/criteria in the major Delta source waters, were not on the State's 303(d) list in the affected environment, were not of concern* ***based on professional judgment*** *or scoping comments, and had no potential for substantial long-term water quality degradation. Consequently, no further analyses were performed for these 110 constituents. Conversely, further analysis was determined to be necessary for 72 constituents. Of these, 15 are addressed further in the Screening Analysis itself in Appendix 8C because they did not warrant alternative-specific analyses, and 1 - temperature - is addressed in Chapter 11, Fish and Aquatic Resources. The remaining 56 constituents are addressed in the Environmental Consequences section, and are contained in the sections noted in Table 8-61.*

Through every step in the screening and evaluative process, professional judgment was used in determining whether a constituent had the potential to exceed thresholds of significance, should be carried forward for further assessment, was a 'constituent of concern,' whether it should be addressed qualitatively or quantitatively and whether the project could result in significant impacts to specific constituents. Of the 182 constituents that were analyzed, detailed assessments were performed on 24 and of those, 8 were assessed quantitatively (modeling, ratios) and 16 were assessed qualitatively (professional judgment).

Unfortunately, the EIR/EIS does not indicate whether professional judgment followed a rigorous step-by-step formal process, if an Ouija board, crystal ball or fortune-teller was involved or if conclusions were simply pulled from someone's arse. It fails to adequately discuss the methodology, science, criteria or analysis used to add, remove or modify constituent inclusion in the screening analysis or to determine the degree of impact significance. There is no discussion of why limited data sets were relied upon or why the more extensive data sets from regulatory programs were ignored. Inadequate data limits professional judgments. There is no discussion justifying the reliance on boundary water quality conditions and the exclusion of the extensive pollutant loading that occurs in the Delta in reaching conclusions. There is no discussion on the use of average or median constituent concentrations or the 95th or average percentile for assessing the potential to violate one-hour or four-day criteria that should not be violated more than once in three years. There is no discussion or attempted quantification regarding the uncertainty of conclusions. Nor is there any discussion of how heavily criticized comparative models, used outside their temporal, spatial and resolution limits, may or may not be sufficient for making explicit determinations regarding the potential effects of BDCP on constituents and impacts to water quality standards caused by a modified hydrology, reduced dilution and increased residence time.

It is the responsibility of those who rely on professional judgment, in the absence of conclusive information, to hold paramount the safety, health and welfare of the public and the environment. Professional judgment must the predicated on ethics and conformance with the respective codes or standards of professional conduct. Professional judgment requires information sufficient to achieve an acceptable degree of accuracy, a working knowledge of the science and criteria, and a degree of synthesis and depth of knowledge necessary to make sound judgment without harm to the environment. An intelligent evaluation of the criteria and a thorough engineering analysis is critical to professional judgment. Professional judgment cannot reside in a black box, but has a responsibility to the public's trust. Professional judgment cannot serve as a substitute for the failure to collect and evaluate adequate data. Professional judgment must disclose a transparent process where explanation of the factors involved, how conclusions were arrived at and the uncertainty of those conclusions is weighed or evaluated. There must be an attempt to quantify uncertainty with error bars or detailed discussion. Whatever professional judgment is, the abject and pervasive failure in the EIR/EIS to acknowledge, quantify and discuss the uncertainty of conclusions is not professional judgment: it is an appalling display of amateurism.

Neither the plan nor EIR/EIS comport with prevailing standards for technical analysis, which is why BDCP's documents are inappropriate, technically invalid and fail to meet the fair disclosure requirements of CEQA and NEPA.

6. Reliance Upon a Truncated and Inadequate Data Set to Screen, Evaluate and Predict Impacts to Water Quality is Technically Indefensible.

Appendix 8C describes the screening analysis. Section 8C.1.1, P. page C-1, Data Sources, states,

> *"This section describes sources for data used in the screening analysis. Water quality data in the Delta has been collected by a myriad of public and private organizations. However, for consistency and due to data availability concerns, the input data for the screening analysis was limited to two data sets that were publically available via the web and managed by a public agency (i.e., data from the DWR Water Data Library and the Bay Delta and Tributaries Project [BDAT])."*

Both data sets are extremely limited. The Bay Delta and Tributaries Project (BDAT) data set is relatively old and is not even presently available on the DWR web site. The DWR data set ignores an enormous quantity of data collected, pursuant to stringent protocols, by other agencies, as evidenced by the extremely few samples of numerous constituents collected. A number of priority pollutants were never sampled or sampled only a few times.

The selection of sites arbitrarily limited the amount and kinds of ambient data that was collected and excluded numerous toxic constituents identified as carcinogens, reproductive toxins, endocrine disruptors and immune suppressors. One, of many, examples is Bis(2-

ethylhexyl)phthalate (DEHP), frequently known as Di(2-ethylhexy)phthalate. Bis(2-ethylhexyl)phthalate is discussed below under its own heading. Regulatory sampling in the Central Valley reveals its presence in both ambient waters and wastewater effluent at concentrations exceeding water quality criteria.

Section 8C.1.1.1, Table SA-1, page 8C-2, identifies the source water locations where data was collected on the upstream Sacramento River, upstream San Joaquin River and Chipps -Mallard – Suisun areas representing the Delta west boundary. It states,

> *"Interior Delta sites were not considered, because modeling performed in support of the Environmental Consequences impact assessments assumed no new sources of water quality constituents and, therefore, water quality concerns are assumed to arise primarily through altered mixing of Delta source waters."*

The assumption that there are "no new sources of water quality constituents" in the Delta illustrates the inadequacies of BDCP modeling or the determination of proponents to only accept facts that support their desired outcome. There are enormous sources of water quality constituents within the Delta. These sources include: municipal wastewater and stormwater discharges from Lodi, Stockton, Manteca, Lathrop, Tracy, Mountain House, Discovery Bay, Brentwood, Iron House Sanitary District, Rio Vista, Isleton and unincorporated areas; industrial and construction stormwater discharges; enormous return flows from irrigated agriculture and dairy operations; discharges from marinas and on-the-water recreational activities; illegal dumping; pesticide drift from aerial spray operations for agriculture and vector control, as well as extensive application of pesticides to control aquatic weeds; and ballast discharges from shipping and spills from bulk loading operations at the ports, among others. Indeed, the permitted waste discharge limits of municipal wastewater treatment plants within the Delta (excluding Sacramento), is over 100 MGD and is almost a third more flow than is flowing in the San Joaquin River at Vernalis, as of this writing.

Failure to consider and analyze the extensive mass loading of an astonishing array of contaminants within the Delta not only renders the screening analysis technically insufficient, it renders all of the subsequent assessments of water quality impacts technically invalid.

Table SA-6, pages 8C-22-27, identifies all constituents (182) measured at the boundary stations, number of times analyzed and detected, and minimum and maximum values reported in the data set.

Because of the extremely limited data set, many of the priority pollutants were not sampled or sampled infrequently. For example, aluminum was not sampled, although the NPDES permit for Sacramento Regional Wastewater Treatment Plant reveals that ambient aluminum in the Sacramento River exceeds the acute water quality criteria for freshwater aquatic life more than tenfold. Cadmium has only one data point on the San Joaquin and 25 (12 dissolved, 13 total) on the Sacramento. The average cadmium concentration on both rivers exceeds the acute and 4-day criteria for aquatic life, adjusted for hardness. The arbitrary selection of screening sampling sites eliminated extensive NPDES and other data sets that would have permitted a more defensible and accurate assessment of potential adverse impacts.

Table SA-11, Step 6 Water quality constituents (totaling 72) for which detailed assessment were performed, page BC-39, identifies which constituents were carried forward for further analysis and which assessments were conducted quantitatively and which were assessed qualitatively. Nine constituents were addressed quantitatively (i.e., modeling) and 63 were assessed qualitatively (i.e., best professional judgment). However, there is virtually no discussion in Appendix 8C or Chapter 8 of what constitutes a quantitative evaluation, the methodology employed, threshold levels and how conclusions were reached. The lack of transparency fails to comply with minimal professional standards for an EIR/EIS for a major water development project.

Chapter 8, Water Quality, Section 8.2.2.1, page 8.27, describes water quality monitoring program and sources of data. Noticeable absent are the vast data sets of the Regional Water Board's NPDES permitting program and Irrigated Lands Program.

Table 8-6, page 8-31, Locations Selected to Represent Existing Water Quality in the Delta, includes only three sites in the interior Delta: San Joaquin River at Buckley Cove, Franks Tract at Russo's Landing and Old River at Rancho del Rio. The data sources were identified as BDAT, again an old data set not currently available on the web. The use of only three sites to represent potential impacts to water quality in an 841 square mile Delta containing 700 miles of meandering waterways is technically indefensible and renders any assessment of impacts to water quality invalid.

Table 8-33, Median Metal Concentrations for Selected Sites, May 1988-September 1993, page 8-105, shows the total and dissolved concentration of the priority pollutants arsenic, cadmium, copper, lead and zinc at San Joaquin River at Buckley Cove, Sacramento River at Green's Landing, Sacramento River above Point Sacramento, San Joaquin River at Antioch Ship Channel, Old River at Rancho Del Rio, Suisun Bay at Bulls Head, Franks Tract and the San Joaquin River at Vernalis. Of these, Buckley Cove, Franks Tract and Old River are within the central Delta. All of the metals are hardness dependent but no hardness data was presented.

Taking the San Joaquin River at Buckley Cove as an example, we found that the lowest ambient hardness in the San Joaquin below the Stockton Wastewater Treatment Plant was 30 mg/l. Buckley Cove is only a few miles downriver from the Stockton Treatment Plant outfall. Table 8-33, shows that the mean ambient concentrations for copper, cadmium and lead (expressed as both dissolved and total recoverable) are 5 ug/l. Adjusting for hardness, per US EPA and SWRCB requirements, the concentrations of all three metals at Buckley Cove are potentially toxic to aquatic life. The hardness adjusted median dissolved or total concentrations of all three metals exceed the acute one-hour and chronic four-day toxicity criteria. As these metal concentrations are median values, the highest recorded concentrations of these metal would potentially be more toxic. The San Joaquin River in the Delta is already listed as impaired for unknown toxicity. Other examples could have been used, as we found relatively low hardness values elsewhere in the Delta; e.g., 36 & 39 mg/l at the Delta pumping plant headworks at Banks.

This issue is discussed more fully in comments on hardness dependent metals below, but it illustrates that the EIR/EIS is deficient in not analyzing the potential adverse impacts caused by the diversion of 2.5 MAF of Sacramento River water and the resulting loss of dilution and increased residence time on water quality and beneficial uses in the eastern Delta. Loss of dilution and increase in residence are recipes for water quality degradation. The EIR/EIS's claims are counterintuitive and without a detailed explanation of how conclusions were arrived at or inclusion of sufficient data to verify conclusions, the EIR/EIS is technically invalid and legally inadequate.

7. The Failure to Evaluate Numerous Toxic Constituents is Unacceptable.

As discussed above, failure to evaluate toxic chemicals because the arbitrarily selected data sets omitted analysis of those chemicals is unacceptable. Bis(2-ethylhexyl)phthalate (DEHP) is an example of a number of chemicals that are known to be highly toxic and for which monitoring data exists. Yet, because these constituents were not included in the very limited data sets used in evaluating impacts for BDCP, there is no analysis of the project's impacts for these constituents.

On 30 December 2009 the US EPA issued a press release announcing an *Action Plan* (a series of actions) on four chemicals raising serious health or environmental concerns, including phthalates. The Action Plan was to address the manufacturing, processing, distribution, and use of these chemicals. One of the phthalates listed is bis(2-ethylhexyl)phthalate, also commonly called di-(2-ethylhexyl)phthalate and abbreviated DEHP. Bis(2-ethylhexyl)phthalate is an organic compound and is produced on a massive scale by many companies. Phthalates were detected in greater than 75% of approximately 2,540 urinary samples collected from participants of the National Health and Nutrition Examination Survey (NHANES). Exposure in the United States to diethyl phthalate, dibutyl phthalate or diisobutylphthalate, benzyl butyl phthalate, and di-(2-ethylhexyl)phthalate is widespread.

Water quality standards for bis(2-ethylhexyl)phthalate were first established in California under the December 1992 National Toxics Rule (NTR), which was amended in 1999. On 18 May 2000, US EPA adopted the California Toxics Rule (CTR). The CTR promulgated new toxics criteria for California and, in addition, incorporated the previously adopted NTR criteria that were applicable in the state. Despite the current regulation under the CTR, US EPA has revised their recommended Ambient Criteria for bis(2-ethylhexyl)phthalate to a significantly lower number. This new lower criteria for bis(2-ethylhexyl)phthalate would result in more wastewater discharges being regulated to keep this plasticizer out of California's waterways.

EPA's existing regulation of bis(2-ethylhexyl)phthalate is based on human consumption of water and fish. EPA has also issued new information regarding the impacts to aquatic life:

> *"Of the 8 phthalates, BBP, DEHP, and DBP elicit the most toxicity to terrestrial organisms, fish, and aquatic invertebrates (EC, 2008a, Staples et al. 1997). Ecotoxicity studies with these phthalates showed adverse effects to aquatic organisms with a broad range of endpoints and at concentrations that coincide with measured environmental concentrations. Toxic effects were observed at*

> *environmentally relevant exposures in the low ng/L to µg/L range (Oehlmann et al. 2008).”*

Sacramento Regional Wastewater Treatment Plant NPDES Permit includes the statement:

> “*The CTR includes a criterion of 1.8 µg/L for bis(2-ethylhexyl)phthalate for the protection of human health for waters from which both water and organisms are consumed… The maximum effluent concentration (MEC) for bis(2-ethylhexyl) phthalate was 8.1 µg/L out of 87 samples while the maximum observed upstream receiving water concentration was 0.58 µg/L out of 55 samples.*”

A CSPA review of phthalates in the Central Valley revealed that 27 wastewater treatment plants had levels of bis(2-ethylhexyl)phthalate in the discharge that presented a reasonable potential to exceed criteria. Receiving water levels in a number of tributaries to the Delta also exceeded criteria, including: Clear Creek (7 ug/l); Yolo Bypass (9 ug/l); Upper Sacramento near Red Bluff (10 ug/l); Deer Creek, tributary to the Yuba River (4 ug/l); Yuba River near Yuba City (10 ug/l); and the San Joaquin River near Turlock (12.3 ug/l) and near Stockton (8.1 ug/l).

Despite the concern by US EPA in issuing an Action Plan for bis(2-ethylhexyl)phthalate, widespread human exposure, the fact that bis(2-ethylhexyl)phthalate has been regulated in California since 1992, sampling is required as a condition of NPDES permits and bis(2-ethylhexyl)phthalate has been detected at levels exceeding criteria in both wastewater discharges and receiving waters that are tributary to the Delta; the EIR/EIS simply concludes that bis(2-ethylhexyl)phthalate is not of concern, is only found in low concentrations and analytical tools have only recently been developed.

The EIR/EIS Chapter 8, page 8-58, states that:

> “*In 2006, CCWD participated in a study to examine the toxicological relevance of EDCs and PPCPs in both raw source and treated water (Contra Costa Water District 2009). Of the 62 compounds analyzed, only five were detected in the treated water: sulfamethoxazole (pharmaceutical), meprobamate (pharmaceutical), atrazine (herbicide—endocrine disruptor), triclosan (pharmaceutical), and dioctyl phthalate (used to make plastics—endocrine disruptor). The study concluded that detection occurred at low concentrations and should not pose any health threats.*” (Emphasis added)

And Appendix 8C, page 15, states that:

> “*Examples of EDCs include natural plant and animal steroid hormones, metals (e.g., arsenic, cadmium, lead, and mercury), dioxins, PAHs, pesticides, pharmaceuticals and personal care products (PPCPs), and PCBs. Sources of anthropogenic EDCs include wastewater treatment plants, private septic systems, urban stormwater runoff, industrial effluents, landfill leachates, discharges from fish hatcheries and dairy facilities, runoff from agricultural fields and livestock enclosures, and land amended with biosolids or manure. Constituents of emerging*

> *concern (CECs) include the following classes of chemicals: perfluoranated compounds (e.g., PFOS, PFOA), polybrominated diphenyl ethers (PBDEs), PPCPs, and phthalates. These chemicals are generally found in such low concentrations in the environment that only recently have analytical tools been developed to detect and quantify these concentrations*." (Emphasis added)

However, the EIR/EIS, in discussing the 2006 Contra Costa Water District Report, failed to consider other significant factors that may have biased the conclusions. Chapter 8, page 8-57, also observes:

> *"In 2001 and 2002, a survey of raw and treated drinking water from four water filtration plants in San Diego County showed the occurrence of several PPCPs including phthalate esters, sunscreens, clofibrate, clofibric acid, ibuprofen, triclosan, and DEET (Loraine and Pettigrove 2006). This is important because on average, roughly a third of the water in San Diego County originates from the Delta via conveyances of the SWP. According to the study, occurrence and concentrations of these compounds were highly seasonally dependent, and reached maximums when the flow of the San Joaquin River was low and the quantity of imported water was high. The maximum concentrations of the PPCPs measured in the raw water were correlated with low-flow conditions in the Delta that feed the SWP."*

For example, 2006 was an extremely wet year in both the Sacramento and San Joaquin river basins, while the preceding year (2005) was above normal in the Sacramento basin and wet in the San Joaquin basin. Had the CCWD study occurred during a drought, results might have been very different. The San Diego County study demonstrates that dry years and reduced dilution are correlated with constituent concentration. The EIR/EIS is deficient for failing to address phthalates and the array of other constituents that were excluded from analysis because of the data set selected.

8. Failure to Adequately Account for Changes in Dilution Undermines Water Quality Impact Analyses.

The EIR/EIS acknowledges that the SWP/CVP water diversions "…reduce the amount of water available for dilution and assimilation of contaminant inputs…" Chapter 8, page 8-14, lines 14-17) Table 8-38, Summary of Methodologies Used for Water Quality Impact Analyses, page 8-14 of Chapter 8, identifies the methodologies and tools employed for impact analyses. CalSim2 served as input to the DSM2 model. DSM2 addressed EC and DOC concentrations and flow fractions. Mass Balance, using flow fractions and constituents addressed the other constituents quantitatively, other than EC and DOC (apparently 6 constituents). Qualitative analysis addressed the remaining parameters (apparently 16 constituents) through a varied approach based on constituent and location but "attempted to estimate concentration changes attributable to the Alternatives."

CalSim II is a heavily criticized large-scale comparative model that runs in 30-day time steps. DSM2 is a heavily criticized, comparative, never-peer-reviewed model that takes CalSim II output and attempts to track particles, representing conservative constituents, through the myriad twisted channels of the Delta. Neither model is sufficient for addressing constituents that are toxic in low micrograms or nanograms with respect to one-hour and four-day criteria that are predicated upon a standard not to be exceeded more than once in three years. Professional judgment, as used in this document, embraces black-box conclusions based on extremely limited data sets collected from few locations and that ignores constituent loading in a heavily polluted estuary. This is not a recipe for making technically valid conclusions regarding available dilution or changes in dilution.

It is an undeniable fact that concentrations of constituents in the Sacramento River are considerably lower than concentrations of equivalent constituents in the San Joaquin River. It is an undeniable fact that removing 2.5 MAF of Sacramento River water decreases dilution and assimilative capacity and increases the residence time for constituents to interact with the environment in the Delta. It is an undeniable fact that many constituents in the Delta exceed applicable water quality criteria and numerous other constituents are extremely close to exceeding criteria. It is an undeniable fact that the Delta is part of a tidal estuary where constituents slosh back and forth with incoming and ebbing tides. It is an undeniable fact that the loss of dilution and increase in residence time in a tidal environment will increase the concentration of constituents. It is an uncontestable fact that this will increase degradation and violations of water quality standards. Yet, through sheer sophistry, magical modeling and black-box conclusions, the EIR/EIS blatantly proclaims that there will be no adverse impacts from the maelstrom of toxic pollutants that currently plague the Delta.

In the previous section on limited data sets, we discussed the San Diego County water filtration plant study that showed that occurrence of PPCP increased during periods when the plants received increased water supplies from the Delta. Chapter 8, page 8-57. It noted that,

> *According to the study, occurrence and concentrations of these compounds were highly seasonally dependent, and reached maximums when the flow of the San Joaquin River was low and the quantity of imported water was high. The maximum concentrations of the PPCPs measured in the raw water were correlated with low-flow conditions in the Delta that feed the SWP."*

Droughts are a normal condition in California. According to DWR, there have been 10 multi-year droughts of large-scale extent in the last 100 years, spanning 40 years or 40% of the time. The increase of an average of 2.5 MAF of water diverted under the Delta will, in effect, create more drought conditions experienced in the Delta regardless of actual weather occurring. It will exacerbate the impacts of drought on water quality. As global warming reduces Delta inflow, the project impacts will be substantially greater because of the tunnels.

The EIR/EIS, Chapter 8, page 8-449, lines 19-31, states in addressing nitrate that,

> *"When dilution is necessary in order for the discharge to be in compliance with the Basin Plans (which incorporate the 10 mg/L-N MCL by reference), not all of the assimilative capacity of the receiving water is granted to the discharger. Thus, limited decreases in flows are not anticipated to result in systemic exceedances of*

> *the MCLs by these POTWs. Furthermore, NPDES permits are renewed on a 5-year basis, and thus, if under changes in flows, dilution was no longer sufficient to maintain nitrate below the MCL in the receiving water, the NPDES permit renewal process would address such cases."*

This statement confirms a basic lack of understanding of the NPDES permitting process in the Central Valley by the EIR/EIS. The Central Valley Regional Board has granted dischargers the entire assimilative capacity of a stream on a number of occasions. For example, the September 2006 NPDES Permit for Linda County Water District Wastewater Treatment Plant (NPDES No. CA0079651) granted the full assimilative capacity of the Feather River for EC to Linda County. Further, the Regional Board frequently issues NPDES permits without requiring an antidegradation analysis that would identify how much authorized but presently unused assimilative capacity has been granted and how much assimilative capacity remains for future allocation. Additionally, the Regional Board never requires watershed wide or basin wide antidegradation analyses. Consequently, there are a number of watersheds where more assimilative capacity has been authorized than remains and other waterways where assimilative capacity is presently exceeded but have not yet been placed on the 303(d) list. The suggestion that lack of assimilative would be addressed in subsequent NPDES renewal processes relies on a regulatory requirement that is not followed or enforced in practice.

9. The Assessment of Hardness Dependent Metals is Wrong and Leads to Significant Errors of Analysis.

The EIR/EIS's analysis of the family of hardness dependent metals is technically wrong. The discussion below is focused on copper but the comments are equally applicable to cadmium, lead, silver and zinc. In fact, even with the extremely limited data set, use of the proper methodology reveals that the San Joaquin River at Vernalis has the potential to exceed both the acute and chronic criteria for copper, cadmium, lead, zinc. The Sacramento River has the potential to exceed both the acute and chronic criteria for copper, cadmium and the chronic criteria for lead. Even using average concentrations and the 5th percentile of hardness reveals potential to exceed some criteria. Silver was not sampled in the data sets provided.

Table 8N.1, Appendix 8N, Trace Metals, page 8N-1, Table 1, Concentration of dissolved copper in primary source waters to Delta, shows the maximum dissolved copper concentrations in the Sacramento River (9.5 ug/l), San Joaquin River, (8.0 ug/l) and San Francisco Bay (2.6 ug/l).

Chapter 8, Water Quality, page 8-170, Table 8-58, Water Quality Criteria and Objectives for Trace Metals (µg/L), presents the dissolved water quality standards for copper as 13 ug/l (acute, 1-hour average) and 9 ug/l (chronic, 4-day average).

Chapter 8, page 8-169, lines17-18, states, "*Criteria were calculated based on each source waters average and 5th percentile hardness.*" The toxicity of hardness dependent metals was based on average (58 mg/l) and the 5th percentile hardness (39 mg/l, Sacramento River, appendix 8N6, table 11) rather than the lowest observed hardness (16 mg/l). Hardness dependent metals exhibit greater toxicity at lower hardness. Ambient criteria for acute values are applicable to short periods of time, acute 1-hour average concentrations and chronic 4-day average concentrations.

The Water-Quality Assessment of the Sacramento River Basin, California Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998 (Open-File Report 2000- 91) by the United States Geological Survey found the hardness of the Sacramento River at Freeport to be 19 mg/l as CaCO3, on 6 January 1997.[9] The USGS is a reliable source of information and there is no reason not to use the lowest reported hardness of 19 mg/l.

Page F-65 of Central Valley Regional Board Order No. R5-2010-0114-01, NPDES NO. CA0077682, for the Sacramento Regional Wastewater Treatment Plant states: "For the receiving water, the applicable copper chronic criterion is 3.0 μg/L and the applicable acute criterion is 4.0 μg/L, as total recoverable, based on a hardness of 26 mg/L (as CaCO3), using USEPA default translators. The maximum observed upstream total copper concentration was 20.4 μg/L, based on data from 1992-2008."

The rationale in the EIR/EIS for using the average and 5th percentile data points rather than the simple worst-case hardness is not presented. There is certainly no indication that a four-day average would be properly represented by an average of data points collected over a 24 year period. The worst-case conditions and the worst-case potential for toxicity have not been evaluated for hardness dependent metals. As can be seen from the Sacramento Regional NPDES permit, the regulatory agency responsible for water quality in most of the Delta, the Central Valley Regional Water Quality Control Board, assessed the applicable receiving water criteria using the lowest observed hardness of 26 mg/l. The permit was appealed because of its use of an elevated hardness value, among other things.

The procedures described in US EPA's *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* indicate that, except possibly where a locally important species is very sensitive, (freshwater or saltwater) aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of (name of material) does not exceed (the Criterion Continuous Concentration) μg/L more than once every three years on the average and if the one-hour average concentration does not exceed (the Criterion Maximum Concentration) μg/L more than once every three years on the average. The use of an average or 95th percentile hardness would potentially allow the criteria for hardness dependent metals to exceed the water quality criteria each time a hardness higher than the lowest recorded hardness is used to calculate the hardness. This in turn allows for exceedance of the criteria more than once in three years, the level EPA suggests would unacceptably affect aquatic life.

US EPA adopted new copper criteria in 2007 based on the biotic ligand model (BLM) which is a metal bioavailability model based on recent information about the chemical behavior and physiological effects of metals in aquatic environments. The EIR/EIS, page 8-171, explains that:

> "*The BLM criteria account for the aggregate effect of several different water quality parameters on copper toxicity in addition to hardness (e.g., dissolved organic carbon, pH, and various salt concentrations), with the protective*

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[9] http://ca.water.usgs.gov/sac_nawqa/Publications/ofr_2000-391/data_sw/Freeport/freefld.html

> *criterion being sensitive to DOC concentrations in water. When calculated based on the average of all necessary parameters and the 5th percentile DOC, copper BLM-based criteria were higher (i.e., less sensitive) than the corresponding non WER-adjusted copper criteria presented in Table 8-59. Therefore, the calculated hardness-based CTR copper criteria are found to be adequately protective of fish olfaction.*"

However, the EIR/EIS again uses average and 95th percentile values for the input values into the BLM model resulting in the situation where water quality is not protected during periods when low hardness occurs.

Using a hardness of 25 mg/l results in dissolved copper criteria of 2.7 ug/l (4-day average) and 3.6 ug/l (1-hour average) which is significantly more protective than the 9 ug/l and 13 ug/l, respectively, developed and used in the EIR/EIS. Using the worst-case hardness of 19 mg/l, as measured by the USGS results in even more restrictive criteria than that required by the Central Valley Regional Board. The EIR/EIS's conclusion on page 8-171 that "*the calculated hardness-based CTR copper criteria are found to be adequately protective of fish olfaction"* is simply misleading, wrong, non-protective and technically deficient.

10. The Analysis of Aluminum is Deficient.

Aluminum is identified as a water quality constituent for which a detailed assessment is performed (Table 8-61, p. 8-174), identified as a constituent carried forward in the screening analysis (Table SA-9, p. 8C-37) and subjected to qualitative analysis (Table SA-11, p. 8C-40). However, water quality data for aluminum is not included in the detailed table of constituents measured at boundary stations (Table SA-6, p. 8C-22) and there is no discussion of aluminum in Chapter 8.

The Sacramento River maximum aluminum concentrations are over 8,000 μg/L (Sacramento Regional Wastewater Treatment Plant NPDES Permit, page F-43, Order No. R5-2010-0114-021). The US EPA water quality criteria for the protection of freshwater aquatic life are four-day average (chronic) and one-hour average (acute) for aluminum are 87 ug/*l* and 750 ug/*l*, respectively. The drinking water standard (maximum contaminant level (MCL)), both state and federal, for aluminum is 200 ug/l. The draft EIR/EIS (8-764, Trace Metals) is quite simply wrong in stating that the primary source of aluminum in the Delta is due to wastewater discharges. As is stated above the background concentration of aluminum in the Delta, above the Sacramento Regional WWTP, was almost 92 times higher than EPA's chronic criteria for aluminum and more than ten times above the acute criteria which is necessary to protect aquatic life. This measured concentration of aluminum in the Delta also exceeds the drinking water standard by 40 times.

The failure to address aluminum in the Water Quality section is a serious omission causing the EIR/EIS to be incomplete and not in compliance with CEQA and/or NEPA.

11. Impacts on Existing Mixing Zones are Ignored.

The Central Valley Regional Water Quality Control Board has issued numerous NPDES permits that allow for mixing zones for numerous constituents in ambient waters. Mixing zones are controversial and only allowed following detailed analysis and modeling that defines the specific dimensions of a zone of initial dilution. Mixing zones are especially difficult in tidal areas as incoming and outgoing tides cause constituents to slosh back and forth: this tidal-action essentially re-doses the area. There must always be a zone of passage, because a mixing zone cannot legally prevent passage of aquatic life. The EIR/EIS does not identify, discuss or provide maps of existing mixing zones in the Delta.

Altering the flow regime in a waterbody would impact the hydraulic and perhaps the constituent assimilative capacity available for mixing zones. Failure to reevaluate and modify mixing zones within the Delta could have significant adverse impacts to the beneficial uses of receiving waters. Mixing zones were also issued based in part on the economic impact to wastewater dischargers to fully treat their wastestream to meet end-of-pipe limitations. The impacts of Alternative 4 to mixing zones, beneficial uses, the associated economics and a requirement for reissuing NPDES permits that contain mixing zones should be evaluated and discussed.

12. Additive and Synergistic Impacts are Not Considered.

The EIR/EIS identifies the Delta as being listed as impaired by numerous pollutants including unknown toxicity. It is reasonable to assume that additive or synergistic effects of the many listed constituents could be contributing to toxicity within the Delta. It is more than reasonable to believe that a massive hydrologic project that proposes to deprive an estuary of more than 2.5 MAF of freshwater, thereby altering the existing flow regime, increasing residence time and affecting the fate and transport of pollutants in a highly degraded Delta, will likely have an impact on additive and synergistic toxicological interactions. However, in reviewing the EIR/EIS, we could only find one sentence mentioning additive or synergistic effects in the 791 pages of Chapter 8, Water Quality, no mention in Appendix 8C, Screening Analysis and only one passing sentence in the 3,055 pages of Chapter 11, Fish and Aquatic Resources, Parts 1 & 2.

If two or more constituents are present together in water, they may exert a combined effect to aquatic life, which can be additive, antagonistic or synergistic. For example: zinc and cadmium are additive in toxicity; copper is more than additive with chlorine, zinc, cadmium and mercury, while it decreases the toxicity of cyanide. The toxicity to mayflies of phenol and ammonia at low concentrations is additive, but at higher concentrations is more than additive. Organophosphate pesticide mixtures frequently exhibit additive or synergistic effects, as do pyrethroid and organophosphate mixtures. Temperature, pH, hardness, salinity and dissolved oxygen levels can exacerbate toxic effects. Acute toxicity to aquatic life can occur even when none of the individual constituents in a mixture exceed a water quality standard. Loss of dilution or increases in residence time enhances toxicity. As many as fifteen different pesticides have been identified in a single sample of Delta waters.

US EPA and the Environmental Research Laboratory published a study of acute and chronic toxicity tests that were conducted to determine the effects of metals combined as mixtures at proposed water quality criteria concentrations and at multiples of the LC50 and obtained from tests on six metals with three aquatic species. Arsenic, cadmium, chromium, copper, mercury and lead caused nearly 100% mortality in rainbow trout and daphnids (*C dubia*) during acute exposure. These results point out the need for additional studies to determine the type and degree of interaction of toxicants because single chemical water quality criteria may not sufficiently protect some species when other toxicants are present concurrently. (http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=91005B2N.txt)

The Central Valley Basin Plan,[10] *Implementation, Policy for Application of Water Quality Objectives* requires that:

> *"Where multiple toxic pollutants exist together in water, the potential for toxicologic interactions exists. On a case by case basis, the Regional Water Board will evaluate available receiving water and effluent data to determine whether there is a reasonable potential for interactive toxicity. Pollutants which are carcinogens or which manifest their toxic effects on the same organ systems or through similar mechanisms will generally be considered to have potentially additive toxicity."* Implementation, page IV-17.00-18.00.

The section provides the specific methodology to be followed to determine additive toxicity.

The EIR/EIS is grievously deficient in failing to acknowledge or adequately address how the project's hydrological modifications and resulting changes in flow, residence time, dilution and the fate, transport and mixing of pollutants will affect aquatic species.

13. Analysis of Potential Impacts Related to pH is Deficient.

Appendix 8C, Section 8C.1.5.7, pH, Page 8C-19, states, in part, the following with regard to pH:

> "*Because pH is a fundamental property of water, it affects the chemistry of numerous other constituents within the water, and thus, in addition to having potential direct effects on beneficial uses (such as municipal and domestic water supply and aquatic organisms), can also affect beneficial uses indirectly by altering the chemistry and toxicity of other constituents in the water.*
>
> *Within the affected environment, pH is typically between 6.5 and 8.5. The pH within the affected environment is controlled primarily by natural factors, such as alkalinity from natural weathering of minerals and carbon dioxide concentrations controlled by algae and bacterial respiration. Figure 8C- 1 shows exceedance probabilities of historical pH data from 1975 to 2009 in the Sacramento River at Freeport/Greene's Landing, the San Joaquin River at Vernalis, and San Francisco Bay at Martinez. The data indicate that the Sacramento River and San*

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[10] http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/index.shtml

> *Francisco Bay are within the Basin Plan objective range of 6.5 to 8.5 >95% of the time, while the San Joaquin River is between the limits >90% of the time. As water moves from these locations to areas within the Delta, pH changes as a result of natural factors, and therefore the pH at any given location within the Delta may have no correlation to the source waters that contribute water to that location. Given this, and given that the alternatives do not include components that would directly depress or elevate pH, it is not expected that pH would change substantially upstream of the Delta, within the Delta, or in the SWP and CVP Service Area under the alternatives, relative to Existing Conditions and (for Alternatives 1A–9) the No Action Alternative. Any negligible changes in pH that may occur in the water bodies of the affected environment would not be of frequency, magnitude and geographic extent that would adversely affect any beneficial uses or substantially degrade the quality of these water bodies, with regards to pH.*"

The quote graphically illustrates the inadequacies of the EIR/EIS's method of assessing pH. It only considers pH loading from tributary rivers to the exclusion of in Delta inputs. Review of the annual monitoring reports from the San Joaquin County and Delta Irrigated Lands Coalition reveals numerous exceedances of pH criteria, as do the annual reports submitted pursuant to the General Industrial and Construction Stormwater Permit program. There are many other sources including illegal dumping (the Delta is a favorite place to dump old batteries) and spills from bulk loading of petroleum coke, sulfur and other fertilizers at the Port of Stockton. The EIR/EIS fails to address how hydrologic modification and increased residence time in Delta channels affects pH impacts on water quality.

For drinking water, pH levels are important due to corrosive effects and adverse impacts to water treatment processes. For aquatic life, the pH range from 6.5 to 9 is considered nontoxic, however the toxicity of many constituents can be affected by changes in pH. Where pH levels are outside the 6.5 to 9.0 range, fish suffer adverse physiological effects increasing in severity until lethal levels are reached. The degree of dissociation of weak acids or bases is affected by changes in pH, which is important since the toxicity of several compounds is affected by the degree of dissociation. US EPA criteria recommend that rapid pH fluctuations should be avoided. The Central Valley Basin Plan water quality objective for pH limits shifts to no more than 0.5 pH units outside the 6.5 to 8.5 range.

The final page of Appendix 8C is Figure 8C-1, Probability of Exceedance for pH for Sacramento River at Freeport/Greene's Landing, San Joaquin River at Vernalis, and San Francisco Bay at Martinez for 1975-2009, shows that the Sacramento River and San Francisco Bay are below the 6.5 objective approximately 5% of the time and the San Joaquin River is below the pH objective almost 10% of the time. The EIR/EIS speaks as if this is a good record of compliance. It is not when one considers the potentially toxic impacts to aquatic life. US EPA Water Quality Criteria procedures are described in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* and indicate that, except possibly where a locally important species is very sensitive, (freshwater or saltwater) aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of (name of material) does not exceed (the Criterion Continuous Concentration) µg/L more than once every three years on the average and if the one-hour average concentration does not exceed (the Criterion Maximum Concentration) µg/L more than once every three years on the average. While pH is not measured as a concentration, surely exceeding the objective 5 or 10% of the time is not an acceptable compliance record when other potentially toxic constituents are present.

The EIR/EIS states that “natural factors” will alter pH levels and any changes in pH would not be of frequency, magnitude and geographic extent that would adversely affect any beneficial uses or substantially degrade the quality of these water bodies. However, there is no information in the EIR/EIS supporting this claim. To the contrary, any exceedance of a water quality objective should be considered serious. As water is withdrawn from the Delta, water from the San Joaquin River would have a proportionally greater impact on the Delta waters under all scenarios of Alternative 4. This could lead to an increase in overall pH violations of the water quality objective for pH. The EIR/EIS fails to discuss pH shifts, which have the potential to increase toxicity and violate the Basin Plan objective for pH.

14. The Assessment of Pesticides Fails to Meet Minimal Requirements for a Disclosure Document.

The impacts of CM1 on pesticides is addressed at: Pesticides (Impact WQ-21: Effects on Pesticide Concentrations Resulting from Facilities Operations and Maintenance (CM1), pp. 8-463 – 8-467. The assessment of pesticide impacts is a largely qualitative analysis based upon best professional judgment. We could find no discussion of the analysis that would justify the subjective conclusion that, “These modeled changes in source water fractions are not of sufficient magnitude to substantially alter the long-term risk of pesticide-related toxicity to aquatic life, nor adversely affect other beneficial uses of the Delta.” (P. 8-465, lines 30-33)

BDCP Appendix 8D, Source Water Fingerprinting Results, reveals that the distribution and mixing of Delta source water would significantly change. Modeling shows that for Alternative 4 H4, relative to the Existing Conditions Alternative, the source water fraction of San Joaquin River water at Rock Slough would increase 15-22% during September through March (11-15% during drought periods). At Contra Costa PP No. 1, the fraction would increase 15-23% during September through March (11-15% during October and November of droughts). At Franks Tract, the San Joaquin fraction would increase 11-16% during October through April and February through June. At Buckley Cove, the fraction would increase 11% in July and 16% in August during droughts. The other scenarios resulted in different fractions, as did comparisons with the No Action Alternative. For example, relative to the No Acton Alternative, the fraction of San Joaquin water at Buckley Cove would increase 16-17% in July (31-34% in drought conditions) and 24-25% in August (47-49% during droughts). Delta agricultural fractions are also projected to increase up to 8%, depending on location.

Not only will the San Joaquin River comprise a greater percentage of volume in eastern and southern Delta channels but the increase in residence time ensures that the suite of pesticides and other pollutants flowing down the river will have a longer period in which to mix with local municipal, industrial and agricultural inputs of pesticides and other pollutants and to interact with the environment.

We could find no credible discussion of the suite of pesticides present in these waters. It appears that limited data sets were used that ignored much of the pesticide monitoring data that has been acquired in recent years, especially monitoring by municipalities and agricultural coalitions. We could find no credible discussion regarding the potential effects of increased residence time on pesticide concentration and potential for bioaccumulative effects in the Delta. Despite the San Joaquin River and Delta being listed as impaired by various pesticides and unknown toxicity, we could find no discussion of the concentration, frequency and synergistic and additive effects of the universe of pesticides found in local waters.

For example, diazinon and chlorpyrifos are additive in toxicity, as are diazinon and esfenvalerate. Carbamate and organophosphate insecticides interact synergistically. There is an expansive literature on the toxicity and sublethal effects of pesticide mixtures.

Addressing pesticides, the Delta Independent Science Board in their Review of the Draft BDCP EIR/EIS and Draft BDCP (15 May 2014) observed,

> "Despite the acknowledged difficulty in predicting water quality impacts of the project, caused by lack of observational field data, as far as we could see there was no call for enhanced monitoring of pesticides in the Delta. As stated above, reliance on model outputs without their validation by comparison to observational data is a flawed approach, especially for assessing the effects of water quality constituents with high levels of uncertainty surrounding them, such as pesticides. In the section on pesticides, it was also remarkable that there was no mention of recent investigations showing very significant synergism between carbamate and organophosphate insecticides." Page B-24.

Apparently, source waters plus local inputs plus increased residence time plus additive/synergistic effects were not modeled or assessed. CM13 herbicide application was found to have significant and unavoidable impacts but we could not find a discussion where the impacts of CM13 were integrated into consideration of potential impacts of CM1. There is no antidegradation analysis that quantifies the degree of degradation, even if degradation fails to exceed a water quality standard. How much degradation or how many toxic events must occur in order to meet a "sufficient magnitude" threshold?

15. The Evaluation of Salinity and Electrical Conductivity is Deficient.

The SWRCB's 2010 Integrated Report, Clean Water Act Section 303(d) List/305(b) Report identifies vast areas of the Delta as impaired and incapable of supporting identified beneficial uses because of electrical conductivity (EC). The EIR/EIS states:

> "*The Region 5 Basin Plan specifies EC objectives for the Sacramento River, Feather River, and San Joaquin River; it also contains EC objectives for the Delta, which have been superseded by the 2006 Bay-Delta WQCP… impairment by elevated EC levels, as follows: (a) southern, northwestern, and western channels in the Delta; (b) Delta export area; (c) Grasslands drainage area, Mud Slough, and Salt Slough in the San Joaquin River valley; (d) San Joaquin River*

> *from Bear Creek to Delta boundary; and (e) Suisun Marsh (State Water Resources Control Board 2011).*" (P. 8-55)

The EIR/EIS acknowledges that:

> *"In the Plan Area, Alternative 4, Scenarios H1-H4, would result in an increase in the frequency with which Bay-Delta WQCP EC objectives are exceeded for the entire period modeled (1976–1991): in the Sacramento River at Emmaton (agricultural objective; 17–19% increase) in the western Delta, and in the San Joaquin River at San Andreas Landing (agricultural objective; 2–3% increase) and Prisoners Point (fish and wildlife objective; 14–25% increase), both in the interior Delta; and in Old River near Middle River and at Tracy Bridge (agricultural objectives; up to 2% increase), both in the southern Delta. Average EC levels at Emmaton would increase by <1–14% for the entire period modeled and 8–13% during the drought period modeled. Average EC levels at San Andreas Landing would increase by 0–9% during for the entire period modeled and 7–13% during the drought period modeled."* (P. 8-440)

Consequently, operation of CM1 results in a significant adverse impact (P. 8-440). Since, the effectiveness of mitigation measures is uncertain, the impacts are termed significant and unavoidable.

With respect to the potential impacts on EC from implementation of CM2-22, the EIR/EIS acknowledges the CM4 would increase the magnitude of daily tidal water exchange and alter other hydrodynamic conditions in adjacent Delta channels. However, the DSM2 modeling included "assumptions regarding possible locations of tidal habitat restoration areas, and how restoration would affect Delta hydrodynamic conditions and thus the effects of this restoration measure on Delta EC were included in the assessment of CM1 facilities operations and maintenance." (P. 8-442, lines 27-30) Consequently, implementation "would not be expected to adversely affect EC levels in the affected environment" and the effects are determined, "to not be adverse." (P. 8-442, lines 31-34) Please explain how CM4 could be evaluated with CM1, which was found to have significant and unavoidable impacts, but that CM4 will not be expected to have adverse effects, especially, as CM4 is only evaluated at a programmatic level. The CEQA conclusion of no adverse impacts is equally baffling. It assumes that the substitution of agricultural lands with habitat will offset any increased tidal effects and, consequently, there will be no adverse impacts and no mitigation is required. (P. 8-442, lines 35-43; P. 8-443, lines 1-2) Since the specific extent and location of habitat has not been determined, on what basis and methodology does the EIR/EIS conclude that CM2-CM22 would not cause significant impacts and that no mitigation will be required?

The EIR/EIS Section 8.2.3.7 Salinity and Electrical Conductivity, beginning on page 8-52 states:

> "*Concern about salinity involves three main issues: drinking water, crop irrigation, and biota/habitat… In addition, industrial processes that require low-salinity water can be negatively affected. Salt removal during the water purification process (for either drinking or process water) is presently very expensive.*"

> "*When salinity concentrations in irrigation water are too high, yields for salt-sensitive crops may be reduced.*" (Page 8-53)
>
> "*Incorporated into the BDCP, as set forth in EIR/EIS Appendix 3B, Environmental Commitments, a separate, non-environmental commitment to address the potential increased water treatment costs that could result from EC concentration effects on municipal, industrial and agricultural water purveyor operations.*"

Agricultural crop yields reductions will occur as salinity in the irrigation water increases, not just for salt sensitive crops but also for more tolerant plant species. (Irrigation with Reclaimed Municipal Wastewater, a Guidance Manual, SWRCB Report No. 84-1 wr, Chapter 3 and Table 3-1) The anticipated reduction in crop yield as EC levels increase is not presented. A methodology for determining crop yield reductions is not presented. The proposed commitment to address "increased water treatment costs" does not address crop yield reductions and the associated lower profits earned since it is unlikely that irrigation water would be treated. In any case, the project does not fully protect the identified beneficial use of irrigated agriculture.

Industrial uses of water can be the most limiting water quality objectives for salinity as shown in Water Quality Criteria (McKee and Wolf, SWRCB 1963) Chapter 5. It is currently not uncommon for industries to use reverse osmosis (RO) system to remove salts prior to use in cooling towers and boiler systems. The EIR/EIS should document how many systems are in place for industrial uses to account for elevated salt levels within the use area. How many additional salt treatment and removal systems will need to be installed to account for the increased EC levels projected by the project? The existing and future costs associated with the EIR/EIS alternatives have not been accounted for. In any case, the project fails to full protect the identified beneficial use of municipal and industrial supply.

The Delta currently exceeds the water quality standard for EC and Alternative 4 will exacerbate this situation. The EIR/EIS essentially states that we will "look at it later" and attempt to mitigate by reimbursing for losses. There is no assessment of the current crop yield losses or those expected to occur due to implementation of the various options. There is no assessment of the current and anticipated impacts to industry or other from increased salinity and modified hydrology. There is no quantification of the actual costs to agriculture, industry, local communities or individuals that may occur due to increasing salinity levels. Mitigation must be feasible: have funds been committed to repay those who experience losses? It's easy to say there will be a commitment to offset the costs when those costs have not been assessed and a mechanism for injured parties to file claims to recover those costs has not been developed. However, this should be analyzed as a part of the EIR/EIS.

The EIR/EIS makes several conclusory, unsupported statements concerning increased EC loading in the future, including:

> *There could be increased discharges of EC-elevating parameters in the future in water bodies upstream of the Delta as a result of urban growth and increased runoff and wastewater discharges. The state has begun to aggressively regulate*

> *point-source discharge effects on Delta salinity-elevating parameters, capping dischargers at existing levels, and is expected to further regulate EC and related parameters upstream of and within the Delta in the future as salt management plans are developed. Based on these considerations, EC levels (highs, lows, typical conditions) in the Sacramento River and its tributaries, the eastside tributaries, or their associated reservoirs upstream of the Delta would not be expected to be outside the ranges occurring under Existing Conditions or the No Action Alternative.* (8-436, lines 9-17)
>
> *However, with the implementation of the adopted TMDL for the San Joaquin River at Vernalis and the ongoing development of the TMDL for the San Joaquin River upstream of Vernalis and its implementation, it is expected that long-term EC levels will improve. Based on these considerations, substantial changes in EC levels in the San Joaquin River relative to Existing Conditions or the No Action Alternative would not be expected of sufficient magnitude and geographic extent that would result in adverse effects on any beneficial uses, or substantially degrade the quality of these water bodies, with regard to EC.* (8-436, lines 29-35)

CSPA routinely reviews municipal and industrial NPDES permits and has filed numerous appeals with the SWRCB over the Regional Board's failure to comply with CWA regulations regarding EC loading. Several of the Regional Board-issued permits have been or are in litigation. CSPA recently submitted comments on the renewal of Waste Discharge Requirements (WDRs) for the Grasslands Bypass Project. We were involved in the development of TMDLs and have unsuccessfully sought to persuade the Regional Board to comply with SWRCB direction to move the salinity compliance point upstream from Vernalis. We authored the legislation that sunset the original agricultural waiver of Waste Discharge Requirements (WDRs), were deeply involved in the development of the replacement conditional waivers and litigated each one of them. We currently have appeals pending before the SWRCB of the recently adopted agricultural WDRs for the Eastside and Westside San Joaquin Valley, San Joaquin County/Delta and the Sacramento Valley. CSPA maintains a rotating docket of 30-35 enforcement cases against industrial violators of the General Industrial Stormwater Permit. We have no evidence and do not believe there is any documented, quantifiable evidence that the mass loading of EC has stabilized, been reduced or that there is significant likelihood of reductions in the near future. If the authors of EIR/EIS believe otherwise, they should provide the documented quantifiable evidence. If not, they should eliminate or modify the unsupported conclusions referenced above.

The SWRCB has refused to enforce water quality standards it adopted in 1995 and incorporated into water rights permits in 2000. For example, between April of 2007 and December 2013, there were 868 documented days of noncompliance with the D-1641 EC standards at the Old River near Tracy Boulevard Bridge compliance point. In 2013 EC standards at Emmaton were ignored, as the SWRCB informed DWR and USBR that it would not seek enforcement. This year, the SWRCB simply waived existing standards. Based on past enforcement history, there is no reasonable basis to assume that EC standards will be enforced in the future. Consequently, the EIR/EIS conclusions that salinity levels are likely to be consistent with levels projected in the EIR/EIS are in error. If the authors of the EIR/EIS have reason to believe that future enforcement or compliance will be substantially different that it has been in the past, please provide it.

As previously noted, the EIR/EIS completely ignores the federally promulgated salinity standards at 40 CFR 131.37. Those standards include estuarine habitat criteria for salinity at Chipps Island, Roe Island and Suisun Marsh plus a criteria of 0.44 micro-mhos between 1 April and 31 May for striped bass and splittail spawning and migration on the San Joaquin River at Jersey Point, San Andreas Landing, Prisoners Point, Buckley Cove, Rough and Ready Island, Brandt Bridge, Mossdale and Vernalis when the San Joaquin Index is greater than 2.5 MAF and at Jersey Point, San Andreas landing and Prisoners Point when the San Joaquin Index is less than 205 MAF. The EIR/EIS must discuss, analyze and address the project's impacts and compliance with currently applicable USEPA federally promulgated criteria for the Delta.

Chapter 8 (Water Quality) and Chapter 11 (Fish and Aquatic Resources, Parts 1 & 2) largely ignore the water quality and habitat needs of striped bass and splittail in the eastern Delta and lower San Joaquin River. The studies US EPA relied upon in establishing salinity criteria protective of the migration and spawning beneficial uses of striped bass and splittail are still applicable.[11]

Neither, Chapter 8 (Water Quality) and Chapter 11 (Fish and Aquatic Resources, Parts 1 & 2) adequately surveys, analyzes or discusses the impacts of EC and other contaminants, or the impacts of modified hydrology and increased residence time on freshwater invertebrates (especially their egg and sensitive stages) in the eastern and southern Delta and lower San Joaquin River. Zooplankton is a critical source of food to numerous fish species. Different zooplankton species tend to inhabit freshwater, low salinity zones or high salinity zones. Native Copepod and Mysid species have plummeted. The same applies to the phytoplankton community.

With respect to native aquatic and adjacent riparian plant species, the EIR/EIS acknowledges that field surveys were limited by continuing legal challenges to efforts to obtain entry permits. In reviewing Chapter 8, we could find little discussion or analysis on the potential salinity and other water quality impacts to aquatic and riparian plants, with the exception of assessments on the effects of CM2-22 herbicide and pesticide use. The problem here is not an inadequate analysis

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[11] Turner, J.L., Striped Bass Spawning in the Sacramento and San Joaquin Rivers in Central California from 1963 to 1972. Calif. Fish and Game, 62(2):106-118, 1972: Turner, J.L. and Harold K Chadwick, Distribution and Abundance of Young-of-the-Year Striped Bass, Morone saxatilis, in Relation to River Flow in the Sacramento-San Joaquin Estuary. Anadromous Fisheries Branch, CDFG, 1972: Fraley, T.C., Striped bass, Roccus Saxatilis, Spawning in the Sacramento-San Joaquin Rivers During 1963 and 1964, 1966: Radtke, L.D. and Jerry L. Turner, High Concentrations of Total Dissolved Solids Block Spawning Migration of Striped Bass, Roccus saxatilis, in the San Joaquin River, California. Transactions of the American Fisheries Society. 96:4, 405-407, 1967: Radtke, L.D., Distribution of Adult and Subadult Striped Bass, Roccus Saxatilis, in the Sacramento-San Joaquin Delta, 1966: Turner J.L and Timothy C. Farley, Effects of Temperature, Salinity, and Dissolved Oxygen on the Survival of Striped Bass Eggs and Larvae. Calif. Fish and Game 57(4):268-273. 1971: See also, SWRCB, Draft Water Quality Control Plan for Salinity, San Francisco Bay/Sacramento-San Joaquin Delta Estuary, 1988 and SWRCB, Water Quality Control Plan for Salinity, San Francisco Bay/Sacramento-San Joaquin Delta Estuary, 1991.

of the impacts of salinity and other contaminants to riparian and channel vegetation communities in the South Delta or San Joaquin River, but that there is virtually no analysis.

The Delta was historically dominated by freshwater and the estuary was where the mixing of fresh and salt waters occurred. There are several natural divisions within the Delta and lower San Joaquin River system. Historically, the Southern and Eastern Delta was dominated by freshwater conditions and once supported myriad native freshwater species. A few of these species include common tules (*Scirpus acutus, S. californicus*), cattails (*Typha spp.)*, common reed (*Phragmites communis*), swamp knotweed (*Polygonum coccineum*), marsh bindweed (*Calystegia sepium*), bur-reed (*Sparganium eurycarpum*), cinquefoil (*Potentilla anserina*), twinberry (*Lonicera involucrata*), dogwood (*Cornus stolonifera*), buttonwillow (*Cephalanthus occidentale*), and willows (*Salix lasiolepis, S. lucida*). This wetland community was once very common and remnants of these communities still can be found on numerous channel islands and along the waterside of levees. Others grow in the water itself. A number of these species, like twinberry (*Lonicera involucrate*), are extremely sensitive to salt. The EIR/EIS must examine potential impacts of increased salinity levels and residence time to native aquatic and riparian plants.

16. The Discussion of the Narrative Toxicity Objective and the Potential for Emerging or Legacy Pollutants to Violate Criteria and Beneficial Uses is Inadequate.

The EIR/EIS Table 8.5, Receptors Affected by Water Quality-Characterized by the Designated Beneficial Uses of the Study Area (p.8-29) identifies emerging pollutants (ECs/PPCPs) as having the potential to affect water quality. The Central Valley Regional Board Basin Plan contains a narrative toxicity objective that prohibits: ***"**Toxic substances to be present, individually or in combination, in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life."*

Constituents of Emerging Concern (CECs) clearly have potential to violate the Basin Plan's narrative toxicity objective. There is an extensive and rapidly expanding body of scientific literature discussing emerging pollutants.

> The increasing production and use of pharmaceuticals and personal care products (PPCPs) – some of which may be endocrine disrupting compounds (EDCs) – have led to a growing concern about the occurrence of these compounds in the environment. Recent studies have reported the occurrence worldwide of EDCs, PPCPs, and other organic wastewater contaminants (OWCs) – collectively referred to as "constituents of emerging concern" (CECs) or "emerging constituents" (ECs) – in wastewater treatment plant (WWTP) effluents, surface waters used as drinking water supplies, and in some cases, finished drinking waters. Of the 126 samples analyzed for the project, one sample (American River at Fairbairn drinking water treatment plant [DWTP] intake collected in April 2008) had no detectable levels of any EDCs, PPCPs, or OWCs. All other samples had one or more analytes detected at or above the corresponding MRLs. The five most frequently detected PPCPs were caffeine, carbamazepine, primidone, sulfamethoxazole, and tri(2-chloroethyl) phosphate (TCEP). At the sample sites upstream of WWTP discharges in all three watersheds, the concentrations of selected PPCPs, except for

caffeine, were low (i.e., ≤ 13 ng/L), pointing to WWTP discharges as the main source of most PPCPs and OWCs in the environment. (Source, Fate, and Transport of Endocrine disruptors, Pharmaceuticals, and Personal Care Products in Drinking Water Sources in California, National Water Research Institute Fountain Valley, California, May 2010)

Over the last 10 years, reports of feminized wildlife have fueled chilling headlines. Most of these reports have focused on the many ways that estrogen in sewage effluent can distort normal male development. Now a new study reveals one way that the hormone pollutant can affect females: Too much estrogen causes subtle changes in female fish's courting behavior, which could alter a population's genetic makeup (Environ. Sci. Technol., DOI: 10.1021/es101185b).

Increase in intersex fish downstream from WWTP possibly associated with endocrine-active contaminants. (Boulder Colorado, Colorado University, 2008)

Skewed sex ratio downstream from WWTP possibly associated with endocrine-active contaminants. (Boulder Colorado, Colorado University, 2006)

Fluoxetine (FLX), Sertraline (SER) and their degradants NFLX, and NSER were the primary antidepressants in brain tissue samples. Little or no venlafaxine (VEN), the dominant antidepressant in both water and bed sediment, was present. Degradates were measured at higher concentrations in brain samples than parent compounds. (Boulder Creek, Colorado & Fourmile Creek, Iowa, the College of Wooster, 2010)

SAR sites (with WWTP or urban runoff influent) males had significantly lower Testosterone (T) than the reference site males. Males from SAR sites had significantly higher17β-estradiol (E2) than reference site. Females from SAR sites had significantly lower E2 than the reference site females. (USGS, Santa Ana River (SAR) SAR sites, 2009)

“Several recent studies have documented endocrine disruption in Delta fish. One of the biomarkers of EDCs is intersex fish, fish with both male and female reproductive organs. A recent histopathological evaluation of delta smelt for the Pelagic Organism Decline found 9 of 144 maturing delta smelt (6%) collected in the fall were intersex males. This study provides evidence that delta smelt are being exposed to EDCs. Brander and Cherr (2008) observed choriogenin induction in male silversides from Suisun Marsh. Riordan and Adam (2008) reported endocrine disruption in male fathead minnows following in-situ exposures below the Sacramento Regional Treatment Plant. Lavado, et al. (in press) conducted studies in 2006 and 2007 to evaluate the occurrence and potential sources of EDCs in Central Valley waterways. In their study, estrogenic activity was repeatedly observed at 6 of 16 locations in the Bay-Delta watershed, including in water from the Lower Napa River and Lower Sacramento River in the Delta. Further studies are needed to identify the compounds responsible for the observed estrogenic activity and their sources.” (Alameda County Water District, Alameda County Flood Control and Water Conservation District, Zone 7, Metropolitan Water District of Southern California, San Luis

& Delta-Mendota Water Authority, Santa Clara Valley Water District, State Water Contractors, June 1, 2010)

A 2008 study of the maternal transfer of xenobiotics and effects on larval fish in the estuary documented that offspring of fish caught in the Delta had undeveloped brains, inadequate energy supplies and dysfunctional livers. An array of compounds known to cause myriad problems in both young and adult fish, including skeletal and organ deformities and dysfunction; changes in hormone function and behavior were identified in fish tissue. A two-year DWR funded study of sublethal factors that might be contributing to the decline of pelagic fish in the Bay-Delta assessed the health status of larval, juvenile and adult female striped bass collected in the Delta using morphometric, histopathological, otolith and biochemical metrics. It concluded that a wide-array of contaminants were significant stressors on the vast majority of juvenile striped bass causing severe physiological stress, morbidity and likely compromised immune systems. Findings of abnormal disease and parasitism were found in juvenile fish in all years studied and were considered to have a significant impact on the health of the fish and the population. In addition, the data suggested that adult striped bass are also likely adverse affected by the bioaccumulation of contaminants, such as PBDE’s, and that such contaminant effects need to be considered a significant stressor that is affecting the decline of striped bass and are likely causing population level effects in early life stages. Both studies can be found accessed at https://sites.google.com/site/drdavidostrach/about-david-ostrach.

A recent study by the Toxic Substances Hydrology Program of the U.S. Geological Survey (USGS) shows that a broad range of chemicals found in residential, industrial, and agricultural wastewaters commonly occurs in mixtures at low concentrations downstream from areas of intense urbanization and animal production. The chemicals include human and veterinary drugs (including antibiotics), natural and synthetic hormones, detergent metabolites, plasticizers, insecticides, and fire retardants. One or more of these chemicals were found in 80 percent of the streams sampled. Half of the streams contained 7 or more of these chemicals, and about one-third of the streams contained 10 or more of these chemicals. This study is the first national-scale examination of these organic wastewater contaminants in streams and supports the USGS mission to assess the quantity and quality of the Nation's water resources. A more complete analysis of these and other emerging water-quality issues is ongoing. Knowledge of the potential human and environmental health effects of these 95 chemicals is highly varied; drinking-water standards or other human or ecological health criteria have been established for 14. Measured concentrations rarely exceeded any of the standards or criteria. Thirty-three are known or suspected to be hormonally active; 46 are pharmaceutically active. Little is known about the potential health effects to humans or aquatic organisms exposed to the low levels of most of these chemicals or the mixtures commonly found in this study. ("Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: A national reconnaissance," an article published in the March 15, 2002 issue of Environmental Science & Technology, v. 36, no. 6, pages 1202-1211. Data are presented in a companion USGS report, "Water-quality data for pharmaceuticals, hormones, and other organic wastewater contaminants

> in U.S. streams, 1999-2000" (USGS Open-File Report 02-94). These and other reports, data, and maps can be accessed on the Internet at http://toxics.usgs.gov.)
>
> PPCPs are found where people or animals are treated with drugs and people use personal care products. PPCPs are found in any water body influenced by raw or treated sewage, including rivers, streams, ground water, coastal marine environments, and many drinking water sources. PPCPs have been identified in most places sampled. The U.S. Geological Survey (USGS) implemented a national reconnaissance to provide baseline information on the environmental occurrence of PPCPs in water resources. You can find more information about this project from the USGS's What's in Our Wastewaters and Where Does it Go? (http://toxics.usgs.gov/highlights/whatsin.html). PPCPs in the environment are frequently found in aquatic environments because PPCPs dissolve easily and don't evaporate at normal temperature and pressures. Practices such as the use of sewage sludge ("biosolids") and reclaimed water for irrigation brings PPCPs into contact with the soil. (http://www.epa.gov/ppcp/faq.html#iftherearei ndeed)

From the recent scientific investigations and literature, it is reasonable to conclude that CECs are present in the Delta at levels that cause toxicity in violation of the narrative toxicity objective. It is also reasonable to conclude that wastewater discharges into the Delta contain CECs in concentrations that at a minimum threaten to violate the Receiving Water Limitation for toxicity, which prohibits toxic substances to be present in concentrations that produce detrimental physiological responses in human or aquatic life.

US EPA has compiled a database; *Treating Contaminants of Emerging Concern A Literature Review Database* (August 2010). Local wastewater treatment system design engineers have also been testing treatment system capabilities for removing CECs. There appear to be treatment technologies that are capable of removing significant levels of CECs.

With respect to CEC’s, the Delta Independent Science Board in their Review of the Draft BDCP EIR/EIS and Draft BDCP (15 May 2014) observed,

> *“Very optimistic descriptions of CECs and their removal from wastewater by WWTPs are given, but no acknowledgment is made of many other CECs that are shown to be highly recalcitrant to such removals. Such demonstrations of unfamiliarity with the subjects covered do not engender confidence in the analysis.”* Page B-22.

With respect to pollutants that bioaccumulate, the Delta Independent Science Board observed,

> *“Also, in regard to bioaccumulation, mercury and selenium appear to be the only constituents that were evaluated for their bioaccumulative properties. A range of organic contaminants (e.g., PAHs, dioxins, some endocrine disrupting compounds) also bioaccumulate, but this was not acknowledged or addressed in the DEIR/DEIS document.”* Page B-24.

The EIR/EIS does not sufficiently assess the current state of water quality within the Delta or compliance with the narrative toxicity objective. The Delta is 303d listed as impaired for unknown toxicity. CECs, legacy and bioaccumulating pollutants present more than a reasonable potential to be causing and/or contributing to this toxicity.

17. There is no Defensible Antidegradation Analysis.

There is a fundamental flaw in the EIR/EIS in the analysis regarding Water Quality. Individual constituents were analyzed and discussed based on the potential for exceedance of federal water quality criteria or state water quality objectives or if the constituent was on the state's Clean Water Act Section 303(d) list. A cornerstone of the State Water Board and Regional Water Board's regulatory authority is the Antidegradation Policy (Resolution 68-16), which is included in the Basin Plans as an appendix. However, the EIR/EIS fails to discuss or analyze constituents which will "degrade" water quality unless they pose a threat to exceed a water quality standard.

Section 101(a) of the Clean Water Act (CWA), the basis for the antidegradation policy, states that the objective of the Act is to "restore and maintain the chemical, biological and physical integrity of the nation's waters." Section 303(d)(4) of the CWA carries this further, referring explicitly to the need for states to satisfy the antidegradation regulations at 40 CFR § 131.12 before taking action to lower water quality. These regulations (40 CFR § 131.12(a)) describe the federal antidegradation policy and dictate that states must adopt both a policy at least as stringent as the federal policy as well as implementing procedures.

The CWA requires the **full** protection of identified beneficial uses. The Federal Antidegradation Policy, as required in 40 CFR 131.12 states, "The antidegradation policy and implementation methods shall, at a minimum, be consistent with the following: (1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." EPA Region 9's guidance on implementing antidegradation policy states, "All actions that could lower water quality in Tier II waters require a determination that existing uses will be fully maintained and protected." (EPA, Region 9, Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12, page 7) The Delta is classified as a Tier II, "high quality," waterbody by US EPA and the SWRCB.

California's Antidegradation Policy is composed of both the federal antidegradation policy and the State Board's Resolution 68-16 (State Water Resources Control Board, Water Quality Order 86-17, p. 20 (1986) ("Order 86-17); Memorandum from Chief Counsel William Attwater, SWRCB to Regional Board Executive Officers, "Federal Antidegradation Policy," pp. 2, 18 (Oct. 7, 1987) ("State Antidegradation Guidance")). As a state policy, with inclusion in the Water Quality Control Plan (Basin Plan), the antidegradation policy is binding on all of the Regional Boards (Water Quality Order 86-17, pp. 17-18).

The BDCP will require a number of waste discharge permits from the SWRCB or Regional Water Quality Control Board for construction and operation of the project. It will require a CWA Section 401 Water Quality Certification, which is necessary for any "federal license or permit to conduct and activity…[that] may result in any discharge into navigable waters." (33 U.S.C. § 1341(a)(1).) In order to obtain a 401 certification, a project must meet CWA requirements to meet water quality requirements CWA Section 303 (33 U.S.C. § 1341(d)) BDCP will require a CWA Section 404 permit from the U.S Army Corps of Engineers, which will trigger the 401 certification process. The state cannot issue a Section 401 certification if there is no reasonable assurance that the project will meet water quality standards. As confirmed by the U.S. Supreme Court, CWA Section 401 certification considers the impacts of the entire activity and not simply the impacts of a particular discharge that triggers Section 401. (*PUD No. 1 of Jefferson County v. Washington Department of Ecology*, 511 U.S. 700 (1994)) Since water quality standards consist of both the water quality criteria and the designated uses of the navigable waters involved, an antidegradation analysis is required to ensure that the "existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected." (40 CFR 131.12)

California's Antidegradation Policy (Resolution 68-16) requires that:

- Existing high quality water will be maintained until it has been demonstrated that any change will be with the maximum benefit to the people of the State.
- The change will not unreasonably affect present and anticipated beneficial uses.
- The change will not result in water quality less than prescribed in the policies.
- Any activity which produces a waste or increased volume or concentration will be required to meet waste discharge requirements which will result in the best practicable treatment or control of the discharge necessary to assure that a pollution or nuisance will not occur and the highest water quality with maximum benefit to the people of the state will be maintained.

Implementation of the state's antidegradation policy is guided by the State Antidegradation Guidance, SWRCB Administrative Procedures Update 90-004, 2 July 1990 ("APU 90-004") and USEPA Region IX, "Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12" (3 June 1987) (" Region IX Guidance"), as well as Water Quality Order 86-17.
The Regional Board must apply the antidegradation policy whenever it takes an action that will lower water quality (State Antidegradation Guidance, pp. 3, 5, 18, and Region IX Guidance, p. 1). Application of the policy does not depend on whether the action will actually impair beneficial uses (State Antidegradation Guidance, p. 6). The proposed project, as defined by the alternatives described in the EIR/EIS, will result in reduced flows and lower water quality in the Delta for some constituents.

The State Board's APU 90-004 specifies guidance to the Regional Boards for implementing the state and federal antidegradation policies and guidance. The guidance establishes a two-tiered process for addressing these policies and sets forth two levels of analysis: a simple analysis and a complete analysis. A simple analysis may be employed where a Regional Board determines that: 1) a reduction in water quality will be spatially localized or limited with respect to the waterbody, e.g. confined to the mixing zone; 2) a reduction in water quality is temporally limited; 3) a proposed action will produce minor effects which will not result in a significant reduction of water quality; and 4) a proposed activity has been approved in a General Plan and has been adequately subjected to the environmental and economic analysis required in an EIR.
A complete antidegradation analysis is required if discharges would result in: 1) a substantial increase in mass emissions of a constituent; or 2) significant mortality, growth impairment, or

reproductive impairment of resident species. Regional Boards are advised to apply stricter scrutiny to non-threshold constituents, i.e., carcinogens and other constituents that are deemed to present a risk of source magnitude at all non-zero concentrations. If a Regional Board cannot find that the above determinations can be reached, a complete analysis is required.

Even a minimal antidegradation analysis would require an examination of: 1) existing applicable water quality standards; 2) ambient conditions in receiving waters compared to standards; 3) incremental changes in constituent loading, both concentration and mass; 4) treatability; 5) best practicable treatment and control (BPTC); 6) comparison of the proposed increased loadings relative to other sources; 7) an assessment of the significance of changes in ambient water quality and 8) whether the waterbody was a ONRW. A minimal antidegradation analysis must also analyze whether: 1) such degradation is consistent with the maximum benefit to the people of the state; 2) the activity is necessary to accommodate important economic or social development in the area; 3) the highest statutory and regulatory requirements and best management practices for pollution control are achieved; and 4) resulting water quality is adequate to protect and maintain existing beneficial uses.

The EIR/EIS, page 8-408 states in part that:

> "*Effects of the Alternative on Delta Hydrodynamics Under the No Action Alternative and Alternatives 1–9, the following two primary factors can substantially affect water quality within the Delta:*
>
> - *Within the south, west, and interior Delta, a decrease in the percentage of Sacramento River sourced water and a concurrent increase in San Joaquin River-sourced water can increase the concentrations of numerous constituents (e.g., boron, bromide, chloride, electrical conductivity, nitrate, organic carbon, some pesticides, selenium). This source water replacement is caused by decreased exports of San Joaquin River water (due to increased Sacramento River water exports), or effects of climate change on timing of flows in the rivers. Changes in channel flows also can affect water residence time and many related physical, chemical, and biological variables.*
> - *Particularly in the west Delta, sea water intrusion as a result of sea level rise or decreased Delta outflow can increase the concentration of salts (bromide, chloride) and levels of electrical conductivity. Conversely, increased Delta outflow (e.g., as a result of Fall X2 operations in wet and above normal water years) will decrease levels of these constituents, particularly in the west Delta.*"

BDCP will reduce flows and result in lower water quality for a number of constituents, including boron, bromide, chloride, electrical conductivity, nitrate, organic carbon, some pesticides and selenium. The Delta is currently impaired for many of the constituents that will increase under the proposed alternative. While California's Antidegradation Policy requires that, "[t]he change will not unreasonably affect present and anticipated beneficial uses and the change will not result in water quality less than prescribed in the policies," the Federal Antidegradation Policy requires a "determination that existing uses will be fully maintained and protected." EPA, Region 9, Guidance on Implementing the Antidegradation Provisions of 40 CFR 131.12, page 7.

The proposed project will result in a substantial increase in mass emissions of constituents that already exceed water quality standards. This does not comply with the Policies set forth in the Basin Plan. Massively exceeding a water quality standard – any water quality standard - does not fully protect present and anticipated beneficial uses. Impacts to the existing impaired water for unknown toxicity and specifically mortality, growth and reproduction of resident species have not been thoroughly discussed or analyzed for toxic constituents. Nor have impacts to native zooplankton and phytoplankton communities that comprise the base of the food chain web been analyzed.

A complete Antidegradation analysis must be conducted to determine: incremental changes in constituent loading, both concentration and mass; the significance of changes in ambient water quality; whether such degradation is consistent with the maximum benefit to the people of the state; whether the activity is necessary to accommodate important economic or social development in the area; and whether the resulting water quality is adequate to fully protect and maintain existing beneficial uses.

18. The Analysis and Discussion of Pathogens is Fundamentally Flawed.

The EIR/EIS (8.2.3.12) identifies the beneficial uses impacted by pathogens as municipal and domestic supply, water contact recreation, shellfish harvesting, and commercial and sport fishing. Missing from this list is irrigated agriculture. Pathogens have not been evaluated for Agricultural Supply water. California Code of Regulations, Title 22, is mentioned in the EIR/EIS specifically with regard to pathogens and protecting Contact Recreational beneficial uses. However, Title 22 equally addresses agricultural irrigation and the acceptable levels of pathogens. From a regulatory point of view, Title 22 requirements are only directly applicable to reclaimed water; however, the science used to determine a protective level for pathogens is directly applicable for protecting irrigated agriculture and recreational activities. The potential impacts to irrigated agriculture and the ingestion of food crops irrigated with water exceeding the recommended levels for pathogens presents at least the same level of concern as does recreational activity in that same water. The impacts to Irrigated Agriculture from pathogens, nitrates, constituents of emerging concern (CECs) and phthalates have not been assessed. The EIR/EIS is therefore incomplete.

This Section of the EIR/EIS, page 8-80 states that: "*Viruses also can be removed effectively through chlorine or ozone oxidation.*" This statement is incorrect; while chlorination may be effective at rendering some limited number of viruses inactive, it removes none. For the most part, viruses and protozoa have a moderate to high tolerance to chlorine. (CDC, Effect of Chlorination on Inactivating Selected Pathogens, 21 March 2012) It is also fairly well documented in Civil Engineering texts that viruses and parasites are best removed by filtration and chlorination is generally accepted as ineffective. Going back to the requirements contained in CCR Title 22, filtration is required to remove pathogens, and one will note that disinfection with chlorine is not a requirement. Tertiary treatment, consisting of chemical coagulation, sedimentation, and filtration, has been found to remove approximately 99.5% of viruses. Filtration is an effective means of reducing viruses and parasites from the waste stream, not disinfection with chlorine.

The EIR/EIS is also incorrect in stating that pathogens experience rapid die off in the natural environment. The latest science shows that pathogens can survive for lengthy time periods and the indicator tests used to identify pathogens may not be reliable:

> A. *“Previous research had raised questions about whether E. coli O157:H7 outlasts indicator bacteria in the environment. So Michael Jenkins and his colleagues at the U.S. Department of Agriculture's Agricultural Research Service decided to test the reliability of the EPA's method by measuring the survival rates of E. coli O157:H7 and four species of indicator bacteria. In one experiment, they injected the E. coli strain and the indicator bacteria into small, porous chambers and then suspended the chambers in test ponds in northeast Georgia. By varying the chambers' depth in the water, the scientists could monitor the microbe's survival rate under different levels of solar radiation. In another experiment, they placed inoculated pond water in bottles in an outdoor laboratory. The researchers then measured bacteria levels at regular intervals. Both experiments exposed the bacteria to predation by other microorganisms—a common fate of microbes in the environment.*
>
> *They found that in both experiments, the indicator bacteria died off significantly more quickly than E. coli O157:H7 did. For example, in the outdoor lab experiments, most cells of fecal Enterococcus—an indicator species—died in less than five days. But it took between seven and 18 days for most of the E. coli O157:H7 to die. The virulent strain appeared to be more resistant than indicator bacteria to solar radiation and to predation by other microorganisms. The findings suggest that the dangerous E. coli could be present in water even when tests for fecal indicator bacteria are negative, Jenkins says. "We need to develop methods that are going to be able to quantify the pathogens themselves," he says.” (*Chemical & Engineering News, ISSN 0009-2347)
>
> B. *“In general, many different kinds of viruses can persist in and on environmental media, including liquid and solid media and in the airborne state, with half-lives of hours, days, weeks or even months. The extent of persistence depends on the type of virus, it physical state (dispersed, aggregated, cell-associated, membrane-bound, adsorb to other solids, etc.), the medium in which it is present (faeces, respiratory secretions, tissues, other liquids or solids, air, etc. and prevailing environmental conditions that influence virus survival. The environmental conditions influencing virus survival generally include: temperature; pH and other physical and chemical properties of the medium in which the viruses are present, such as moisture content, organic matter, particulates, salt concentration, protective ions, and antiviral chemicals such as proteolytic enzymes; antiviral microbial activity, and light. On environmental surfaces and in aerosols additional environmental factors also influence virus survival, such as relative humidity and physico-chemical forces at air-water and air-water-solid interfaces.”* (WHO Virus Survival Report, Virus Survival in the Environment with Special Attention to Survival in Sewage Droplets and Other Environmental Media of Fecal or Respiratory Origin, August 21, 2003)
>
> C. *“Three enteroviruses — polioviruses, echoviruses and coxsackieviruses — were used to contaminate soil and vegetables; their survival times, under various storage*

> *conditions, were then recorded (2). The concentration of the viruses employed varied from 1 x 104-5 to 1 x 105-5 CCID50/ml. Depending on soil type, moisture content, pH and temperature, the viruses survived for 150 to 170 days in soil. When added to uncooked vegetables and stored under household conditions, the viruses survived for as long as 15 days."* (Rev. sci. tech. Off. int. Epiz., 1991, 10 (3), 733-748, Virus survival in the environment)

Pathogens and their longevity are important in the context of multiple beneficial uses. Below, we describe how many of these uses affect and are affected by pathogens, and how these effects, of and on, these uses should have been analyzed

Recreational Waters Criteria and Beach Closures

In most areas of California, the current water quality criterion for bacteria in recreational waters is based on fecal coliform organisms:

- In waters designated for contact recreation (REC-1), the fecal coliform concentration based on a minimum of not less than five samples for any 30-day period shall not exceed a geometric mean of 200/100 ml, nor shall more than ten percent of the total number of samples taken during any 30-day period exceed 400/100 ml.

US EPA's evaluation of the bacteriological data indicated that using the fecal coliform indicator group at the maximum geometric mean of 200/100 ml would cause an estimated 8 illnesses per 1,000 swimmers at marine beaches (*Ambient Water Quality Criteria for Bacteria – 1986)*. US EPA now recommends the addition of criteria for E. coli (126/100 ml) and enterococci (33/100 ml) based on the same "acceptable" illness rate of 8 illnesses per 1,000 swimmers at marine beaches.

Even at the "acceptable" illness rate of 8 out of every 1,000 swimmers; the National Resources Defense Council (NRDC) in 2008 issued a press release interpreting EPA's data that beach closures were at their highest level in 18 years. In 2002, the Centers for Disease Control and Prevention (CDC) concluded that the incidence of waterborne infections from recreational water use has steadily increased over the last several decades. Despite the beach closures and the increase in reported sewage-related illnesses, in a healthy population, most of the illnesses resulting from exposure to inadequately treated sewage are relatively minor (respiratory illness; ear, nose, or throat irritation; and especially gastroenteritis) and go unreported. Even if such illnesses are reported to doctors, there is seldom an attempt to find or track an environmental source.

Another complicating issue is inadequate data on the occurrence of sewer spills or overflows. The State Water Board has only begun requiring reporting of sewer spills into its new sanitary sewer overflow (SSO) database and reporting compliance rates are mixed. The lack of data regarding sewer spills and the under-reporting of illnesses makes it difficult to definitively estimate the incidence of diseases caused by exposure to sewage-contaminated waters. The number of reported cases is a small subset of the actual number of illnesses caused by sewage exposure or waterborne pathogens.

The Delta is a recreational magnet, attracting many thousands of water enthusiasts, including boaters, swimmers, water-skiers, windsurfers, fishermen and others who routinely come into contact with the water. The Delta is also home to thousands of people who permanently live on boats, many of which do not always follow proper sanitation protocols. During warmer weather, many people anchor boats for extended periods of time in attractive anchorages, without always returning to pump-out facilities empty marine sanitation devices. A large homeless population lives in the Delta and along urban tributary streams and lack even rudimentary sanitation facilities.

CSPA staff and members have spent thousands and thousands of days on Delta waters and are acutely aware of the numerous cases of gastrointestinal illnesses and seriously infected cuts experienced by individuals following exposure to the water. Few of these illnesses are formally report to health authorities. We are aware that urban stormwater monitoring reveals that, following rainfall, stormwater discharges and local receiving waters far exceed water quality standards for pathogens.

The EIR/EIS fails to identify how many exceedances of bacteria standards were recorded during the period analyzed, discuss or estimate the number of illnesses typically occurring or that are projected to occur or identify recreational closures.

Beneficial Uses of the Receiving Water

By memorandum, dated September 28th 2000, Jeff Stone, California Department of Health Services (DHS), Office of Drinking Water, Recycled Water Unit, to Regional and District Engineers wrote that: "Federal Standards for water quality where recreational bathing may occur were developed for freshwaters which are not directly influenced by sewage discharges (treated or untreated)." The memorandum goes on to state that the Department does not believe that the federal criteria are protective if the source of water is domestic wastewater and cites the "Uniform Guidelines" prepared by the Department.

Irrigated Agriculture

Although the discussion of pathogens has largely been limited to recreational uses, Irrigated Agriculture is a designated beneficial use of most inland waters. Outbreaks of bacteria-contaminated food have made headlines over the past few years. California Department of Public Health, Regulations, CCR Title 22, Section 60303, require that for the irrigation of Food Crops, including edible root crops, reclaimed water be tertiary treated water disinfected to 2.2 MPN/100 ml (total coliform organisms). Obviously, 2.2 MPN total coliform is significantly less than the 200 MPN fecal coliform bacteria criteria established for recreational waters.

Undiluted surface water can be and is used to irrigate food crops. The science used to develop the bacteria limitation in the Title 22 Reclamation Criteria for the irrigation of food crops is applicable to surface waters even though the Title 22 regulatory requirements do not apply. By Memorandum to Regional Water Boards, dated August 18, 1992, the then Department of Health Services, Office of Drinking Water, issued the *Uniform Guidelines for the Disinfection of*

Wastewater (Uniform Guidelines). The Uniform Guidelines recommend that for agricultural uses where there is less than a twenty-to-one dilution of wastewater within the receiving stream, that a tertiary level of treatment be required with a 2.2 MPN/100 ml limitation for total coliform organisms. A footnote for this situation states that where there is no dilution, the water reclamation criteria shall apply. The Uniform Guidelines further recommend that: when there is dilution available in the receiving stream of at least 20-to-1 the wastewater be treated to a secondary level and disinfected to a 23 MPN/100 ml; and when there is dilution available of at least 100-to-1 the wastewater be treated to a secondary level and disinfected to a 240 MPN/100 ml.

Municipal (Drinking) and Domestic

The Uniform Guidelines recommend that for drinking water uses where there is less than a twenty to one dilution of wastewater within the receiving stream, no domestic wastewater discharges be allowed. Tertiary treated, 2.2 MPN/100 ml, wastewater could only be allowed to a receiving stream with a drinking water beneficial use if greater than a twenty-to-one dilution reliably exists.

Contact Recreation

The Uniform Guidelines and the Reclamation Criteria of CCR Title 22 require that for unrestricted recreational uses that wastewater be tertiary treated and disinfected to 2.2 MPN/100 ml (total coliform organisms), unless a 20 to 1 in stream dilution exists then the wastewater may be secondary treated and disinfected to 23 MPN/100 ml. This recommendation for contact recreational uses is directly comparable to the US EPA recommended bacteria criteria.

Domestic Wastewater Treatment

As stated above, the California Department of Public Health, formerly the Department of Health Services, does not support the Federal Criteria as being protective if the source of water in the receiving stream is domestic wastewater (treated or untreated).

Domestic wastewater discharges are regulated under Federal NPDES permits issued by the State and Regional Boards. The federal Clean Water Act, Section 101(a)(2), states: “it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water be achieved by July 1, 1983.” Federal Regulations, developed to implement the requirements of the Clean Water Act, create a rebuttable presumption that all waters be designated as fishable and swimmable. Federal Regulations, 40 CFR Sections 131.2 and 131.10, require that all waters of the State regulated to protect the beneficial uses of public water supply, protection and propagation of fish, shell fish and wildlife, recreation in and on the water, agricultural, industrial and other purposes including navigation.

The diversion of approximately 2.5 MAF of relatively good dilution flow from the estuary will increase the relative percentage of water from the San Joaquin River in the eastern and southern Delta. This will inevitably increase the relative concentration of human and agricultural wastes in these waters, including dairy and livestock wastes that have been identified as sources of pathogens. It will also increase the residence time of pathogens and increase the potential to impact those who come in contact with the water. It will increase the opportunity for pathogens to affect irrigated food crops and domestic water supplies. The EIR/EIS is deficient because it fails to adequately and accurately consider the potential adverse effects of pathogens on human health

19. The Analysis of Water Temperature is Deficient.

The Water Quality section of the EIR/EIS states that: "*Because the primary concern of water temperature is effects on fish and aquatic organisms, temperature is addressed in Chapter 11, Fish and Aquatic Resources.*" Any discussion of Water Quality is incomplete without including temperature. There are water quality objectives for temperature in the Basin Plan; Water Quality Objectives (Page III-8.00, Sacramento and San Joaquin Basins), and the Water Quality Control Plan for Temperature (Thermal Plan, an appendix to the Basin Plan). Elevated temperature is a pollutant and compliance with objectives is a relevant discussion with regard to water quality. Also, temperature directly affects the toxicity of other constituents such as ammonia. Temperature also impacts dissolved oxygen concentrations and may impact compliance with the DO objective. Strictly in terms of compliance with objectives and the impacts to other constituents, a thorough discussion of temperature must be included in the Water Quality section of the EIR/EIS. The Water Quality section must be amended to discuss temperature, compliance with limitations, protection of beneficial uses and the impacts from the various alternatives described in the EIR/EIS.

The temperature objectives in the Basin Plan and the Thermal Plan are principally based on antidegradation (changes in temperature) and not necessarily on the direct protection of beneficial uses of receiving water or the Delta. The Delta is home to numerous species of Coldwater fish and all life stages. Maximum temperatures for the protection of Coldwater fish species are well documented; and the Central Valley Regional Board has included specific temperature regimes in NPDES permits, such as for the Cities of Lincoln and Placerville. Any discussion of temperatures must not be limited to regulatory compliance with objectives but must also discuss the temperatures necessary to assure a productive population of Coldwater aquatic life.

20. Color is Inadequately Addressed.

CCR Title 22, Chapter 15, Article 16, Secondary Water Standards, Section 64449, states, in part, that: "The secondary MCLs shown in Tables 64449-A and 64449-B shall not exceed in the water supplied to the public by community water systems." Table 64449-A contains a MCL for color of 15 units.

Drinking water MCLs are included in the Central Valley Basin Plan by direct reference under the Chemical Constituents Objective; therefore the MCLs are applicable water quality standards.

The EIR/EIS (Section 8C.1.5.2) incorrectly states that: "*Color in water has a secondary MCL of 15 color units. Secondary MCLs are established <u>only as guidelines</u> to assist public water systems* *in managing their drinking water for aesthetic considerations*." In California the secondary MCL for color is a regulatory requirement and an applicable water quality standard.

The EIR/EIS (Section 8C.1.5.2) continues:

> "*To the degree that color itself is a concern from an aesthetic standpoint, conventional drinking water treatment removes many of the constituents that cause high color levels in water. <u>Coagulation/flocculation and filtration remove metals like iron, manganese and zinc</u>. <u>Aeration removes iron and manganese</u>. <u>Granular activated carbon removes most of the contaminants which cause color</u> (U.S. EPA 2012b). Color in the three major source waters to the Delta does not vary considerably (see Step 1, Table SA-6). The average in the Sacramento River at Freeport/Greene's Landing is approximately <u>22 units</u>, while San Francisco Bay at Martinez and San Joaquin River at Vernalis average approximately <u>30 units</u>. The standard deviations at these locations are 22–37 units, indicating that substantial variability exists at all three locations, and no specific source waters is consistently highest in color. <u>The Delta is not 303(d) listed for color and thus no beneficial use impairment due to its current levels is occurring</u>.*"

The total portions of iron, manganese and zinc may be removed by coagulation, flocculation and filtration; however, the dissolved segment will likely pass through such treatment systems. The EIR/EIS does not present any information regarding the total and/or dissolved speciation of these metals.

It makes no engineering sense that aeration would remove iron and manganese from a water column. Aeration is a process where air is added to a treatment process; this may remove volatile constituents to the atmosphere, but not metals.

The EIR/EIS clearly shows that color exceeds the water quality standard throughout the Delta where the average levels of 22 units and 30 units clearly exceed the 15 unit standard. The fact that the 303(d) list has not been modified to include color does not indicate that the water quality standard is not being exceeded.

The State Water Resources Control Board's Policy, Resolution No. 88-63, "Sources of Drinking Water" states that All surface and ground waters of the State are considered to be suitable, or potentially suitable, for municipal or domestic water supply and should be so designated by the Regional Boards…" Drinking water quality must be maintained within the waters of the State not just following extraction and treatment.

The drinking water beneficial use is impaired by color within the Delta; the EIR/EIS clearly documents this case by showing average color levels, which exceed the drinking water MCL. The EIR/EIS is not only deficient with regard to the discussion of color, but it is misleading and simply incorrect.

In closing, the EIR/EIS is seriously misleading, grossly inadequate, technically deficient and fails, in multiple ways, to meet the minimal CEQA and NEPA requirements for an environmental review document.

Thank you for considering these comments. If you have questions or require clarification, please don’t hesitate to contact us.

Sincerely,

Bill Jennings

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Attachment: Comments on Bay Delta Conservation Plan (BDCP) Draft EIR/EIS Chapter 8 – Water Quality, Chapter 25 – Public Health, G. Fred Lee, PhD, PE, BCEE, F.ASCE and Anne Jones-Lee, PhD

Comments on Bay Delta Conservation Plan (BDCP) Draft EIR/EIS
Chapter 8 – Water Quality
Chapter 25 – Public Health
G. Fred Lee, PhD, PE, BCEE, F.ASCE and Anne Jones-Lee, PhD
G. Fred Lee & Associates
El Macero, California
July 25, 2014

The following comments are offered in response to the request for public comment on the Bay Delta Conservation Plan (BDCP) Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) (http://baydeltaconservationplan.com/PublicReview.aspx). According to published information (http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Highlights_of_the_Draft_EIR-EIS_12-9-13.sflb.ashx),

> *"The proposed Bay Delta Conservation Plan (BDCP) is a comprehensive conservation strategy that intends to address the critical issues in the Delta using an ecosystem-based approach. The Plan would help to restore fish and wildlife species in the Delta and to improve reliability of water supplies, while minimizing impacts on Delta communities and farms."*
>
> *"The Draft EIR/EIS is intended to analyze and disclose the potential impacts on the human environment from the proposed action and alternatives."*

These comments address Chapter 8 of the draft EIR/EIS, which is devoted to Delta Water Quality as impacted by the preferred alternative plan described thus: (http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/Draft_BDCP_Highlights_12-9-13.sflb.ashx):

> *"The proposed BDCP project includes three new intakes along the Sacramento River in the north Delta and twin underground main tunnels through the Delta, approximately 30 miles long, to carry water under the Delta to the CVP* [Central Valley Project] *and SWP* [State Water Project] *pumping plants. A forebay would be needed near the intakes to collect water diverted from the river, then gravity flow would move water supplies through the tunnels."*
>
> *"The twin tunnels would be lined with concrete segments and capable of moving a maximum of 9,000 cubic feet per second (cfs). The gravity-flow system requires two 40-foot-diameter tunnels to convey the needed flows and overcome friction losses to keep water moving through the system."*

These comments also address additional aspects of public health impacts of the proposed project as included in Chapter 25 of the draft EIR/EIS, which is described thus (Chapter 25 page 1):

> *"This chapter focuses on issues related to human health and safety that could potentially be affected by implementation of the BDCP alternatives, particularly with respect to water quality, the potential to cause or worsen water borne illness, the potential to create habitat for vectors that may carry diseases; and to address potential health related concerns from additional electric transmission lines needed under most of the alternatives."*

Overall Assessment

Overall, the draft BDCP EIR/EIS and approaches used in its development are inadequate in scope and reliability for evaluating the potential impacts of diverting substantial amounts of Sacramento River water around or through the Delta on chemical constituents and water quality in Delta channels. The draft EIR/EIS basically used model output of expected changes in the concentrations of a few water quality parameters that have not been found to exceed a water quality objective at a few selected locations in the Delta as was done for this draft EIR/EIS. The approach used does not adequately or reliably consider the range of water quality impacts caused by the wide variety of potential pollutants present in the various Delta channels, that can be expected to result from the removal of large amounts of high-quality Sacramento River water from the Delta by this project.

As discussed herein the existing database on chemical contaminants contributed to the Delta, the impacts of sources of flow and changes in those sources on contaminant concentration, distribution, and impact within the Delta, and Delta channel water quality overall is too limited to make a sufficiently reliable assessment of the impacts of a project as extensive, expensive, and far-reaching as that proposed. Further, the level of uncertainty inherent in the existing modeling of Delta channel flows, and the Sacramento River component of those flows, renders it insufficiently reliable to adequately estimate the change in channel flow and character that will be expected to result from the massive diversion of Sacramento River flow around or through the Delta as proposed, much less the influence on those flow alterations on the concentrations, distribution, and impacts of chemical contaminants in the Delta.

As discussed in these comments there are a number of issues that should have been, but were not adequately, considered in assessing the water quality impacts of the existing Sacramento River flow into the Delta as well as the impacts of significantly reducing that flow. An area of the Delta of importance and with which Dr. Lee is particularly familiar is the Central Delta where the Sacramento River mixes with the San Joaquin River below Columbia Cut. As found in his studies of that area, and discussed in his reports that are on Drs. Lee and Jones-Lee's website, [www.gfredlee.com in the San Joaquin River Delta section at http://www.gfredlee.com/psjriv2.html] the amount of Sacramento River in the San Joaquin River channel is dependent on the amount of south Delta water that is pumped from the Delta by the CVP and SWP; the Sacramento River is drawn through the Delta by and toward the export pumps While the export pumps for those two projects will continue to draw south Delta water from the Southern Delta with half of total exports will coming from the north Delta facilities and, in the long-term alternative 4 will lead to increased exports and reduced outflow. These issues as well as others discussed herein need to be defined and evaluated before further consideration is given to the proposed BDCP diversion project.

A properly developed EIR/EIS would have included a detained analysis of potential errors in predicting constituent concentrations in the various Delta channels and in predicting the changes in flow and associated impacts on constituent concentrations, distribution, and effects. As it stands now Chapter 8 of this EIR/EIS does not reliably inform the public or decision-makers about the magnitude of the errors in estimates and conclusions inherent in the BDCP analysis of the impact of the diversions on Delta water quality/beneficial uses.

Background to Comments

Dr. G. Fred Lee has been involved and pioneered in graduate-level teaching, research, laboratory direction, consulting, and professional service in a myriad aspects of sources, fate, transport, and public health and environmental quality impacts of chemicals in natural waters (including lakes, reservoirs, rivers, estuaries, and nearshore marine waters) since the early 1960s; he has published nearly 1000 professional papers and reports on his work. Information on Drs. Lee and Jones-Lee's experience in these areas and publications are available on their website, www.gfredlee.com; their involvement in, and publications concerning, the Sacramento San Joaquin River Delta specifically are addressed at http://www.gfredlee.com/psjriv2.html.

Drs. Lee and Jones-Lee began working on Delta water quality issues in the summer of 1989 when he was a Distinguished Professor and she was Associate Professor of Engineering at the New Jersey Institute of Technology. At that time they were contracted by Delta Wetlands, a proposed private project to develop water supply reservoirs in the Delta, to evaluate the expected water quality in the proposed reservoirs based on their more than 25 years of work on reservoir water quality in the USA and many other areas of the world. Their project involved collecting and reviewing existing Delta water quality and related data and assessing the anticipated water quality in the proposed Delta reservoirs for water supply and other beneficial uses, since it was to be Delta water that would be used to fill the proposed reservoirs.

Beginning in 2002 Drs. Lee and Jones-Lee became technical advisors to the San Joaquin River Deep Water Ship Channel (DWSC) Low-DO (dissolved oxygen) TMDL Steering Committee. That involvement led to their being appointed principal investigators (PIs) for a $2-million CalFed project to investigate the causes of the low-DO problems in the DWSC. As project PIs they coordinated the studies of 12 investigators and developed synthesis reports for the project. In addition, they published additional papers and reports discussing the study findings and their significance and implications for water quality in Delta. Appendix A to these comments provides a brief description and citations with URLs for many of those writings; additional papers and reports on Delta water quality issues are available in the San Joaquin River & Delta section of their website (http://www.gfredlee.com/psjriv2.html). The SJR DWSC low DO TMDL project led to the development of,

> Lee. G. F., and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003). http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf
>
> Lee, G. F. and Jones-Lee, A., "Supplement to Synthesis Report on the Low-DO Problem in the SJR DWSC," Report of G. Fred Lee & Associates, El Macero, CA, June (2004). http://www.gfredlee.com/SJR-Delta/SynthRptSupp.pdf

and a number of other papers and reports on these studies. Further information on these studies is presented below.

Following the completion of the SJR DWSC DO TMDL synthesis report developed, Lee, G. F. and Jones-Lee, A., "Overview of Sacramento-San Joaquin River Delta Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA (2004). http://www.gfredlee.com/SJR-Delta/Delta-WQ-IssuesRpt.pdf

Lee, G. F., and Jones-Lee, A., "Overview—Sacramento/San Joaquin Delta Water Quality," Presented at CA/NV AWWA Fall Conference, Sacramento, CA, PowerPoint Slides, G. Fred Lee & Associates, El Macero, CA, October (2007). http://www.gfredlee.com/SJR-Delta/DeltaWQCANVAWWAOct07.pdf

The Lee and Jones-Lee (2004) Delta water quality report was the first comprehensive report on Delta water quality issues that examined the water quality implications of violations of water quality objectives in the Delta channels.

A major finding discussed therein was that the flow through the Delta channels impacted the location and magnitude of violations of water quality objectives in a Delta channel. While the importance of channel flow was impacting water quality/beneficial uses of the channel, it was pointed out that there was very little concrete understanding of how altering the channel flow impacted the water quality.

Of particular note with respect to addressing issues of the draft EIR/EIS Chapter 25 is Dr. Lee's BA and MSPH degrees in public health and his PhD in environmental engineering with a minor with public health. Much of his work during his five-decades-long profession career has been in water quality research and consulting activities that address public health and water quality aspects of chemical and biological contaminants in the environment and drinking water.

In summary these comments on the adequacy of the BDCP draft EIR EIS to adequately and reliably present information on the impact of proposed diversion of 9,000 cfs of Sacramento River around the Delta began in 1989. Since then we have been active in review of Delta water quality issues including developing over 90 reports/papers on these issues. Further information on this experience is in

Lee, G. F., and Jones-Lee, A., "Experience in Reviewing Delta Water Quality Issues," G. Fred Lee & Associates, El Macero, CA, April 3 (2011). http://www.gfredlee.com/SJR-Delta/GFLAJL-Delta-EXP-REV.pdf

Specific Comments on Draft EIR/EIS BDCP "Chapter 8 Water Quality"

"8.1 Readers' Guide

Chapter 8, Water Quality, describes the environmental setting and potential impacts of the BDCP on water quality in and upstream of the Sacramento-San Joaquin Delta. The chapter provides the results of the evaluation of the effects of implementing the BDCP conservation measures on water quality constituents under a no action alternative and 15 different project alternatives."

Pages 8-15&16 Table 8-1 lists the beneficial uses of the Delta. An issue that needs to be acknowledged and understood is that Sacramento River flow into and through the Delta plays an important part in reducing the water quality impacts of regulated and unrecognized/unregulated pollutants added to Delta water, both by its dilution of pollutant concentration and by decreasing the pollutant residence times in the Delta. The reduction in Sacramento River flow into and through the Delta that will result from the proposed plan will be expected to increase the water quality and public health significance of unrecognized/unregulated pollutants in the Delta waters. These issues were discussed in the following presentations and writings:

> Lee, G. F., and Jones-Lee, A., "Enhanced Delta Flows Needed to Help Control Water Quality Impacts of Delta Pollutants," Testimony for CA State Water Resources Control Board Public Workshop: Comprehensive (Phase 2) Review & Update to Bay-Delta Plan Workshop 1: Ecosystem Changes and the Low Salinity Zone, Sacramento, CA, September 5, 2012, Report of G. Fred Lee & Associates, El Macero, CA, August 17 (2012).
> http://www.gfredlee.com/SJR-Delta/Lee_Testimony_BayDelta_Workshop_1.pdf
>
> Lee, G. F., and Jones-Lee, A., “Discussion of Water Quality Issues That Should Be Considered in Evaluating the Potential Impact of Delta Water Diversions/Manipulations on Chemical Pollutants on Aquatic Life Resources of the Delta,” Report of G. Fred Lee & Associates, El Macero, CA, February 11 (2010).
> http://www.gfredlee.com/SJR-Delta/Impact_Diversions.pdf
>
> Lee, G. F., and Jones-Lee, A., “Comments on Water Quality Issues Associated with SWRCB’s Developing Flow Criteria for Protection of the Public Trust Aquatic Life Resources of the Delta,” Submitted to CA State Water Resources Control Board as part of Public Trust Delta Flow Criteria Development, by G. Fred Lee & Associates, El Macero, CA, February 11 (2010).
> http://www.gfredlee.com/SJR-Delta/Public_Trust_WQ.pdf

The proposed BDCP diversion of Sacramento River water around the Delta rather than continuing to allow river water to flow through the Delta to the CVP and SWP diversions will be detrimental to Delta water quality.

Section 8.2.1.8 beginning on Page 8-25 presents a review of “water quality constituents of concern,” and makes mention of some of the unrecognized pollutants. That section, however, does not adequately address this issue. There are many more unregulated and unrecognized potential pollutants that could be impacting Delta water quality beneficial uses; these issues are reviewed in:

> Lee, G. F., and Jones-Lee, A., “Unrecognized Environmental Pollutants,” Water Encyclopedia: Surface and Agricultural Water, Wiley, Hoboken, NJ pp 371-373 (2005).
> http://www.gfredlee.com/SurfaceWQ/WileyUnrecognizedPollutants.pdf
>
> Volume 13 Number 1, January 12, 2010 - Topics: Impacts of unmonitored, unregulated, and unrecognized chemicals in the aquatic systems.
> www.gfredlee.com/Newsletter/swnewsV13N1.pdf

As noted, above the proposed BDCP diversion of Sacramento River water around the Delta will be adverse to beneficial uses of the Delta due by enhancing the water quality impacts of unregulated and unregulated potential pollutants.

Page 8-26 lines 16-17 states, *“Excess nutrients can cause blooms of nuisance algae and aquatic* *vegetation, and their decay can result in depleted DO."* The draft does not adequately address the at least equally, and in some areas, more significant impacts of aquatic macrophytes on aquatic life (fish) habitat and recreational use (boating) in the Delta.

Page 8-36 lines 20-22 state, *"Nutrient concentrations currently in the Delta are high enough that they are probably not a true limiting factor for overall algal growth, and therefore increases in ammonia generally will not lead to an increase in algal growth (Jassby et al. 2002:1)."* It should be noted that the Central Valley Regional Water Quality Control Board (CVRWQCB) recently established a limit on the release of ammonia in city of Stockton wastewater discharges to the SJR on the belief that that ammonia is significant in stimulating the growth of algae in Southern California water supply reservoirs, causing tastes and odors in the water supply.

Page 8-47 presents a discussion of PCB-pollution of the Delta. That discussion is highly deficient in that it fails to mention the large amount of work that has been done on PCB accumulation in fish in the Delta and Delta tributaries. In 2002 Dr. Lee reviewed the extensive data on PCBs in fish of the Central Valley on behalf of the State Water Resources Control Board (SWRCB)/CVRWQCB. From that work, Lee and Jones-Lee developed the following reports:

> Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002).
> http://www.gfredlee.com/SurfaceWQ/OClTMDLRpt12-11-02.pdf
>
> Lee, G. F., and Jones-Lee, A., "Update of Organochlorine (OCl) 'Legacy' Pesticide and PCB Concentrations in Delta and Central Valley Fish," Report of G. Fred Lee & Associates, El Macero, CA, September 10 (2007).
> http://gfredlee.com/SurfaceWQ/UpdateLegacyPestCVFish.pdf

As discussed in those reports, the PCB-pollution of Delta and Delta tributary fish is a major water quality issue in the Central Valley waterways, sufficient to render the consumption of some large game fish such as largemouth bass hazardous to human health. While the California Office of Environmental Health Hazard Assessment (OHHEA) has reported that the levels of legacy chlorinated hydrocarbon pesticides such as DDT/DDE in fish tissue has been decreasing, the PCB content of Central Valley fish has not decreased.

Pages 8-51&52 present some information on the low-DO situation in the SJR DWSC. That discussion is deficient, however, in that it fails to discuss how manipulation of SJR DWSC flow has been, and still can be, a major factor in causing low-DO conditions in the DWSC. As discussed in reports cited in the Background section of these comments and Appendix A, the export of Delta waters by the CVP and SWP is a major contributor to low DO in the DWSC. The draft EIR/EIS fails to adequately discuss the current situation concerning the low DO in DWSC. As written, it misleads a reader to believe that the installation and operation an aeration system will control the low-DO situation in the DWSC. It also fails to discuss that there are no funds available to operate an aeration system in a manner to control the low DO that can result from the residual oxygen demand contributed from agricultural sources. Agricultural sources contribute algal nutrients to the upstream SJR waters; those nutrients support the growth of algae that cause significant oxygen demand in the DWSC especially under low-flow conditions in the SJR DWSC. The loss of Sacramento River water in the ship channel will potentially expand the downstream range of dissolved oxygen problems. Information on the current low-DO situation in the SJR DWSC is available in the following reports:

> Lee, G. F., Comments on SJR DWSC Low-DO issues discussed at March 28, 2012 BDCP meeting. Comments submitted to J. Grindstaff, Executive Officer, Delta Stewardship Council, by G. Fred Lee & Associates, El Macero, CA, April 28 (2012). http://www.gfredlee.com/SJR-Delta/Comments_SJR_DO_Issues_DSC.pdf
>
> Lee, G. F., and Jones-Lee, A., "Background Information on SJR Upstream Oxygen Demand Control Issues," Prepared for San Joaquin River Technical Work Group, Report of G. Fred Lee & Associates, El Macero, CA, July 11 (2010). http://www.gfredlee.com/SJR-Delta/Bkgrnd-SJR-DO.pdf
>
> Lee, G. F., and Jones-Lee, A., "Issues in Controlling the Residual Oxygen Demand in the SJR DWSC That Leads to DO WQO Violations," Report of G. Fred Lee & Associates, El Macero, CA, November 3, 2010; updated February 6 (2011). http://www.gfredlee.com/SJR-Delta/Residual-Ox-Demand-DWSC.pdf

As discussed in those reports, algal nutrients discharged by irrigated agriculture in the Grasslands Project area needs to be controlled in order to control algal growth in the SJR that contributes to the residual oxygen demand in the DWSC that can lead to low-DO conditions. The control of that source is especially important under the proposed plan that would divert Sacramento River water around the Delta, in order to mitigate the impact of the loss of Sacramento River on the low-DO situation in the SJR DWSC. The control of algal nutrients upstream in the SJR could greatly reduce, if not eliminate, the need for an aeration system.

Page 8-52 lines 36-37 states, *"EC and TDS values tend to be highly correlated because the majority of chemicals that contribute to TDS are charged particles that impart conductance of water."* It is incorrect to describe ions that contribute to electrical conductivity as "charge particles." The ions are not particles.

Pages 8-69 through 8-74 are devoted to "Nitrate/Nitrite and Phosphorus" in the Delta. That discussion is significantly deficient as it does not adequately discuss problems with the Gilbert discussion of N/P ratios as factor in influencing fish populations in the Delta. While those issues were discussed in an earlier section of the draft EIR/EIS, they are not discussed in the section that focuses on these issues on pages 8-70 and 8-71. When Gilbert first proposed to rely on N/P ratios, we developed the paper cited below to address the unreliability of that approach.

> Lee, G. F., and Jones-Lee, A., "Comments on the Adequacy of C. Dahm's Discussion of Delta Eutrophication Issues & Delta N/P Rations as a Cause of Adverse Impact on Delta Fish," Comments to Delta Stewardship Council, Report of G. Fred Lee &Associates, El Macero, CA, November 17 (2011). http://www.gfredlee.com/SJR-Delta/DSC-Comments-Dahm-Eutroph.pdf

> Lee, G. F., and Jones-Lee, A., "Comments on P. Glibert Defense of N/P Ratios as Major Influence on Aquatic Ecosystems Composition in Delta," Report of G. Fred Lee & Associates, El Macro, CA, September 17 (2012).
> http://www.gfredlee.com/SJR-Delta/Comments_Glibert_NPRatio.pdf

The BDCP draft EIR/EIs Water Quality Chapter 8 should have discussed the findings presented in Dr. Erwin van Nieuwenhuyse's professional workshop presentation and publication concerning the response in average summer chlorophyll concentration in the Delta to an abrupt and sustained reduction in phosphorus discharge from the Sacramento Regional Wastewater Treatment Plant. His presentation slides are available at http://www.cwemf.org/workshops/DeltaNutrientsWrkshp/VanNieuwenhuyse.pdf and his published paper is:

> vanNieuwenhuyse, E., "Response of Summer Chlorophyll Concentration to Reduced Total Phosphorus Concentration in the Rhine River (Netherlands) and the Sacramento– San Joaquin Delta (California, USA)," Can. J. Fish. Aquatic, Sci. 64(11):1529-1542 (2007).
> [http://www.ingentaconnect.com/content/nrc/cjfas/2007/00000064/00000011/art00006]

His presentation and paper provided important information on the impact of phosphorus discharges from that facility on planktonic algae in the Delta. He found that the changes in the fish production and ecosystem in Delta that occurred was more likely a result of the decrease in phosphorus discharged rather than of a change in N/P ratios.

Another issue that was not properly addressed in the draft EIR/EIS is that particulate inorganic phosphorus is largely not available to support algal growth. This issue has been reviewed in a number of publications including:

> Lee, G. F., "A Proposal for Assessing Algal-Available Phosphorus Loads in Runoff from Irrigated Agriculture in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, November (2006).
> http://www.gfredlee.com/Nutrients/AlgalAssayAvailP.pdf
>
> Lee, G. F., "Assessing Algal Available Phosphorus," Submitted for Inclusion in the Proceedings of US EPA Science Symposium: "Sources, Transport, and Fate of Nutrients in the Mississippi River and Atchafalaya River Basins," Minneapolis, MN, November 7-9 (2006).
> http://www.gfredlee.com/Nutrients/AvailPEPASymp06.pdf
>
> Lee, G. F., and Jones-Lee, A., "Assessing the Water Quality Significance of N & P Compound Concentrations in Agricultural Runoff," Invited Paper Presented at Agrochemical Division, American Chemical Society National Meeting, San Francisco, CA, September (2006).
> http://www.gfredlee.com/Nutrients/N-PRunoffACS.pdf

It is the algal-available P load to the Delta –soluble ortho P as well as algal-cell phosphorus – that needs to be the focus of phosphorus control programs to control excessive algal growth in Delta waters.

Pages 8-162 & 8-163 present a discussion of organic carbon. That discussion should include the findings reported in:

> Lee, G. F., "Synopsis of G. Fred Lee and Anne Jones-Lee's Work on Domestic Water Supply Water Quality, and TOC Issues in the Sacramento/San Joaquin River Delta," Report of G. Fred Lee & Associates, El Macero, CA (2004).
> http://www.gfredlee.com/SJR-Delta/GFL-DeltaTOCWork.pdf
>
> Lee, G. F. and Jones-Lee, A., "Issues that Need to Be Considered in Evaluating the Sources and Potential Control of TOC that Leads to THMs for Water Utilities that Use Delta Water as a Water Supply Source," Report of G. Fred Lee & Associates, El Macero, CA, May (2003).
> http://www.gfredlee.com/SJR-Delta/TOC_update.pdf

Pages 8-164 devoted to pesticides fails to mention the comprehensive review of the organochlorine legacy pesticides such as DDT that are still present in Delta tributary soils and sediments and contribute to the presence of some of these pesticides in some fish in the Delta and Delta tributaries in concentrations that represent a threat to human health. These issues are reviewed in:

> Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002).
> http://www.gfredlee.com/SurfaceWQ/OClTMDLRpt12-11-02.pdf
>
> Lee, G. F., and Jones-Lee, A., “Update of Organochlorine (OCl) ‘Legacy’ Pesticide and PCB Concentrations in Delta and Central Valley Fish,” Report of G. Fred Lee & Associates, El Macero, CA, September 10 (2007).
> http://gfredlee.com/SurfaceWQ/UpdateLegacyPestCVFish.pdf

While OEHHA has been finding that DDT concentrations in Central Valley fish are decreasing they remain sufficiently high in some fish to be of human health concern.

> Lee, G. F. and Jones-Lee, A., "Organochlorine Pesticide, PCB and Dioxin/Furan Excessive Bioaccumulation Management Guidance," California Water Institute Report TP 02-06 to the California Water Resources Control Board/Central Valley Regional Water Quality Control Board, 170 pp, California State University Fresno, Fresno, CA, December (2002).
> http://www.gfredlee.com/SurfaceWQ/OClTMDLRpt12-11-02.pdf
>
> Lee, G. F., and Jones-Lee, A., “Update of Organochlorine (OCl) ‘Legacy’ Pesticide and PCB Concentrations in Delta and Central Valley Fish,” Report of G. Fred Lee & Associates, El Macero, CA, September 10 (2007).
> http://gfredlee.com/SurfaceWQ/UpdateLegacyPestCVFish.pdf

Page 8-166 devoted to phosphorus fails to discuss key issues concerning the importance of phosphorus in impacting Delta water quality discussed above. Of particular importance is the work of vanNieuwenhuyse (2007) that found that when the phosphorus load to the Delta was decreased, the phytoplankton concentrations also decreased.

Page 8-173 begins Section 8.4.2 Determination of Effects. The comments presented below concerning this section focus on the BDCP's assessment of the impacts of the proposed BDCP diversion of Sacramento River water around the Delta on Delta water quality as presented in 8.4.3.9 Alternative 4 – Dual Conveyance with Modified Pipeline/Tunnel and Intakes 2, 3, and 5 (9,000 cfs; Operational Scenario H) that begins on page 8-407. These comments are also applicable to the other identified alternatives identified in the document.

Page 8-173Section 8.4.2.1 Screening Analysis and Results beginning on line 16 states:
"This water quality analysis assessed the potential effects of implementing the various alternatives on 182 constituents (or classes of constituents). The initial analysis of water quality effects, referred to as the "screening analysis" in the Methods of Analysis section (above) resulted in the following findings. Of the 182 constituents, 110 were determined to have no potential to be adversely affected by the alternatives to an extent to which adverse environmental effects would be expected. Historical data for these constituents showed no exceedances of water quality objectives/criteria in the major Delta source waters, were not on the State's 303(d) list in the affected environment, were not of concern based on professional judgment or scoping comments, and had no potential for substantial long-term water quality degradation. Consequently, no further analyses were performed for these 110 constituents."

The approach described for excusing particular constituents from further consideration of impact was imprudent. Such disregard may well result in not considering water quality parameters that are present in one or more of the Delta channels at concentrations just under current water quality criteria/standards/objectives and may well be of concern once the Sacramento River flow is reduced as proposed, and under future revisions of the US EPA water quality criteria, state of California water quality objectives, and regional boards' basin plan objectives. Further it is well-recognized that some of the current water quality criteria, state standards, and Basin Plan objectives are not protective of the beneficial uses of water. Also the BDCP approach for selecting the chemical constituents for analysis of impacts of diverting Sacramento River flow ignores the well established facts of additive and syngistic impacts of chemical where two or more chemicals that exist at less than toxic concentrations can be combined to cause toxicity.

As summarized in writings referenced in Appendix A, Dr. Lee has extensive experience in developing water quality criteria and state standards, and in their implementation in discharge limits for the protection of beneficial uses of waterbodies. On numerous occasions he has been asked to serve as an independent technical peer-reviewer of federal and state water quality criteria and standards. He and Dr. Jones-Lee have published several papers and reports on their work and findings in these areas including:

> Lee, G. F., and Jones-Lee, A., "Clean Water Act, Water Quality Criteria/Standards, TMDLs, and Weight-of-Evidence Approach for Regulating Water Quality," Water Encyclopedia: Water Law and Economics, Wiley, Hoboken, NJ, pp 598-604 (2005).
> http://www.gfredlee.com/SurfaceWQ/WileyCleanWaterAct.pdf
>
> Lee, G. F. and Jones-Lee, A., "Appropriate Use of Numeric Chemical Water Quality Criteria," Health and Ecological Risk Assessment, 1:5-11 (1995).
> http://www.gfredlee.com/SurfaceWQ/chemcri.pdf

Lee, G. F., Jones, A., and Newbry, B., "Water Quality Standards and Water Quality," Journ. Water Pollut. Control Fed. 54(7):1131-1138 (1982). http://www.gfredlee.com/SurfaceWQ/WQStds-WaterQuality.pdf

The draft BDCP EIR/EIS discussion of anticipated water quality impacts of the proposed plan did not appropriately or adequately address the fact that the concentrations and distribution/locations of regulated and unregulated/inadequately regulated chemicals, whether or not they have or are presently known to exceed regulatory limits, will be expected to be altered by the diversion of large amounts of Sacramento River water around the Delta. This will be expected to affect the water quality impacts of regulated and unregulated/inadequately regulated chemicals in Delta waters. The BDCP's dismissing from further analysis of potential water quality effects, constituents that it concluded based on inadequate evaluation and without appropriate attention to the impact of the loss of Sacramento River water to the system, had not exceeded water quality objectives/criteria in the major Delta source waters, were not on the State's 303(d) list in the affected environment, or were not of concern, renders the draft EIR/EIS fundamentally flawed. That flaw alone is sufficiently significant to merit the denial of certification of this draft EIR/EIS.

As discussed in our review of the Delta Water Quality report cited below, as part of SWRCB water rights decision D-1641, several agencies, through the Interagency Ecological Program (IEP), conduct an Environmental Monitoring Program (EMP) that is supposed to provide information on the impacts of Delta water exports to central and Southern California on Delta resources and water quality.

Lee, G. F. and Jones-Lee, A., "Overview of Sacramento-San Joaquin River Delta Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA (2004). http://www.gfredlee.com/SJR-Delta/Delta-WQ-IssuesRpt.pdf

A critical review of the IEP EMP, however, shows that it falls short of adequately defining the full range of water quality impacts of the export of Delta water by the federal project (Central Valley Project – CVP) and state project (State Water Project – SWP). In 2004 Dr. Lee was a member of the peer-review panel that reviewed the adequacy of the IEP water quality monitoring program. In that forum he pointed out that that program was highly deficient in providing the information needed to evaluate the impacts of the SWP diversions on Delta water quality. His comments were ignored, and even today large amounts of money continue to be spent on Delta monitoring but are not directed to the stated purpose of the D-1641 water rights decision that allowed the SWP to divert large amounts of water from the Delta.

The CVRWQCB and SWRCB have been trying for several years, without success, to develop a comprehensive Delta water quality monitoring program. The basic problem is a lack of funding for such a program. If the BDCP-proposed Delta diversion project is allowed to be implemented, those benefiting from the project should be required to fund a comprehensive water quality monitoring program to adequately define the impacts of that diversion on Delta water quality.

Page 8-407 begins the discussion of Section 8.4.3.9, Alternative 4 – Dual Conveyance with Modified Pipeline/Tunnel and Intakes 2, 3, and 5 (9,000 cfs; Operational Scenario H). This section states, "Alternative 4 would comprise physical/structural components similar to those under Alternative 1A, however, there are notable differences. Alternative 4 would convey up to 9,000 cfs of water from the north Delta to the south Delta and that Alternative 4 would include an operable barrier at the head of Old River. Diverted water would be conveyed through pipelines/tunnels from three screened intakes (i.e., Intakes 2, 3 and 5) located on the east bank of the Sacramento River between Clarksburg and Courtland. Alternative 4 would include a 245 acre intermediate forebay at Glannvale Tract. Clifton Court Forebay would be dredged and expanded by approximately 690 acres to the southeast of the existing forebay. Water supply and conveyance operations would follow the guidelines described as Scenario H1, H2, H3, or H4, which variously include or exclude implementation of fall X2 and/or enhanced spring outflow. Conservation Measures 2–22 would be implemented under this alternative, and would be the same as those under Alternative 1A."

The subsection, "Effects of the Alternative on Delta Hydrodynamics," begins on page 408 with: *"Under the No Action Alternative and Alternatives 1–9, the following two primary factors can substantially affect water quality within the Delta:*

- *Within the south, west, and interior Delta, a decrease in the percentage of Sacramento River-sourced water and a concurrent increase in San Joaquin River-sourced water can increase the concentrations of numerous constituents (e.g., boron, bromide, chloride, electrical conductivity, nitrate, organic carbon, some pesticides, selenium). This source water replacement is caused by decreased exports of San Joaquin River water (due to increased Sacramento River water exports), or effects of climate change on timing of flows in the rivers. Changes in channel flows also can affect water residence time and many related physical, chemical, and biological variables.*

- *Particularly in the west Delta, sea water intrusion as a result of sea level rise or decreased Delta outflow can increase the concentration of salts (bromide, chloride) and levels of electrical conductivity. Conversely, increased Delta outflow (e.g., as a result of Fall X2 operations in wet and above normal water years) will decrease levels of these constituents, particularly in the west Delta."*

As discussed in these comments, not only would the concentrations of the mentioned constituents increase with increases in the proportion of San Joaquin River water but also the concentrations of many other known pollutants as well as unregulated, unrecognized and inadequately regulated pollutants be increased. For some constituents the concentrations would be expected to increase in some Delta channels to levels in excess of water quality objectives and in some cases significantly impact Delta water quality. The draft EIR/EIS is deficient in that it fails to address this issue. Also, decreases in the amount of Sacramento River water in the Delta will result in changes in the areas in which adverse impacts on Delta channel water quality occur.

The draft EIR EIS fails to mention that increasing the concentrations of pollutants that are already causing water quality objectives is a violation of SWRCB/CVRWQCB antigradation issues that preclude degrading existing water quality of causing a degradation of water quality that causes and water quality objective violation.

Page 8-432 lines 39-43 and page 8-433 lines 1-2 state, *“Amounts of oxygen demanding substances present (e.g., ammonia, organics) in the reservoirs and rivers upstream of the Delta, rates of photosynthesis (which is influenced by nutrient levels/loading), and respiration and decomposition of aquatic life is not expected to change sufficiently under Alternative 4 to substantially alter DO levels relative to Existing Conditions or the No Action Alternative. Any minor reductions in DO levels that may occur under this alternative would not be expected to be of sufficient frequency, magnitude and geographic extent to adversely affect beneficial uses, or substantially degrade the quality of these water bodies, with regard to DO.”*

That assessment ignores the importance of Sacramento River water currently drawn into the Delta by the current export projects, CVP and SWP, in the existing DO levels in the Delta, and the effect on DO that the reduction of that flow as proposed would have. As discussed in the synthesis report cited below, the flow of the Sacramento River water through the Delta limits the downstream extent of the low-DO conditions in the SJR DWSC to Turner Cut. With the reduced Sacramento River flow into the Central Delta as proposed, the lower SJR DWSC could experience low-DO conditions.

> Lee. G. F., and Jones-Lee, A., "Synthesis and Discussion of Findings on the Causes and Factors Influencing Low DO in the San Joaquin River Deep Water Ship Channel near Stockton, CA: Including 2002 Data," Report Submitted to SJR DO TMDL Steering Committee/Technical Advisory Committee and CALFED Bay-Delta Program, G. Fred Lee & Associates, El Macero, CA, March (2003). http://www.gfredlee.com/SJR-Delta/SynthesisRpt3-21-03.pdf

As discussed in our reports the current operation of the CVP and SWP draws SJR water that enters the DWSC to the export pumps at Turner Cut. This has important implications for the homing of Chinook Salmon to SJR watershed spawning waters since there is no homing signal as the fish enter San Francisco Bay/Delta to guide them to their home stream waters. We have discussed this issue in,

> Lee, G. F., and Jones-Lee, A., “Need for SJR Watershed Water to Reach San Francisco Bay,” Comments submitted to Delta Stewardship Council, Sacramento, CA by G. Fred Lee & Associates, El Macero, CA, May 22 (2011).
> http://www.gfredlee.com/SJR-Delta/NeedSJRtoSFBay.pdf

Page 8-433 lines 13 through 21 state,
Under all operational scenarios of Alternative 4, minor DO level changes could occur due to nutrient loading to the Delta relative to Existing Conditions and the No Action Alternative (see WQ-1, WQ-15, WQ-23). The state has begun to aggressively regulate point-source discharge effects on Delta nutrients, and is expected to further regulate nutrients upstream of and in the Delta in the future. Although population increased in the affected environment between 1983 and 2001, average monthly DO levels during this period of record show no trend in decline in the presence of presumed increases in anthropogenic sources of nutrients (see Table 4.4-15 in the ES/AE section). Based on these considerations, excessive nutrients that would cause low DO levels would not be expected to occur under any operational scenario of Alternative 4.

Based on Dr. Lee’s more than five decades of experience assessing the impacts of nutrients on DO in waterbodies throughout the world and his 25 years of experience in investigating nutrient

sources and impacts in the Delta watershed and within the Delta, it is misleading to characterize the current SWRCB efforts in developing nutrient objectives as having *“begun to aggressively regulate”* nutrient discharges. It will be many years before reliable and workable nutrient objectives will be available that can be used to regulate nutrient discharges from agricultural sources in the Delta watershed. As discussed above the major cause of the residual oxygen demand and low-DO in the SJR DWSC is nutrient input from upstream agricultural sources that stimulates the growth of algae in the DWSC which because of the flow-related residence time, are able to decompose in the DWSC where their bacterial decomposition exerts greater oxygen demand than can be assimilated.
We have developed several paper/reports on the impact of and controlling nutrients in SJR watershed including.

> Lee, G. F., and Jones-Lee, A., “Potential Water Quality Impacts of Agriculture Runoff/Discharges in the Central Valley of California,” Presented at Central Coast Agricultural Water Quality Coalition’s 2007 National Conference on Agriculture & the Environment, Monterey, CA, PowerPoint Slides, G. Fred Lee & Associates, El Macero, CA, November (2007).
> http://www.gfredlee.com/SJR-Delta/SJRAgImpactsMontereyNov2007.pdf
>
> Lee, G. F., and Jones-Lee, A., “Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA,” Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008). http://www.gfredlee.com/SJR-Delta/CWEMF_WS_synopsis.pdf
>
> “Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modeling,” Agenda for Technical Workshop sponsored by California Water and Environmental Modeling Forum (CWEMF), Scheduled for March 25, 2008 in Sacramento, CA (2008).
> http://www.gfredlee.com/SJR-Delta/CWEMF_Workshop_Agenda.pdf

An issue that needs to be addressed by the SWP is the low-DO situation that occurs in the southern-most part of Old River channel in the South Delta in the vicinity of the Tracy Boulevard Bridge. The SWP export pumping of South Delta water resulted in major flow problems in the South Delta. The temporary barriers constructed to try maintain the water levels in the South Delta channels to enable agriculture to continue to pump irrigation water from the channel have restriced the flow in the southern-most part of Old River channel sufficiently to allow large-scale algal growth and die-off leading to low DO in the channel. As part of an extension of the SJR DWSC Low-DO TMDL project, we organized a boat tour of the South Delta channels on August 5, 2004. The DeltaKeeper (Bill Jennings) made available a DK boat and crew that enabled several members of the CVWQCB and CalFed staff to accompany Lee on this tour. During the tour the evidence of a large fish kill that had occurred the evening before was observed near the Tracy Blvd Bridge; hundreds of dead fish were observed floating on the surface of the water. The DWR maintains a DO monitoring station in the region of the fish kill, which showed that the previous night the DO in the channel dropped to near-zero. A report on that tour and the fish kill is presented in,

> Lee, G. F.; Jones-Lee, A. and Burr, K., "Results of the August 5, 2003,Tour of the South Delta Channels," Report of G. Fred Lee & Associates, El Macero, CA, February (2004).

http://www.gfredlee.com/SJR-Delta/South-Delta-Tour.pdf

Lee, G. F., "Comments on SWRCB Review of South Delta Channel Water Quality," Report of G. Fred Lee & Associates, El Macero, CA, January 15 (2011). http://www.gfredlee.com/SJR-Delta/SoDeltaWQ1-11.pdf

Review of the data from the DWR monitoring station at that location shows frequent DO water quality objective violations occurred in this channel. That situation has been occurring for many years. It is clear that DWR as part of the SWP should be required to eliminate the low-DO problems that occur in the South Delta as a result of the operation of the SWP.

The low DO in the Old River channel is the result of high nutrient and algal lows in SJR that enters Old River at the Head of Old River and the lack of adequate flow of the channel due to the barrier constructed to maintain water levels in the Old River Channel.

Page 8-435 lines 17-20 states with regard to NEPA Effects:
"CM2–CM22 would not be expected to contribute to adverse DO levels in the Delta. The increased habitat provided by CM2–CM11 could contribute to an increased biochemical or sediment demand, through contribution of organic carbon and the action of plants decaying. However, similar habitat exists currently in the Delta and is not identified as contributing to adverse DO conditions."

Dr. Lee has considerable experience in examining the character of water discharged from wetlands; he conducted some of the first work done on the impacts of wetlands on water quality, which was discussed in the following paper:

Lee, G. F., Bentley, E., and Amundson, R., "Effects of Marshes on Water Quality," IN: Ecological Studies 10, Coupling of Land and Water Systems, Springer-Verlag, New York, pp. 105-127 (1975). http://www.gfredlee.com/SurfaceWQ/MarshesBentleyAmundson.pdf

Based on the monitoring programs and studies that have been conducted in the Delta, it is inappropriate to use the range of DO found in low-flow channels that receive predominately tidal flow from wetlands. The development of wetlands as part of establishing addition shallow habitat as part of the proposed BDCP Delta improvement.

Page 8-435 lines 25-27 states:
"CM14, an oxygen aeration facility in the Stockton Deep Water Ship Channel to meet TMDL objectives established by the Central Valley Water Board, would maintain DO levels above those that impair fish species when covered species are present."

As discussed elsewhere in these comments, the implementation of an aeration facility in the SJR DWSC to eliminate DO water quality objectives since the funding for construction and operation is not available. Further there is significant questions about whether the proposed aeration facility can prevent DO depletions below the water quality objective especially in the near bottom waters of the DWSC so that there are no more than one violation of the DO objective in any amount more than once every three years.

Page 8-440 lines 44-45 and page 8-441 lines 1-3 states:
"In addition to and to supplement Mitigation Measure WQ-11, the BDCP proponents have incorporated into the BDCP, as set forth in EIR/EIS Appendix 3B, Environmental Commitments, a separate, non-environmental commitment to address the potential increased water treatment costs that could result from EC concentration effects on municipal, industrial and agricultural water purveyor operations."

While it may be possible to pay water utilities and agricultural interests as compensation for impact of increased salinity due to the diversion of Sacramento River around the Delta, an issue that needs to be considered is the impact of increased salinity in domestic waters on the recharge of domestic wastewaters. An increase in the salinity in a municipality's water supply can lead to restrictions on the recharge of its domestic wastewaters as part of groundwater replenishment projects. This is already an issue in the use of Delta waters as a water supply for some Southern California municipalities. It can be very expensive to treat a domestic wastewater to achieve groundwater recharge limits.

Page 8-447-261. The section on the Effects of Nitrate Concentrations Resulting from Facilities Operations and Maintenance (CM1) that begins on line 13 needs to be expanded to include the impact of the CVRWQCB's recent adoption of reduced nitrate loads to the SJR and Delta from the Stockton waste water treatment plant.

Page 8-407 line 32 begins the presentation of Section 8.4.3.9 Alternative 4 – Dual Conveyance with Modified Pipeline/Tunnel and Intakes 2, 3, and 5 (9,000 cfs; Operational Scenario H). Many of the issues discussed above in reference to Alternative 4 are applicable to all of the alternatives involved in diversion of Sacramento River water around the Delta. While the relative reduction in the amount of diversion could be expected to lessen or increase the magnitude of some of the impacts, those impacts would still need to be better defined.

Page 8-700 line 28 begins the discussion of 8.4.3.16 Alternative 9—Through Delta/Separate Corridors (15,000 cfs; Operational Scenario G). The diversion of Sacramento River water through the Delta via isolated facilities would lead to many of the same adverse impacts noted above for diversion of Sacramento River water around the Delta via tunnels and or canals.

Page 8-771 line 15 begins a list of references for this draft EIR/EIS. While the list of references is voluminous, as noted in these comments there are a number of key, pertinent papers and reports not included in this list that should have been reviewed, discussed, and referenced in a certifiable EIR/EIS for the proposed BDCP project. The exclusion of those sources contributed to the deficiencies discussed in these comments.

Additional Comments

The limitations of the ability of DWR to provide reliable information on flow of water in Delta channels occurred when we were trying to understand the flow of Sacramento River and the San Joaquin River through the Central Delta as part of our work on SJR DWSC Low-DO TMDL project. We were unable to obtain from DWR modeling staff the respect flows in the Central Delta channels as a function of SJR, Sacramento River, Old River flows and export pumping by the CVP SWP. This situation still exists today. This is the type of information that is needed to begin to reliably evaluate the impact of diversion of Sacramento River flow around or through the Delta.

MBK Engineers conducted a detailed review of BDCP modeling; Walter Bourez of MBK Engineers presented to the DISB his findings on one of the models used in the BDCP draft EIR/EIS which differed from those presented by BDCP. (He used a 2013 version of the model, rather than the 2009 model BDCP used.)

MBK Engineers concluded in its presentation to the Delta Independent Science Board (2014), *"An initial review led the Reviewers to conclude that the BDCP Model, which serves as the basis for the environmental analysis contained in the BDCP Environmental Impact Report/Statement (EIR/S), provides very limited useful information to understand the effects of the BDCP. The BDCP Model contains erroneous assumptions, errors, and outdated tools, which result in impractical or unrealistic Central Valley Project (CVP) and State Water Project (SWP) operations. The unrealistic operations, in turn, do not accurately depict the effects of the BDCP."*
MBK Engineers presentation to Delta Independent Science Board (2014)

The Delta Independent Science Board (DISB) is required by the Delta Reform Act of 2009 to review the BDCP draft EIR/EIS and to submit its comments to the Delta Stewardship Council and the Department of Fish and Game. In its May 15, 2014 cover letter transmitting its comments pursuant to that requirement [http://deltacouncil.ca.gov/sites/default/files/documents/files/Attachment-1-Final-BDCP-comments.pdf], the DISB acknowledged the monumental task faced by the preparers of the draft EIR/EIS but expressed the following conclusion:
"We find, however, that the science in this BDCP effort falls short of what the project requires. We highlight our concerns in the attached report. The report, in turn, draws on our detailed responses to charge questions from the Delta Stewardship Council (Appendix A) and on our reviews of individual chapters in the DEIR/DEIS (Appendix B). Our concerns raise issues that, if not addressed, may undermine the contributions of BDCP to meeting the co-equal goals for the Delta."

The DISB report transmitted by that letter, cited below, begins with the following summary:

"Summary of Major Concerns
Does the Bay Delta Conservation Plan (BDCP) Draft EIR/EIS (DEIR/DEIS) use the best available science in analyzing project alternatives and their effects? That is, do the analyses use science that is good enough, and use it well enough, for a project that is so large, complex, expensive, long-lasting, and important?

We find that the DEIR/DEIS currently falls short of meeting this "good enough" scientific standard. In particular:
1. Many of the impact assessments hinge on overly optimistic expectations about the feasibility, effectiveness, or timing of the proposed conservation actions, especially habitat restoration.
2. The project is encumbered by uncertainties that are considered inconsistently and incompletely; modeling has not been used effectively to bracket a range of uncertainties or to

explore how uncertainties may propagate.
3. The potential effects of climate change and sea-level rise on the implementation and outcomes of BDCP actions are not adequately evaluated.
4. Insufficient attention is given to linkages and interactions among species, landscapes, and the proposed actions themselves.
5. The analyses largely neglect the influences of downstream effects on San Francisco Bay, levee failures, and environmental effects of increased water availability for agriculture and its environmental impacts in the San Joaquin Valley and downstream.
6. Details of how adaptive management will be implemented are left to a future management team without explicit prior consideration of (a) situations where adaptive management may be inappropriate or impossible to use, (b) contingency plans in case things do not work as planned, or (c) specific thresholds for action.
7. Available tools of risk assessment and decision support have not been used to assess the individual and combined risks associated with BDCP actions.
8. The presentation, despite clear writing and an abundance of information and analyses, makes it difficult to compare alternatives and evaluate the critical underlying assumptions."

> Delta Independent Science Board, "Review of the Draft EIR/EIS and Draft BDCP," Report to the Delta Stewardship Council and California Department of Fish and Wildlife, May 15 (2014).

Comments made to the Delta Stewardship Council by Dr. Alex Parker of the California Maritime Academy and a member of the independent science review panel of the BDCP's Effects Analysis established at the request of the Department of Water Resources and the Bureau of Reclamation concerning the technical aspects of the plan were quoted in a June 3, 2014 posting on: http://mavensnotebook.com/2014/06/03/reviewing-the-science-of-the-bay-delta-conservation-plan/. That posting stated:
"Dr. Parker said he would just provide the highlights of their analysis and the major themes that emerged as a result of their review. 'We are heartened to see that the Delta Independent Science Board review of the draft BDCP and the EIR/EIS echoed a lot of our concerns, and I think that probably highlights for folks the areas where attention needs to be paid.'

He said there were four themes that emerged for the panel: [two of which are quoted here:]

- *The first is a real disconnect between the assessments of scientific certainty or uncertainty that is reflected in the Effects Analysis chapter versus what is in technical appendices, he said. 'This was a concern to us because we know that with a set of documents this vast, most people are going to read the Effects Analysis and not the technical appendices. There's a real concern that the effects analysis doesn't adequately address that level of uncertainty around virtually all of the conclusions that are made.'*
- *The implementation of the BDCP and its effects are highly uncertain, so the way to address this is through adaptive management, he said. 'It is part of the plan; however the Effects Analysis needs to really clearly articulate the uncertainty in order to have an effective adaptive management process and at present, that simply doesn't exist within the main document.'"*

"Another place where this [a lack of a whole ecosystem approach in the BDCP effects analysis] is clear to us is with respect to hydrodynamics modeling, Dr. Parker said. 'Hydrodynamics is

basically the movement of water, and this is a master variable in the system,' he said. 'If we want to have any conversation about circulation patterns, temperatures, submerged aquatic vegetation, contaminants, nutrients – we need to have reasonable modeling of the hydrodynamic system, and because we don't know where the restoration opportunity areas are necessarily defined in all cases – these are places where major conservation and restoration activities will take place – they were limited in what they could model in terms of hydrodynamics. That wasn't adequately acknowledged throughout, and again, raises high level of uncertainty in the ultimate analysis.' He also noted there were some counterintuitive results from some of the hydrodynamic modeling that was done there, but there wasn't sufficient information to really understand where those results came from."

Those conclusions concerning the lack of a reliable database and Delta flow information to develop a credible EIR/EIS for the BDCP for assessing the impacts of the diversion of Sacramento River water around or through the Delta, are in keeping with a number of the specific comments made by us independently above.

Comments on Chapter 25 – Public Health

Page 25-1 line 3 states, *"This chapter focuses on issues related to human health and safety that could potentially be affected by implementation of the BDCP alternatives, particularly with respect to water quality, the potential to cause or worsen water borne illness, the potential to create habitat for vectors that may carry diseases; and to address potential health related concerns from additional electric transmission lines needed under most of the alternatives."*

Page 25-1 lines 20-22 states, *"This chapter does not duplicate the information provided in other sections of the EIR/EIS, but rather focuses the discussion on potential impacts on human health of implementing the BDCP action alternatives."* Our comments on those bioaccumulating constituents in Chapter 8 are also applicable to the same constituents covered in Chapter 25.

Page 25-4 lines 9-11 states, *"Please see Chapter 8, Water Quality, Section 8.1.3.13, Pesticides and Herbicides, for a detailed discussion on the prior use of legacy pesticides in the Plan Area."* As discussed in our comments on those sections of Chapter 8, the BDCP draft EIS EIR is deficient as it fails to adequately discuss the readily available compilation data of organochlorine pesticides and PCBs in Delta and Central Valley water and fish developed and discussed by Lee and Jones-Lee.

Page 25-6 presents information on some of the sources of mercury in the Delta watershed. In addition to those mentioned, another tributary source of mercury is the Putah Creek. The findings of Lee and Jones-Lee's study of the current situation regarding mercury in Putah Creek have been published as,

> Lee, G. F., and Jones-Lee, A, "LEHR Superfund Stormwater Runoff and Putah Creek Mercury Issues," *Journal Remediation*, **19(2)**:123-134, Spring (2009). http://www.gfredlee.com/SJR-Delta/LEHRrunoffHgRemediation.pdf
>
> Lee, G. F., and Jones-Lee, A., "Summary of Slides – Putah Creek Mercury Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA, Presented to Delta Tributaries Mercury Council, December 2 (2008).

http://www.gfredlee.com/SJR-Delta/PutahHgMineSummary.pdf

Lee, G. F., and Jones-Lee, A., "Runoff of Mercury from UCD/DOE LEHR Superfund Site – Putah Creek Mercury Issues," PowerPoint Slides for Presentation to Delta Mercury Tributaries Council, Sacramento River Watershed Program [http://www.sacriver.org/issues/mercury/dtmc/], December 2 (2008). http://www.gfredlee.com/SJR-Delta/PutahHgMinesli.pdf

As discussed in those papers and reports, soils along Putah Creek are polluted with mercury that accumulates in fish tissue. The source of that mercury is mercury mines in the creek's watershed. Before the Lake Berryessa dam was constructed, stormwater runoff from the Putah Creek watershed transported mercury from former mercury mines to the Putah Creek flood plain. It will be very difficult to remediate the mercury-polluted soils along Putah Creek, and thus difficult to reduce the Putah Creek as source of mercury for the Delta.

Page 25-7 section on PCBs makes reference to deVlaming (2008). More reliable sources of information on PCBs in Delta tributaries and Delta water and fish are those included in the reports:

Lee, G. F., and Jones-Lee, A., "Update of Organochlorine (OCl) 'Legacy' Pesticide and PCB Concentrations in Delta and Central Valley Fish," Report of G. Fred Lee & Associates, El Macero, CA, September 10 (2007). http://gfredlee.com/SurfaceWQ/UpdateLegacyPestCVFish.pdf

Lee, G. F., "Need for Funding to Support Studies to Control Excessive Bioaccumulation of Organochlorine 'Legacy' Pesticides, PCBs and Dioxins in Edible Fish in the Central Valley of California," Report of G. Fred Lee & Associates, El Macero, CA, July (2003). http://www.gfredlee.com/Runoff/OCl_Support.pdf

Lee, G.F, and Jones-Lee, A., "Developing TMDLs for Organochlorine Pesticides and PCBs," Presented at the American Chemical Society Environmental Chemistry Division national meeting in San Diego, California, April (2001). http://www.gfredlee.com/Runoff/sandiego_030801.pdf

Lee, G. F. and Jones-Lee, A., "Excessive Bioaccumulation of Organochlorine Legacy Pesticides & PCBs in CA Central Valley Fish," PowerPoint Slides made available at US EPA National Fish Contaminant Forum, San Diego, CA, January (2004). http://www.gfredlee.com/Runoff/OCl-slides-SanDiego.pdf

Page 25-7 devoted to Legacy Pesticides failed to reference the reports of Lee's comprehensive review of legacy pesticides in Delta and Central Valley fish on behalf of the SWRCB and CVRWQCB; those reports were referenced in the comments above on draft EIR/EIS Chapter 8.

Page 25-8 lines 17-21 states, *"In March 2004, the U.S. Food and Drug Administration (FDA) issued recommendations for the consumption of fish or shellfish for women who might become pregnant, women who are pregnant or nursing, and young children (no other sensitive receptors were identified). While FDA states fish and shellfish are an important part of a healthy diet,* *nearly all fish and shellfish contain trace amounts of mercury (U.S. Food and Drug Administration 2011). However, some species contain higher amounts of the toxicant, and thus it is not recommended that women who might become pregnant, women who are pregnant or nursing, or young children eat shark, swordfish, king mackerel, or tilefish. None of these species are commonly found in the Delta. Further, local advisories should be checked for the safety of locally caught fish and if these advisories are unavailable, the weekly consumption of fish or shellfish species should be limited."* As discussed in US EPA guidance referenced below, it is highly inappropriate to compare Delta or other waterbody fish tissue concentration to FDA tissue limits for the purpose of assessing the health hazard associated with consuming those fish.

> US EPA, "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Volume 1 Fish Sampling and Analysis, Third Edition," EPA 823-B-00-007, US EPA Office of Water, Washington, DC, November (2000).
> USEPA_2000_Guidance_Document_volume2.pdf

As stated in the above-referenced US EPA guidance,
"EPA and FDA have agreed that the use of FDA Action Levels for the purpose of making local advisory determinations is inappropriate. in letters to all states, guidance documents, and annual conferences, this practice has been discouraged by EPA and FDA in favor of EPA's risk-based approach to derive local fish consumption advisories."

"FDA action levels and tolerances are indicators of chemical residue levels in fish and shellfish that should not be exceeded for the general population who consume fish and shellfish typically purchased in supermarkets or fish markets that sell products that are harvested from a wide geographic area, including imported fish and shellfish products. However, the underlying assumptions used in the FDA methodology were never intended to be protective of recreational, tribal, ethnic, and subsistence fishers who typically consume larger quantities of fish than the general population and often harvest the fish and shellfish they consume from the same local waterbodies repeatedly over many years."

The US EPA guidelines or the California Office of Environmental Health Hazard Assessment (OEHHA) fish consumption advisory values should be used to determine the potential public health hazards associated with consumption of contaminated fish.

Page 25-24 lines 33-34 states, *"The CWA sets water quality standards for all contaminants in surface waters. In California, such responsibility has been delegated to the State, which administers the CWA through the Porter-Cologne [Water Quality Control] Act (Water Code, Section 13000 et seq.)."* As discussed in reviews cited below, the Clean Water Act establishes the approach for establishing water quality criteria that can be developed into state water quality standards. Contrary to the BDCP's statement quoted above, the CWA does not "set water quality standards for all contaminants."

> G. Fred Lee and Anne Jones-Lee Expertise and Experience in Water Quality Standards and NPDES Permits Development and Implementation into NPDES Permitted Discharges
> http://www.gfredlee.com/exp/wqexp.htm
>
> Lee, G. F., and Jones-Lee, A., "Clean Water Act, Water Quality Criteria/Standards, TMDLs, and Weight-of-Evidence Approach for Regulating Water Quality," Water Encyclopedia:

Water Law and Economics, Wiley, Hoboken, NJ, pp 598-604 (2005).
http://www.gfredlee.com/SurfaceWQ/WileyCleanWaterAct.pdf

Page 25-36 lines 6-8 states, discussed in Chapter 8, Water Quality (Section 8.1.1.6), numerical water quality objectives and standards have been established to protect beneficial uses, and therefore represent concentrations or values that should not be exceeded. “That statement is not accurate in that water quality objectives and standards can be exceeded once every three years.

Page 25-36 Section 25.3.1.3 Constituents of Concern and Water Quality again describes the approach used for the draft BDCP EIR/EIS to identify the constituents of concern, that is limiting the constituents considered to those that have been found to be present in concentrations above a water quality object or other standard. As discussed in our comments on Chapter 8 above, this approach is not technically valid for identifying all the constituents that need to be considered in evaluating potential water quality and public health impacts of the proposed BDCP.

As discussed above in the overall assessment, there is insufficient valid information to reliably evaluate the impact of diverting Sacramento River around or through the Delta on water quality/beneficial uses of the Delta.

Appendix A

The following professional papers, reports, and presentations provide examples of Drs. Lee and Jones-Lee's experience in reviewing Delta water quality issues.
Lee, G. F., "New & Updated Presentations/Publications on Delta and SJR Water Quality Issues," Comments to J. Grindstaff, Director CALFED, Sacramento, CA, G. Fred Lee & Associates, El Macero, CA, October 2 (2007).
http://www.gfredlee.com/SJR-Delta/PubsPresentsDeltaSJR.pdf

Lee, G. F., and Jones-Lee, A., "Delta Nutrient-Related Water Quality Problems," PowerPoint Slides Presented at CALFED Science Conference, Sacramento, CA, October 24 (2008).
http://www.gfredlee.com/SJR-Delta/CALFED_SciConf10-08.pdf

Lee, G. F., and Jones-Lee, A., "San Joaquin River Water Quality Issues,"(PowerPoint Slides) Invited Paper Presented at Great Valley Conference, "At the Tipping Point," Sacramento, CA, Sponsored by Great Valley Center, Modesto, CA, May 11 (2006).
http://www.gfredlee.com/SJR-Delta/SJR-April2006.pdf

Lee, G. F., Jones-Lee, A., "San Joaquin River Water Quality Issues," Report of G. Fred Lee & Associates, El Macero, CA, June (2006).
http://www.gfredlee.com/SJR-Delta/sjr-WQIssues.pdf

In recent years the State Water Resources Control Board (SWRCB) and CA Department of Fish and Game have conducted reviews of the impact of altering Delta flows into and through Delta channels on impacting Delta aquatic life resources. Drs. Lee and Jones-Lee have been asked to prepare comments on these issues. This has led to development of several reports and professional presentations on these issues including:
Lee, G. F., and Jones-Lee, A., "Comments on Delta Stewardship Council Staff May 14, 2012 Draft of the Delta Plan," Comments to Delta Stewardship Council by G. Fred Lee & Associates, El Macero, CA, June 13 (2012).
http://www.gfredlee.com/SJR-Delta/DSC-Comments-May2012-StaffDraft.pdf

Lee, G. F., and Jones-Lee, A., "Comments on the DSC Staff Fifth Draft of Chapter 6 Devoted to Delta Water Quality Issues in the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, August 21 (2011).
http://www.gfredlee.com/SJR-Delta/DeltaPlan5DraftCh6Comm.pdf

Lee, G. F., and Jones-Lee, A., "Comments on Revised Delta Plan Staff Draft Chapter 6 'Improve Water Quality to Protect Human Health and the Environment' as Presented in the Fourth Staff Draft of the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, June 14 (2011).
http://www.gfredlee.com/SJR-Delta/DeltaPlan4DraftCh6Comm.pdf

Lee, G. F., and Jones-Lee, A., "Discussion of Water Quality Issues That Should Be Considered in Evaluating the Potential Impact of Delta Water Diversions/Manipulations on Chemical Pollutants on Aquatic Life Resources of the Delta," Report of G. Fred Lee & Associates, El

Macero, CA, February 11 (2010).
http://www.gfredlee.com/SJR-Delta/Impact_Diversions.pdf

Lee, G. F., and Jones-Lee, A., "Comments on Water Quality Issues Associated with SWRCB's Developing Flow Criteria for Protection of the Public Trust Aquatic Life Resources of the Delta," Submitted to CA State Water Resources Control Board as part of Public Trust Delta Flow Criteria Development, by G. Fred Lee & Associates, El Macero, CA, February 11 (2010).
http://www.gfredlee.com/SJR-Delta/Public_Trust_WQ.pdf

Lee, G. F., and Jones-Lee, A., "Review of Need for Modeling of the Impact of Altered Flow through and around the Sacramento San Joaquin Delta on Delta Water Quality Issues," and "Summary: Water Quality Modeling Associated with Altered Sacramento River Flows in & around the Delta," Report to CWEMF Stormwater Committee, by G. Fred Lee & Associates, El Macero, CA, March (2009). http://www.gfredlee.com/SJR-Delta/Model-Impact-Flow-Delta.

Lee, G. F., and Jones-Lee, A., "Synopsis of CWEMF Delta Nutrient Water Quality Modeling Workshop – March 25, 2008, Sacramento, CA," Report of G. Fred Lee & Associates, El Macero, CA, May 15 (2008). http://www.gfredlee.com/SJR-Delta/CWEMF_WS_synopsis.pdf

"Overview of Delta Nutrient Water Quality Problems: Nutrient Load – Water Quality Impact Modeling," Agenda for Technical Workshop sponsored by California Water and Environmental Modeling Forum (CWEMF), Scheduled for March 25, 2008 in Sacramento, CA (2008).
http://www.gfredlee.com/SJR-Delta/CWEMF_Workshop_Agenda.pdf

Drs. Lee and Jones-Lee have also submitted comments on Delta water quality issues to BDCP, Delta Stewardship Council, including:

Lee. G. F., "Comments on the CVRWQCB Review of Delta Water Quality Issues," Comments submitted to K. Longley, Chair Central Valley Regional Water Quality Control Board, by G. Fred Lee & Associates, El Macero, CA, March (2008).
http://www.gfredlee.com/SJR-Delta/DeltaIssuesLongleyMarch08.pdf

Lee, G. F., and Jones-Lee, A., "Comments on Strategy 3.5 of the 'Volume 2: Delta Vision Strategic Plan - Fifth Staff Draft Version 5.5,'" Comments submitted to P. Isenberg, Chair, Delta Vision Blue Ribbon Task Force, Sacramento, CA. Report of G. Fred Lee & Associates, El Macero, CA, October 17 (2008).
http://www.gfredlee.com/SJR-Delta/DeltaVisionStaffDraft5.pdf

Lee, G. F., and Jones-Lee, A., "Comments on September 19, 2008 Delta Vision Task Force Meeting Discussion of Nutrient-Related Water Quality Problems in the Delta," Comments submitted to P. Isenberg, Chair, Delta Vision Blue Ribbon Task Force, Sacramento, CA. Report of G. Fred Lee & Associates, El Macero, CA, October 14 (2008).
http://www.gfredlee.com/SJR-Delta/DeltaVisionCom9-19-08.pdf

Lee, G. F., and Jones-Lee, A., "Comments on the DSC Staff Fifth Draft of Chapter 6 Devoted to Delta Water Quality Issues in the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, August 21 (2011).

http://www.gfredlee.com/SJR-Delta/DeltaPlan5DraftCh6Comm.pdf

Lee, G. F., and Jones-Lee, A., “Comments on Revised Delta Plan Staff Draft Chapter 6 ‘Improve Water Quality to Protect Human Health and the Environment’ as Presented in the Fourth Staff Draft of the Delta Plan," Comments Submitted to Delta Stewardship Council, Sacramento, CA, by G. Fred Lee & Associates, El Macero, CA, June 14 (2011).
http://www.gfredlee.com/SJR-Delta/DeltaPlan4DraftCh6Comm.pdf

As well as a number of other comments on Delta management issues that are on Drs. Lee and Jones-Lee’s website.

California Sportfishing Protection Alliance
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28 July 2014

Mr. Ryan Wulff
National Marine Fisheries Service
650 Capitol Mall, Suite 5-100
Sacramento, CA 95814
BDCP.Comments@noaa.gov

VIA: Electronic Submission
Hardcopy if Requested

RE: Comment Letter No. 3: Bay Delta Conservation Plan and Associated EIR/EIS Related to Delta Smelt and Summer Outflow Protection

Dear Mr. Wulff,

The California Sportfishing Protection Alliance (CSPA) has reviewed the proposed Bay Delta Conservation Plan and associated Environmental Impact Report/Environmental Impact Statement (hereinafter, BDCP) submits the following comments. Comment Letter No. 3 relates to Delta smelt and summer outflow protection and includes a report, included below, titled *Delta Smelt on the Scaffold*, and an attached report titled, *The Summer of 2013, The demise of Delta smelt under D-1641 Delta Water Quality Standards.* The three documents constitute our comments on juvenile Delta smelt and we request that all three be considered and responded to as a single submittal.

CSPA worked closely with the Environmental Water Caucus (EWC) in developing their comments and incorporates by reference into these comments both submittals by the EWC on all issues related to BDCP. We also incorporate by reference the submittal by Michael Jackson on behalf of CSPA, California Water Impact Network and AquAlliance, as well as the individual comments submitted by AquAlliance. We further incorporate by reference the submittals by the County of San Joaquin, South Delta Water Agency, Central Delta Water Agency, Restore the Delta, Earth Law Center and Friends of the River.

The BDCP and the EIR/EIS inexplicable fail to acknowledge, analyze or discuss the presence of juvenile Delta smelt in the western Delta during summer and fail to acknowledge, analyze or discuss the preferred Alternative's potential adverse impacts on juvenile Delta smelt in July and August. Consequently, the BDCP and EIR/EIS are deficient and fail to comply with minimum CEQA and NEPA requirements for an environmental review document.

Since the start of Delta export pumping by the State Water Project in 1967, California Department of Fish and Wildlife (CDFW) Fall Midwater Trawl abundance indices for Delta smelt, striped bass, longfin smelt, American shad and threadfin shad have declined 95.6, 99.6, 99.8, 90.9, 98.5, 97.8 percent, respectively. The five-year abundances between 1967-1971 and

2009-2013 for Delta smelt, striped bass, longfin smelt, American shad and threadfin shad have declined 89.8, 98.8, 99.4, 87.7 and 98.1 percent, respectively. The abundance indices of CDFW's Summer Townet Survey for Delta smelt and striped bass declined 94.2 and 98.2 percent, respectively, between 1967 and 2013 and the five year average decline between 1967-1971 and 2009-2013 for Delta smelt and striped bass was 93.8 and 98.1 percent, respectively.

Of these pelagic species, Delta smelt are likely at serious risk of short-term extinction. Last year the Fall Midwater Trawl abundance index for Delta smelt was the second lowest in history, indistinguishable from the lowest. This year CDFW's 20-mm Survey 9 collected the fewest Delta smelt in history. Inexplicably, the BDCP and EIR/EIS virtually ignore the critical juvenile life-stage of Delta smelt in the summer months.

While there is extensive discussion of the impacts of entrainment (understating risks to eggs and sensitive life stages and impingement), predation (ignoring the project's creation of habitat favoring predators) and habitat area (based upon flawed optimistic projections of expanded habitat acreage) we could find no discussion regarding the significant impacts of near-lethal or lethal July-August temperatures and low June-August Delta outflows, with respect to juvenile life stages of Delta smelt. We also could not find substantial discussion of effects of low outflow during drier years and how low outflow, coupled with water exports, draws the low salinity zone (LSZ) into the western Delta. This omission is apparently based on the assumption that, since habitat conditions in the western Delta during the summer are not good for Delta smelt, they aren't there. Almost twenty years of 20-mm surveys demonstrate that this is simply not true. Low outflow conditions, coupled with exports, draw the LSZ and Delta smelt into the western Delta. At times, the majority of juvenile Delta smelt is in the western Delta in late June and early July.

The EIR/EIS acknowledges that outflow will decrease in summer months. Chapter 11, Fish and Aquatic Resources, Section 11.0.2.8, Alternative 4-Summary of Effects, states,

> *"SWP and CVP exports in summer months would increase and result in lower outflow under all four scenarios compared to No Action Alternative."* Page 11-52, lines 23-25.

The four evaluated operating scenarios of the preferred alternative included or excluded enhanced flows in spring or fall. Protective summer outflows were essentially ignored.

The Chapter 11, beginning on page 11-1289 describes the differences between the four scenarios of Alternative 4 as:

> *"Scenario H1 – Does not include enhanced spring outflow or Fall X2 requirements.*
>
> *Scenario H2 – includes enhanced spring outflow, but not Fall X2 requirements. This scenario lies within the range of the other scenarios.*

> *Scenario H3 – Does not include enhanced spring outflow, but includes Fall X2 requirements 16 (similar to Alternative 2A). This scenario lies within the range of the H1 and H4 scenarios.*
>
> *Scenario H4 – Includes both enhanced spring outflow requirements, and Fall X2 requirements."*
> Page 11-1290, Lines 13-18.

In discussing Impact AQUA-4: Effects of Water Operations on Spawning and Egg Incubation Habitat for Delta Smelt, the EIR/EIS states,

> *"**CEQA Conclusion**: As described above, operations under Alternative 4 would not reduce abiotic spawning habitat availability or change water temperatures for spawning delta smelt under any of the proposed flow scenarios. Consequently, the impact would be less than significant, and no mitigation is required."* Page 11-1295, lines 29-32

However, we could find no discussion regarding summer juvenile rearing impacts, except for a brief mention in the EIR/EIS's discussion of Impact AQUA-5; Effects of Water Operation on Rearing Habitat for Delta Smelt, which states,

> *"They also concluded that water temperature was not a predictor of delta smelt presence in the fall, although it has been shown to be important during summer months (Nobriga et al. 2008)."* Page 11-1296, Lines 11-13.

Chapter 5 of BDCP Effects Analysis seems to imply that Delta smelt cannot by found in areas of the Delta where key habitat attributes are not met. It states;

> *"During summer, water temperatures can reach stressful if not lethal levels in parts of the estuary (Nobriga et al. 2008), a trend that is anticipated to worsen given projected climate warming (Brown et al. 2013). Further, the interaction of water temperature and prey density is a widely agreed-upon constraint on delta smelt (Kimmerer 2008; Mac Nally et al. 2010; Maunder and Deriso 2011; Miller et al. 2012; Rose et al. 2013a, 2013b). However, low water salinity and transparency contribute to delta smelt's occurrence at Liberty Island and the adjacent reach of the Sacramento Deep Water Shipping Channel in the Cache Slough subregion (e.g., Nobriga et al. 2005).* ***In addition, the trawl survey sampling grids are large enough to have robustly documented that delta smelt cannot be expected to occur in large numbers where the key abiotic habitat attributes (low salinity/low turbidity, and low water temperature in the summer) are not met*** *(Feyrer et al. 2007; Nobriga et al. 2008; Kimmerer et al. 2009; Feyrer et al. 2011; Sommer and Mejia 2013)."* Page 5.5.1-19, lines 14-24.

The assumption that significant numbers of Delta smelt are not expected to be in waters that potentially jeopardizes their existence apparently is the basis for the U.S. Fish and Wildlife (USFWS) Biological Opinion that provides no protection for Delta smelt in July and August and why the State Water Resources Control Board (SWRCB), with the concurrence of state and federal agencies, reduced Delta outflow requirements in July of this year and allowed the salinity compliance point at Emmaton to be moved upstream to Three Mile Slough. Unfortunately, as we document below, it's simply not accurate.

This belief is apparently why the U.S. Fish and Wildlife (USFWS) Biological Opinion provides no protection for Delta smelt in July and August and why the State Water Resources Control Board (SWRCB), with the concurrence of state and federal agencies, reduced Delta outflow requirements in July of this year and allowed the salinity compliance point at Emmaton to be moved upstream to Three Mile Slough. This belief is apparently why BDCP and the EIR/EIS virtually ignored and failed to discuss juvenile Delta smelt and the impacts of lethal temperatures and low outflow during summer periods and failed to consider protective outflows in summer.

Given the decades-long collapse of smelt populations amid the astonishing array of biological opinions, water quality control plans, water rights decisions and adaptive management programs and habitat restoration projects; no professional deference can be accorded to the agencies involved in the planning, management, analysis or approval of BDCP. These agencies have literally escorted Delta smelt to the brink of extinction. And no deference or benefit-of-doubt can be accorded to the speculative claims and assurances that habitat restoration projects and adaptive management efforts will be more successful and result in different outcomes this time around. Especially, given agency's historical track record of failure.

Contrary to the assumptions of BDCP and the EIR/EIS, large percentages of Delta smelt juveniles are in the western Delta in late June and early July and probably August, especially in drier years. In fact, 100% of the Delta smelt identified in the recently completed Survey 9 of the 20-mm survey, are at the southern end of Sherman Island and not in Suisun Bay where the BDCP and the EIR/EIS seem to assume they are. In 2013, more than 60% of Delta smelt juveniles were in the western Delta.

Over centuries, Delta smelt evolved within salinity parameters for various life stages. They can't magically change their habitat needs simply because it inconveniences water exporters. Low Delta outflow, coupled with excessive water exports, shifts the low salinity zone (LSZ) and juvenile Delta smelt eastward into the western Delta where smelt are exposed to near-lethal and lethal water temperatures during heat waves similar to what occurred in July 2013 and is occurring in July 2014.

The attached CSPA report titled *The Summer of 2013, the demise of Delta smelt under D-1641 Delta Water Quality Standards*, chronicles conditions in 2013 when Delta outflow was suddenly reduced and water exports by the state and federal project facilities dramatically increased. The LSZ and juvenile Delta smelt were drawn into the western Delta where they encountered lethal water temperatures. As predicted, the 2013 Fall Midwater Trawl Delta smelt Index plunged to its second lowest on record, statistically indistinguishable from the lowest.

Delta Smelt on the Scaffold, included below, contains;

- CSPA developed indexes that reveal that, based on CDFW 20-mm survey data, abundances of juvenile Delta smelt reached their lowest level in history in late June and early July 2014. Survey 9, of the 20-mm Survey collected only two Delta smelt in 141 separate trawls at 40 locations stretching from Cache Slough to San Pablo Bay.

- Examination of the startling difference between the calculated Net Delta Outflow Index (NDOI), relied upon by the SWRCB, USBR, DWR to measure compliance with D-1641 outflow requirements, and the actual tidally filtered data collected by the U.S. Geological Survey's (USGS) stations at Rio Vista, Three Mile Slough, San Joaquin River at Jersey Point and Dutch Slough. The USGS gaged results of Delta outflow better correlate with salinity intrusion that the NDOI.

- Late June and early July 20-mm surveys for Delta smelt between 1998 and 2014.

Together, they establish, contrary to conclusions in the BDCP and the EIR/EIS, that juvenile Delta smelt are in the western Delta during June, July and potentially August, where they are at risk from lethal temperatures. They also establish that the NDOI relied upon to determine compliance with water quality and flow standards established by the SWRCB are flawed and overestimate actual outflow.

Consequently, any assumptions, analyses, conclusions or determinations contained in the BDCP or the EIR/EIS that rely on the NDOI as representing actual Delta outflow are inaccurate. Likewise, any assumptions, analyses or conclusions that compliance with D-1641's flow and water quality standards are protective of identified beneficial uses are similarly flawed.

BDCP and the EIR/EIS are inadequate and violate CEQA and NEPA by failing to disclose these facts and analyze the project's potential adverse impacts to juvenile Delta smelt in summer.

Thank you for considering these comments. If you have questions or require clarification, please don't hesitate to contact us.

Sincerely,

Bill Jennings

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Enclosed: CSPA, No. 3, Exhibit 1: Delta Smelt on the Scaffold
Attachment: CSPA, No. 3, Exhibit 2: The Summer of 2013, The demise of Delta smelt under D-1641 Delta Water Quality Standards

Delta Smelt on The Scaffold

Juvenile Delta Smelt Abundance Levels at All-Time Low

Thomas Cannon
Bill Jennings

California Sportfishing Protection Alliance

July 2014

During the summer of 2013, reductions in outflow, coupled with increased water exports, drew the low salinity zone (LSZ) and Delta smelt eastward into the western Delta where smelt encountered lethal water temperatures. That situation was chronicled in a California Sportfishing Protection Alliance (CSPA) report titled *The Summer of 2013, the demise of Delta smelt under D-1641 Delta Water Quality Standards*, which predicted that the smelt population would plunge.[1] As we predicted, the following Fall Midwater Trawl's Delta smelt abundance index was the second lowest level on record, statistically indistinguishable from the absolute lowest.

In 2014, the State Water Resources Control Board has significantly relaxed flow and water quality standards protecting the estuary. Delta outflow is below levels in recent memory. Exports and water transfers are being approved with little environmental review because state and federal agencies claim that Delta smelt are not in the Delta in late June and July. As we show below, this is simply not true. Low outflows have drawn Delta smelt into the Delta where they're at risk from lethal temperatures. Further, outflows are significantly less than being reported by the agencies. Delta smelt populations are headed for new record lows. The point of no return, i.e., the level where the population cannot recover, is unknown. But, that point is likely approaching.

The California Department of Fish and Wildlife (DFW) conducts four primary surveys of Delta smelt in the Bay-Delta: Smelt Larval Survey, 20-mm Survey, Summer Townet and Fall Midwater Trawl. Each survey provides an annual index of abundance for specific life stages of Delta smelt. The 20-mm survey monitors post-larval-juvenile Delta smelt and comprises nine separate surveys. However the 20-mm index is based on initial surveys in March/April and do not reflect conditions in late June and early July, as smelt are drawn into the Delta by low outflow and export pumping and exposed to high temperatures. DFW's Smelt larval & 20-mm survey indices are not published.

Because DFW's 20-mm index doesn't reflect what happens to Delta smelt in June and July, CSPA took DFW's 20-mm survey data and developed indices for early June, late June and early July between 1996-2014. Our method simply stacks average densities from survey areas for each survey on a bar graph to derive an index. Our index demonstrates changes over the three survey periods and the relative contribution of the six different Delta regions. It is not weighted by the area or volume of the regions and includes the northern population of smelt and includes stations in Cache Slough and the Sacramento Deep Water Ship Channel that were added to the 710s group in the past decade.

The two methods provide similar indices and patterns of indices over the years. The early June smelt index was the second lowest in history but the late June and early July indexes were, by a significant margin, the lowest in history. Astonishingly, DFW's early July 2014 20-mm survey managed to capture only 2 smelt in 147 separate trawls. The early July index pattern over the years is also similar to the Fall Midwater Trawl Indices, which is an alarming indication of likely results from this fall's upcoming FMWT index.

Following are the CSPA Delta smelt indexes for June and July 2014, DFW's June/July 2014 survey results, a discussion concerning the inadequacies of DWR, USBR Delta outflow calculations and the DFW 20-mm surveys between 1996 and 2014.

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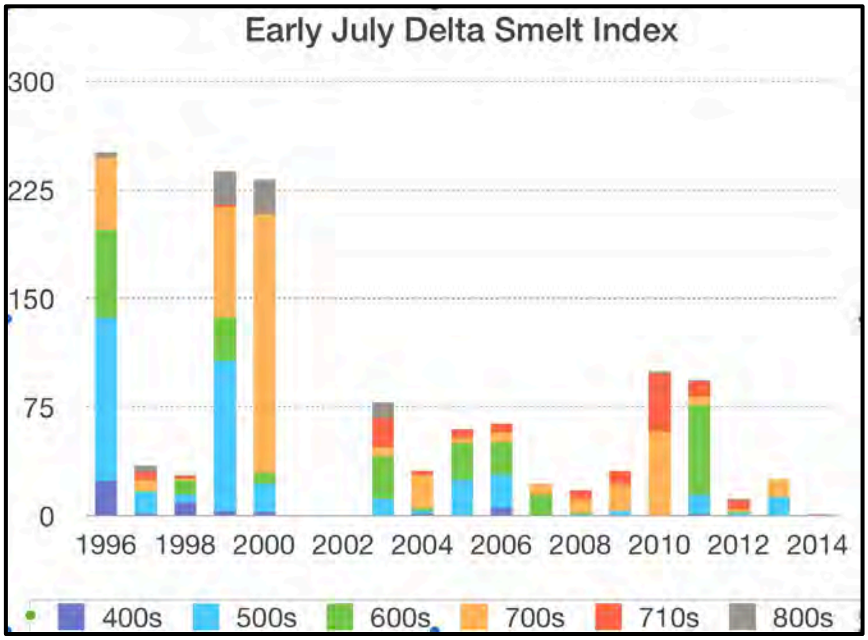
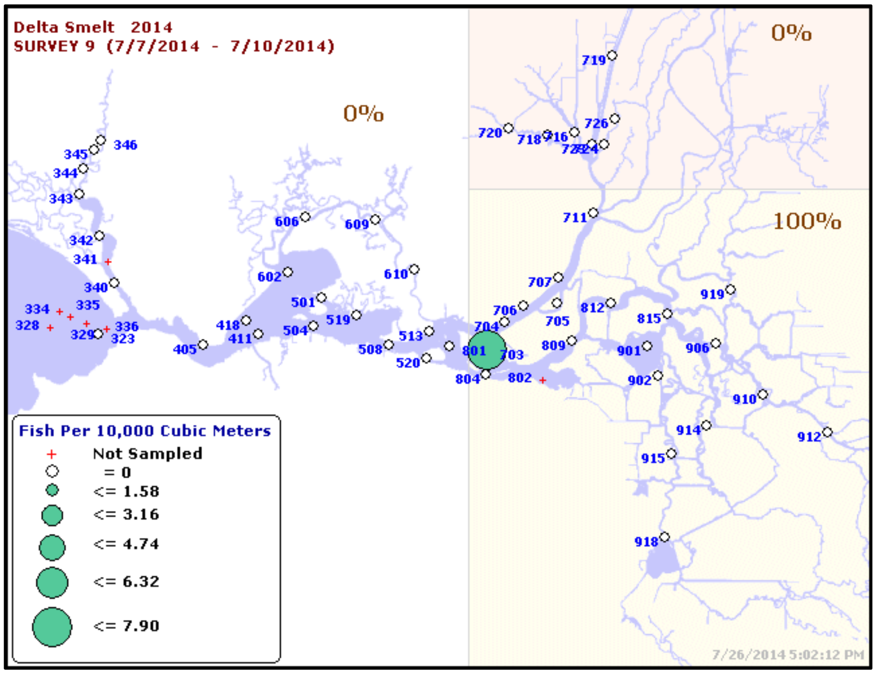
[1] http://calsport.org/news/wp-content/uploads/CSPA-Cannon-Summer-2013-6.pdf



CSPA Index by Catch and Sampled Area, 20mm DFW Survey 8, Early July, no survey 2001-2002
Note: 400s = West Suisun Bay; 500s = East Suisun Bay; 600s = Montezuma Slough; 700s = Lower Sacramento River; 710s = Cache Slough/Sacramento Ship Channel; 800s = Lower San Joaquin River



California Department of Fish and Wildlife 20mm Delta Smelt Survey 9, 7-10 July 2014 Chart weighted by volume of area sampled.[2]
Only 2 Delta smelt were collected in 141 trawls (3 trawls at each of 47 locations).

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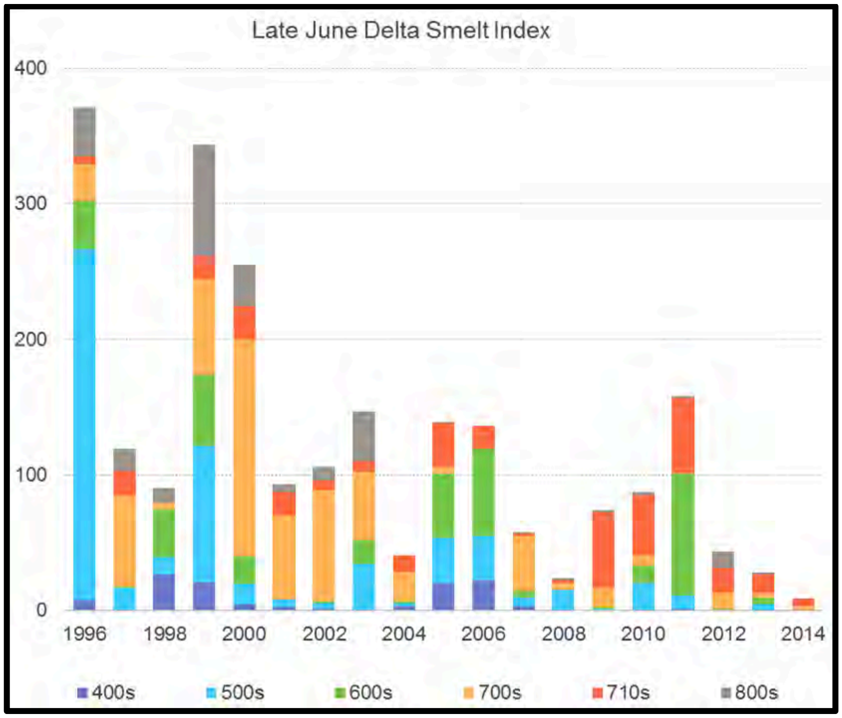
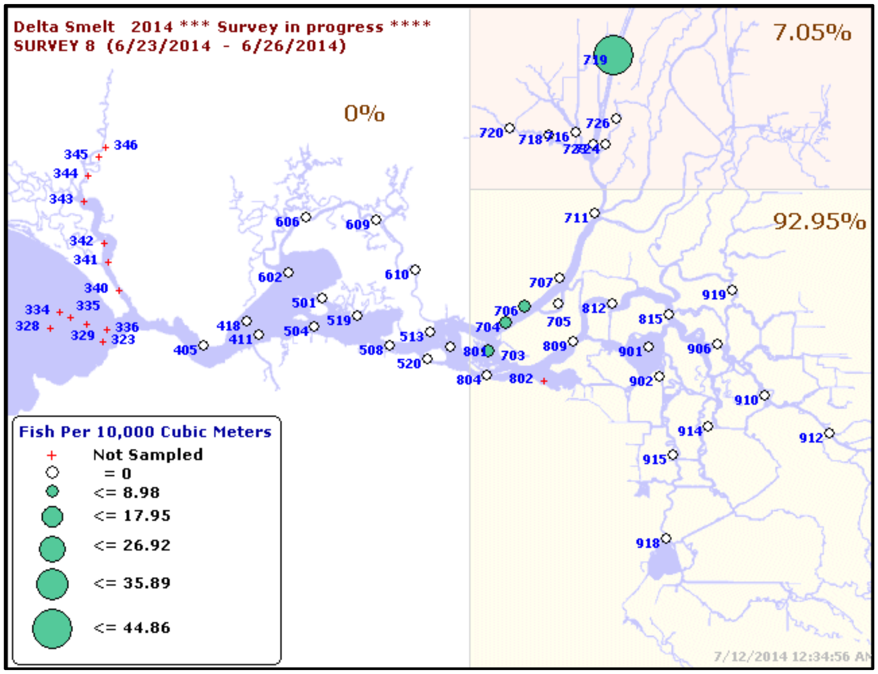
[2] http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp



CSPA Index by Catch and Sampled Area, 20mm DFW Survey 8, Late June
Note: 400s = West Suisun Bay; 500s = East Suisun Bay; 600s = Montezuma Slough; 700s = Lower Sacramento River; 710s = Cache Slough/Sacramento Ship Channel; 800s = Lower San Joaquin River



California Department of Fish and Wildlife 20mm Delta Smelt Survey 8, 23-26 June 2014 Chart weighted by volume of area sampled.[3]
Only 18 Delta smelt were collected in 120 trawls (3 trawls at each of 40 locations).

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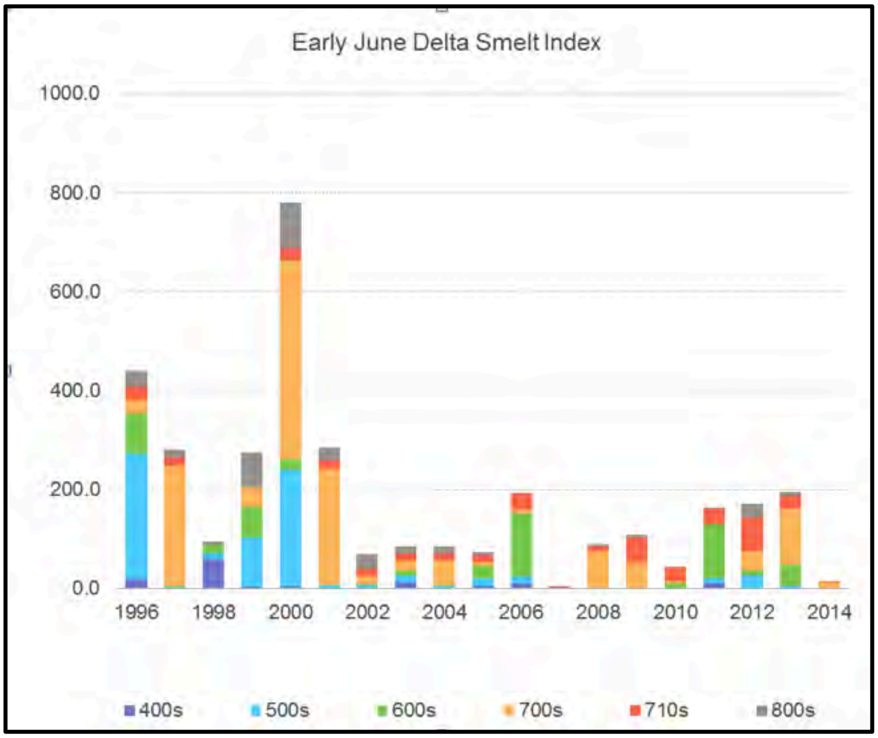
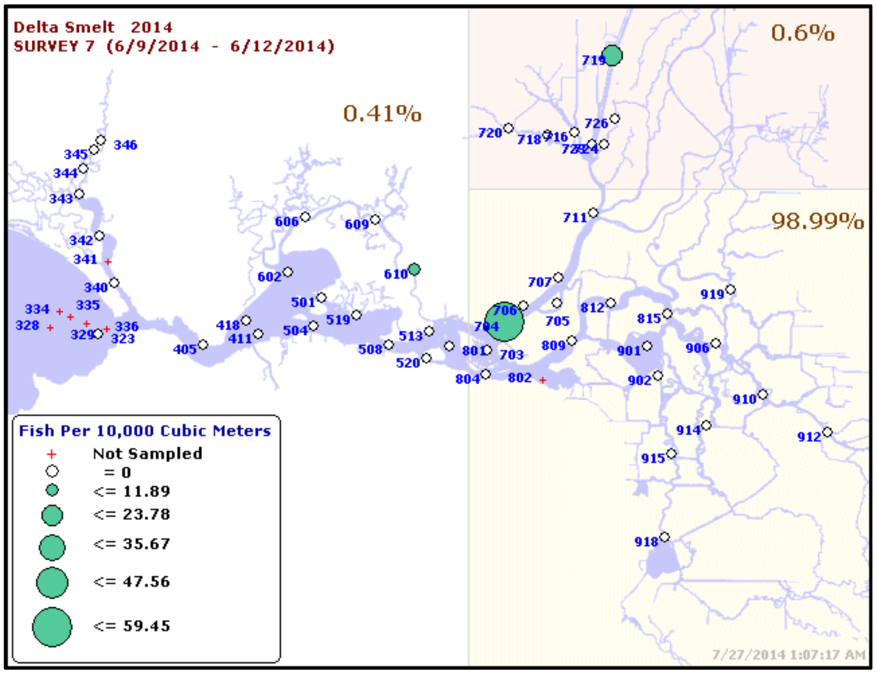
[3] http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp



CSPA Index by Catch and Sampled Area, 20mm DFW Survey 8, Early June
Note: 400s = West Suisun Bay; 500s = East Suisun Bay; 600s = Montezuma Slough; 700s = Lower Sacramento River; 710s = Cache Slough/Sacramento Ship Channel; 800s = Lower San Joaquin River



California Department of Fish and Wildlife 20mm Delta Smelt Survey 8, 6-12 June 2014 Chart weighted by volume of area sampled.[4]
Only 24 Delta smelt were collected in 141 trawls (3 trawls at each of 47 locations).

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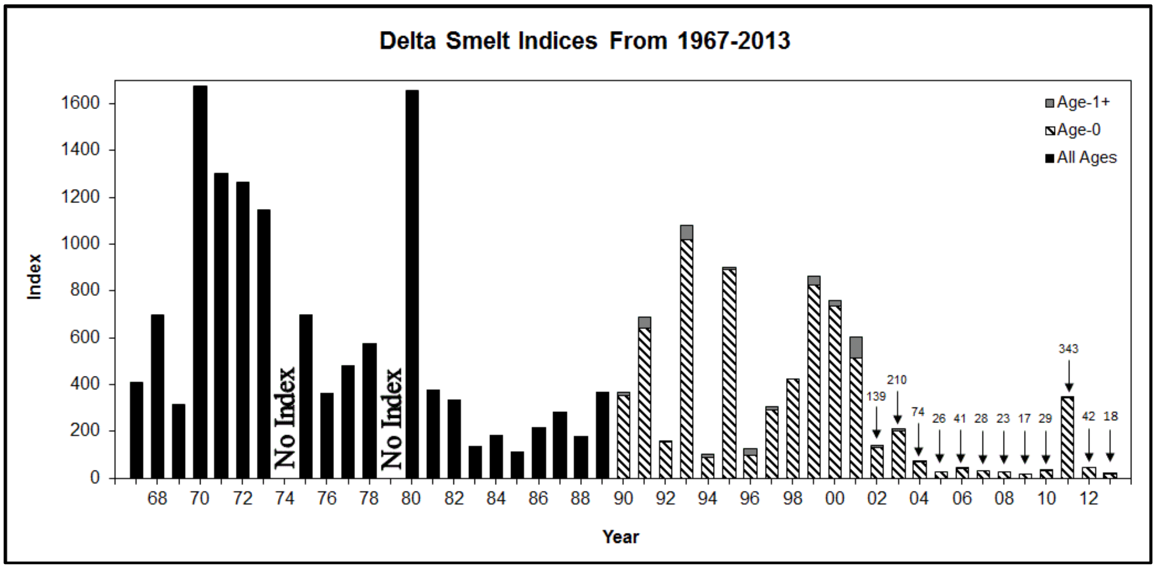
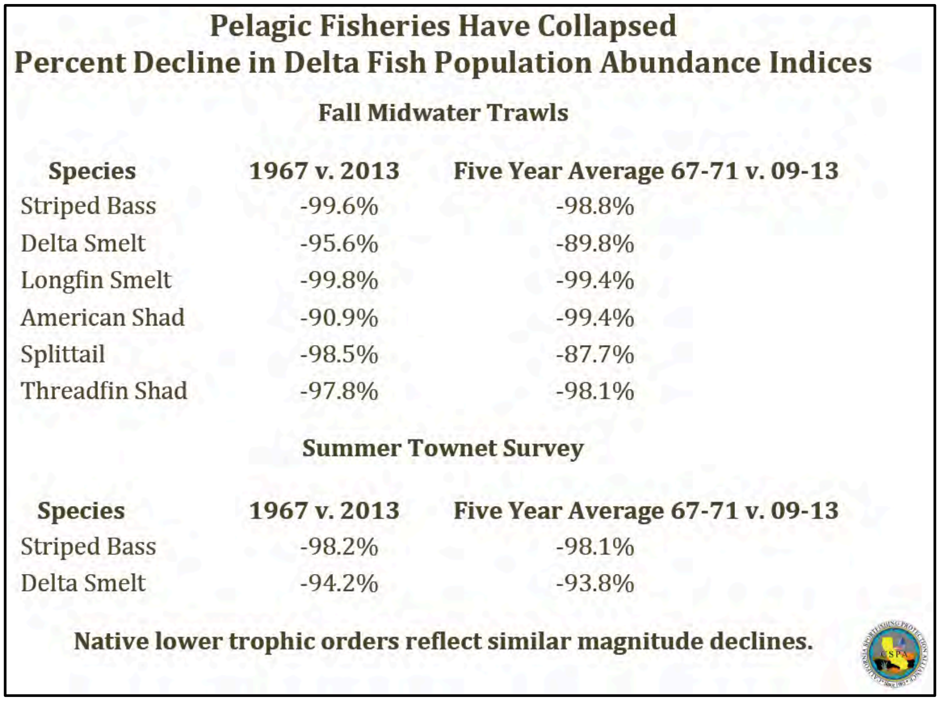
[4] http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp

This pattern is replicated in the annual abundance indices of the Fall Midwater Trawl, which illustrates the continued decline of Delta smelt since the State Water Project began exporting water in 1967.



California Department of Fish and Wildlife: Delta Smelt Fall Midwater Trawl Indices 1967-2013.[5]

The decline of Delta fisheries is not limited to Delta smelt but encompasses the entire range of pelagic species.[6]



Pelagic Fisheries Have Collapsed
Percent Decline in Delta Fish Population Abundance Indices

Fall Midwater Trawls

Species	1967 v. 2013	Five Year Average 67-71 v. 09-13
Striped Bass	-99.6%	-98.8%
Delta Smelt	-95.6%	-89.8%
Longfin Smelt	-99.8%	-99.4%
American Shad	-90.9%	-99.4%
Splittail	-98.5%	-87.7%
Threadfin Shad	-97.8%	-98.1%

Summer Townet Survey

Species	1967 v. 2013	Five Year Average 67-71 v. 09-13
Striped Bass	-98.2%	-98.1%
Delta Smelt	-94.2%	-93.8%

Native lower trophic orders reflect similar magnitude declines.

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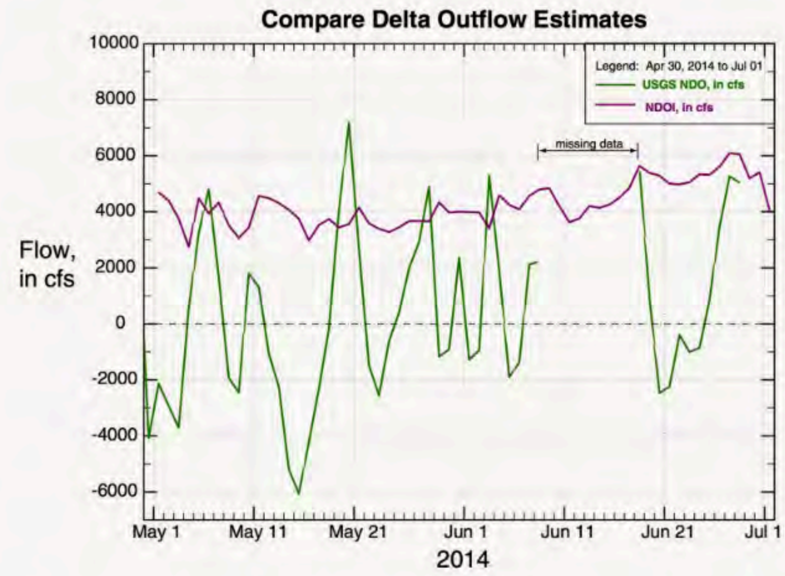
[5] http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT
[6] http://calsport.org/news/wp-content/uploads/St-Bd-Drought-Wkshp1.pdf

The problem has been exacerbated in recent years by excessive water exports from the Delta coupled with extremely low outflow to the Bay and relaxed or ignored flow and water quality standards. This combination low flow and exports draws the crucial low salinity zone (LSZ) into the Delta where pelagic species are subjected to entrainment in the massive export pumps and lethal summer water temperatures. Last year was bad as a combination of low outflows and high exports hammered Delta smelt.[7] This year is likely to be much worse and Delta smelt are literally on the brink of extinction.

The Estimates of Delta Outflow by USBR and DWR are Simply Wrong!

U.S. Bureau of Reclamation (USBR) and California Department of Water Resources (DWR) claim that net Delta outflow (NDOI) averaged 3170 cubic feet per second (cfs) between I July and 11 July 2014.[8] However, the NDOI, which is a complicated computation that guesses at net Delta channel depletion, is simply wrong.

The U.S. Geological Survey (USGS) maintains four state-of-the-art UVM flow gages on the Sacramento and San Joaquin Rivers and Three-mile and Dutch Sloughs that, cumulatively, record total Net Delta Outflow (NDO). Examination of tidally filtered outflow data from these gages reveals that the outflows reported by USBR and DWR are seriously inflated in low water conditions.



By official estimates, fresh water outflow from the Delta is about 4,000 cfs; USGS monitors show that outflow to the Bay vacillated between minus 6,000 cfs and plus 6,000 but the average for May and June was close to zero.
Graph by Pete Smith

Retired USGS Engineer, Pete Smith, prepared the above comparison of NDO versus NDOI that was recently reported in the California Spigot.[9]

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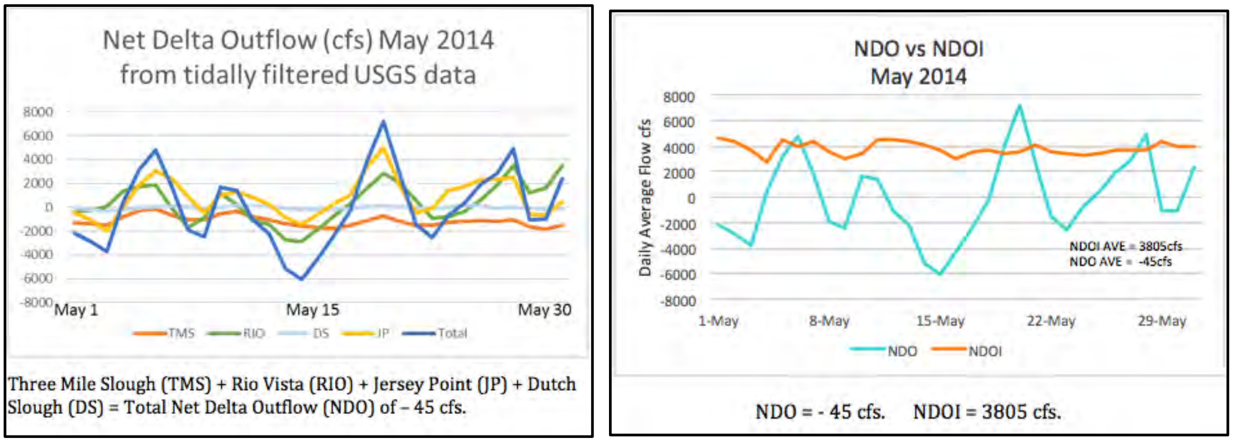
[7] http://calsport.org/news/wp-content/uploads/CSPA-Cannon-Summer-2013-6.pdf
[8] http://www.usbr.gov/mp/cvo/vungvari/doutdly.pdf
[9] http://www.californiaspigot.blogspot.com

CSPA fishery consultant and biostatistician, Thomas Cannon, also prepared an assessment for CSPA that analyzed the NDOI index and discovered that it seriously overestimates actual Delta outflow. Mr. Cannon calculated that the actual Delta outflow in May 2014 was a minus 45 cfs, instead of the positive 3805 cfs claimed by USBR and DWR. He also discovered that DWR had long aware been of the discrepancy.[10]

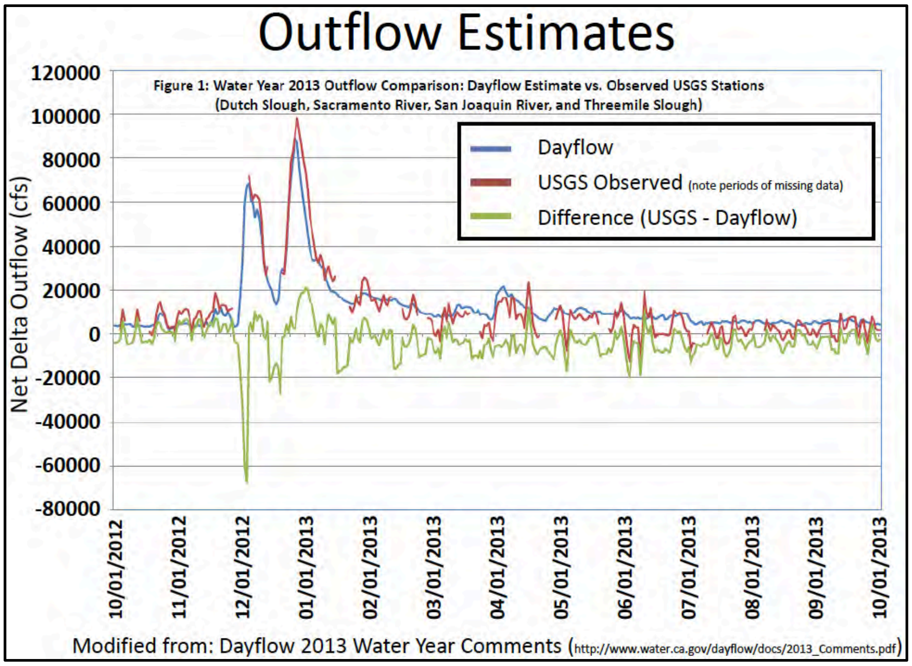


Three Mile Slough (TMS) + Rio Vista (RIO) + Jersey Point (JP) + Dutch Slough (DS) = Total Net Delta Outflow (NDO) of – 45 cfs.

NDO = - 45 cfs. NDOI = 3805 cfs.

Thomas Cannon: Net Delta Outflow in May 2014 and NDO vs. NDOI.

Dr. Michael L. MacWilliams, of Delta Modeling Associates, in a presentation to the Delta Science Program's workshop on Delta outflows and related stressors, observed that NDOI estimates during the fall of 2013 were more than double the USGS measured outflows.



Modified from: Dayflow 2013 Water Year Comments (http://www.water.ca.gov/dayflow/docs/2013_Comments.pdf)

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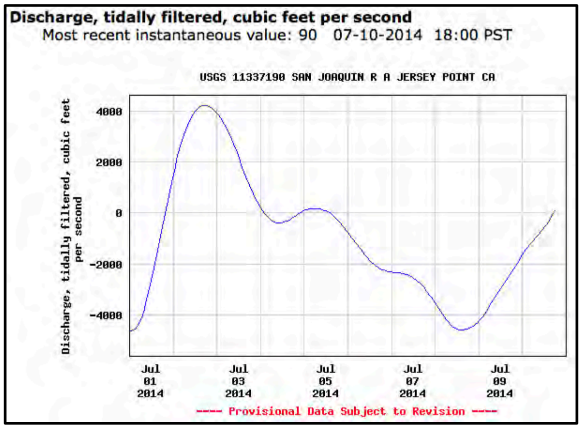
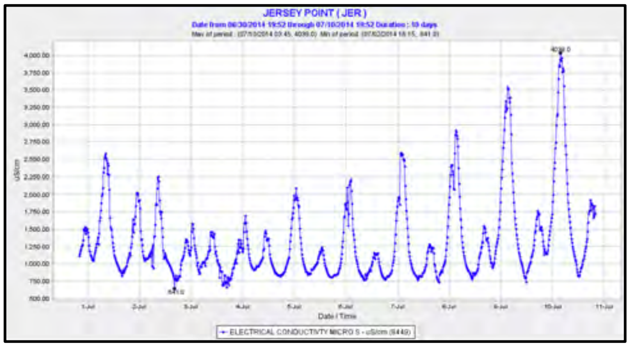
[10] http://calsport.org/news/wp-content/uploads/CSPA-NDO-v-NDOI-2.pdf

Dr. MacWilliams testified that, based on measured data for salinity intrusion and X2, the NDOI estimates appeared to be clearly incorrect.[11]

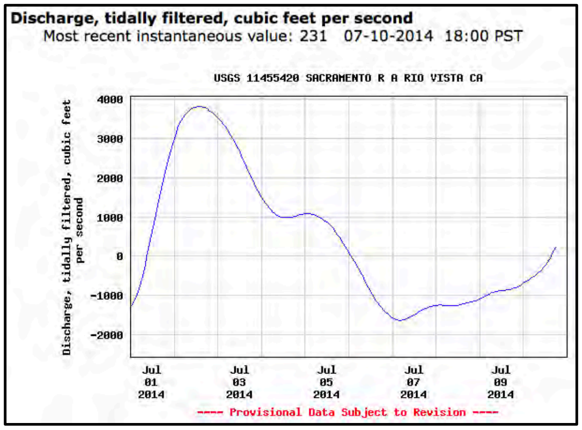
During the first ten days of July 2014, the NDOI was reported as a positive outflow averaging 3170 cfs. However, examination of the four USGS tidally filtered stations at Rio Vista, Threemile Slough, Jersey Point and Dutch Slough reveals that outflow had become negative, beginning around 4/5 July. Inflow from the Bay approached 7000 cfs by 8 July. This was reflected in sharply increasing salinity (EC) levels in the Delta, which could not have occurred under a positive NDOI outflow.



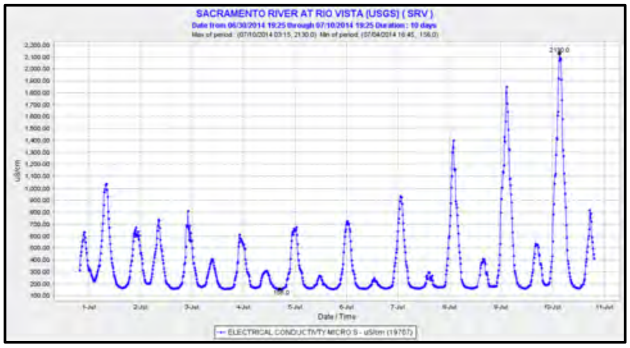
USGS Jersey Point Flow (11337190)



CDEC Jersey Point EC (JER)



USGS Rio Vista Flow (11455420)



CDEC Rio Vista EC (SRV)

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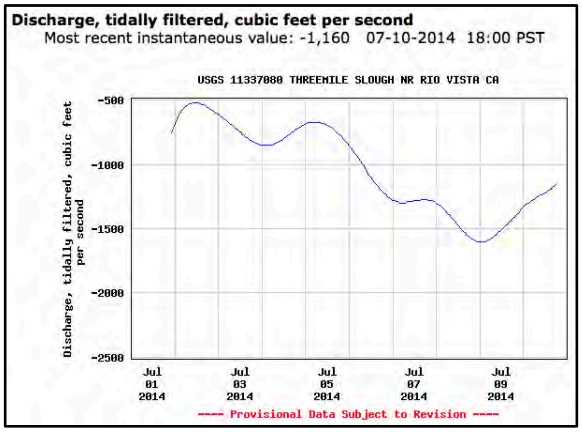
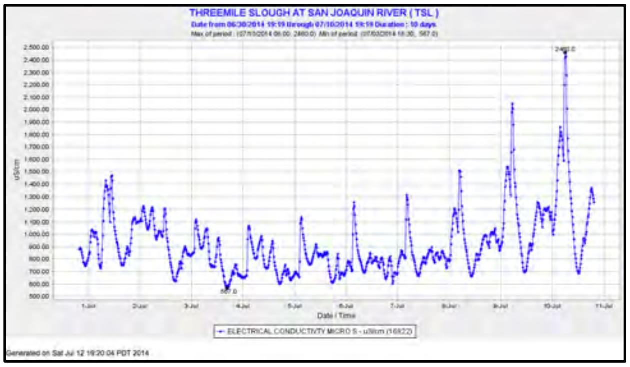
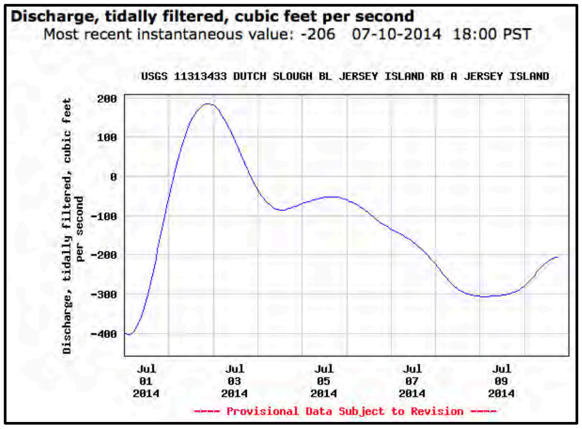
[11] http://deltacouncil.ca.gov/sites/default/files/documents/files/10-Outflow-Workshop-MacWilliams-02-10-14-Final.pdf



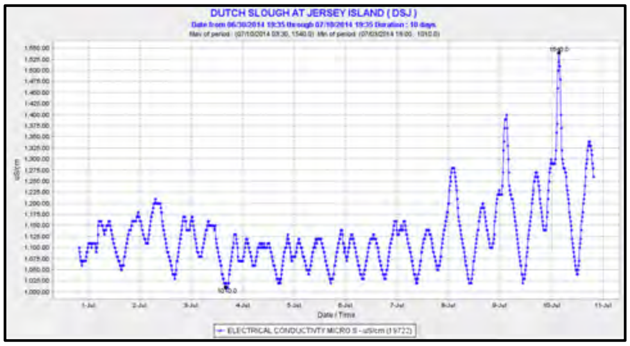
USGS Threemile Slough Flow (11337080)



CDEC Threemile Slough EC (SJJ)



USGS Dutch Slough Flow (11313433)



CDEC Dutch Slough EC (DSJ)

Real time data from the USGS[12] and California Data Exchange Center (CDEC)[13] can be accessed online.

The final report of the expert panel observed that, "Although a precise estimate of the accuracy of the measured outflow is not known, the measured values should be more accurate than the NDOI as long as the four monitoring stations used in the calculations are operating properly." The panel asked, "why the measured outflows (rather than NDOI) aren't used for the specific outflow standards during the July-to-January period, and also why they aren't used as the alternative flow compliance option in the springtime X2 standard."[14]

The California Spigot quoted State Water Resources Control Board engineer, Rick Satkowski, as saying, in light of these findings, the State Board will be looking at, "possible changes in determining outflow.

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[12] http://waterdata.usgs.gov/ca/nwis/current/?type=flow&group_key=basin_cd

[13] http://cdec.water.ca.gov/staMeta.html

[14] http://deltacouncil.ca.gov/sites/default/files/documents/files/Delta-Outflows-Report-Final-2014-05-05.pdf

USBR and DWR have long known of the difference between measured net delta outflow and the calculated net delta outflow index. They have long known that they do not have reliable data on in Delta channel depletions. They have long known that not all inflow into the Delta from tributary streams is accurately gaged. But they are also aware that if NDO, instead of the NDOI, is used as the standard of net delta outflow, more water will have to be directed to outflow and less to exports, especially in dry years.

USBR and DWR are committed to maximizing water deliveries to contractors, even if it sends the Delta smelt, once the most abundant fish in the Delta, toward extinction. That is unacceptable!

Contrary to USBR and DWR Claims, Delta Smelt are in the Delta in June, July and August

The USFWS Biological Opinion for Delta smelt provides no protection in July and August because the service claims that there are no Delta smelt in the Delta during those months. On that basis, USBR and DWR, with USFWS concurrence, provided no protection for smelt during water transfers. Earlier this year, the State Water Board, again with USFWS concurrence, lowered the Delta outflow criteria, contained in D-1641, from 4000 cfs to 3000 cfs during the months of May and July. However, they are simply wrong!

Last year, as chronicled in CSPA's report titled *The Summer of 2013, the demise of Delta smelt under D-1641 Delta Water Quality Standards*,[15] reductions in outflow, coupled with increased water exports, drew Delta smelt into the western Delta where they encountered lethal water temperatures. Abundance levels plunged.

Delta smelt are in the Delta. They shouldn't be. During late June and July, Delta smelt should be in the LSZ in Suisun Bay, protected from the lethal 76-77 degrees water temperatures frequently found in the Delta during summer. However, a combination of low outflow and excessive exports draws the LSZ and Delta smelt into the Delta during drier years.

There is also a small population of smelt that spawn in the Cache Slough-Sacramento Ship Channel area. However, they become trapped and unable to migrate back to the LSZ and seek to survive in the stratified waters of the deep water in the ship channel. Extended heat waves pose a severe threat to that population, as the coldwater pool will ultimately dissipate. In 2009, the California Department of Fish and Wildlife (CDFW) conducted supplemental monitoring at six sites in the ship channel and found that smelt populations decreased through July and virtually disappeared by August. The USFWS's 2008 Biological Opinion does not suggest that the Cache Slough-Sacramento Ship Channel area provides a viable temperature refuge for Delta smelt when their only recognized habitat – the LSZ in the Delta – has been rendered unsuitable for survival.

Below are the CDFW's late June and early July 20mm Delta smelt surveys from 1996 to 2014. The 20mm surveys are comprised of three separate trawls conducted at 40 sites in the Delta. They demonstrate that in all but the wettest years, Delta smelt are in the Delta during late June and early

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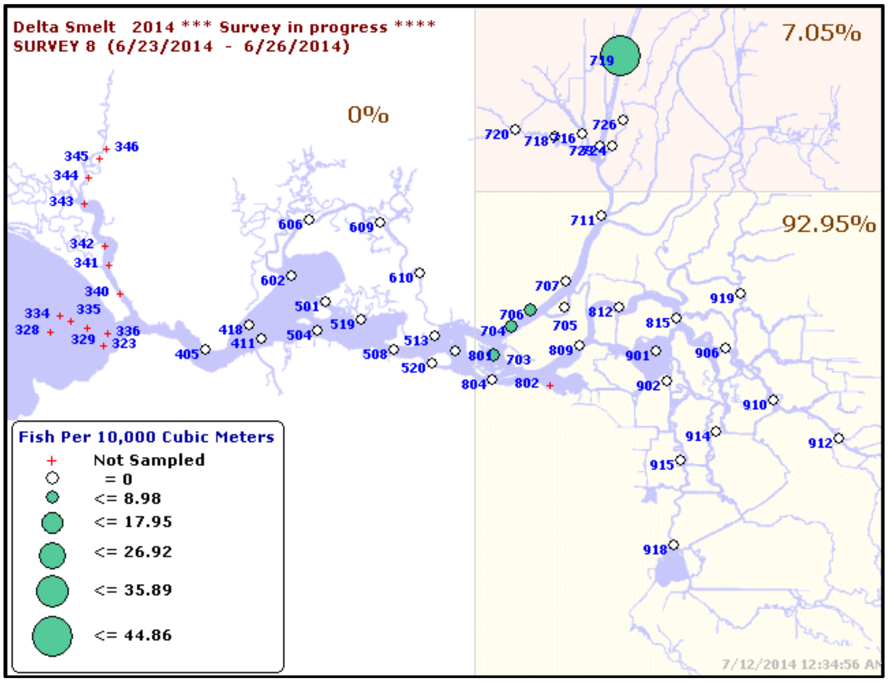
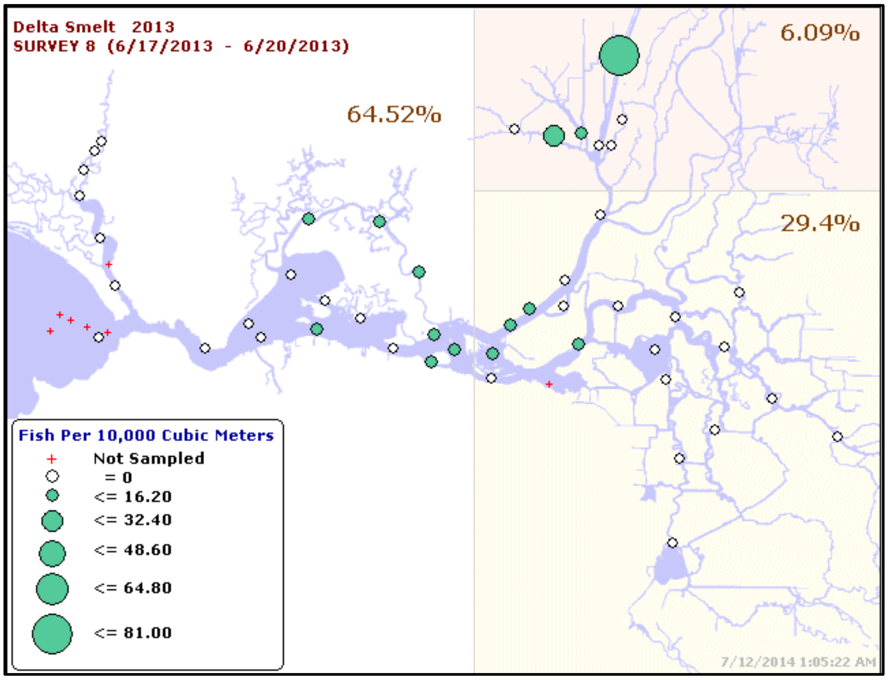
[15] http://calsport.org/news/wp-content/uploads/CSPA-Cannon-Summer-2013-6.pdf

July. In drier years, a significant percentage of Delta smelt, perhaps the majority of juveniles, are in the Delta.

CDFW: 20mm Delta Smelt Surveys, Late June 1996-2014 (with percentages)[16]



2014 Water Year: Sacramento = Critical; SJR = Critical



2013 Water Year: Sacramento = Dry; SJR = Critical

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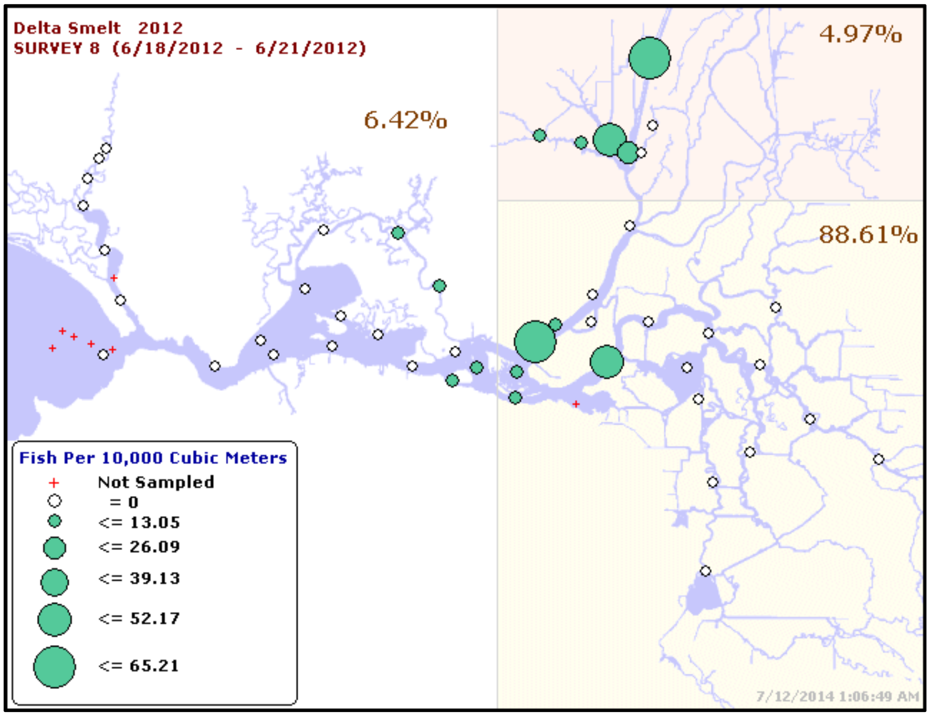
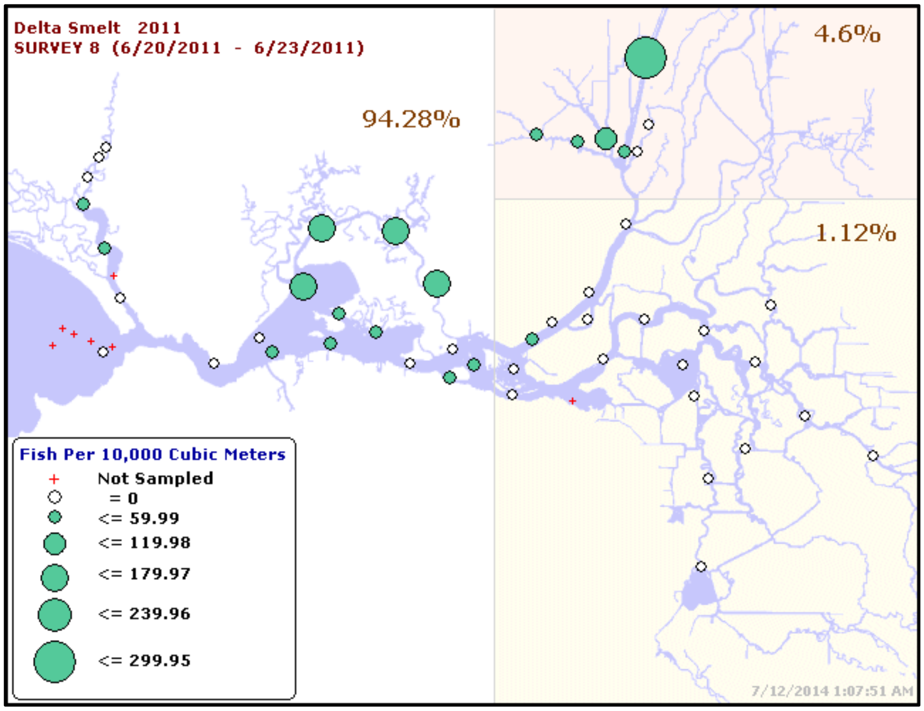
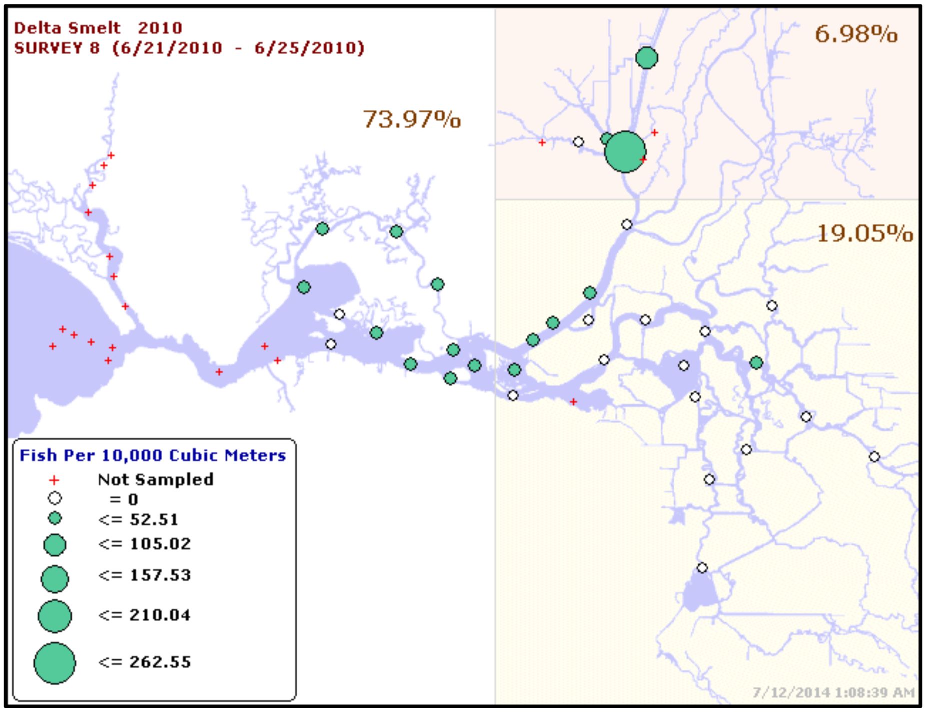
[16] http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp



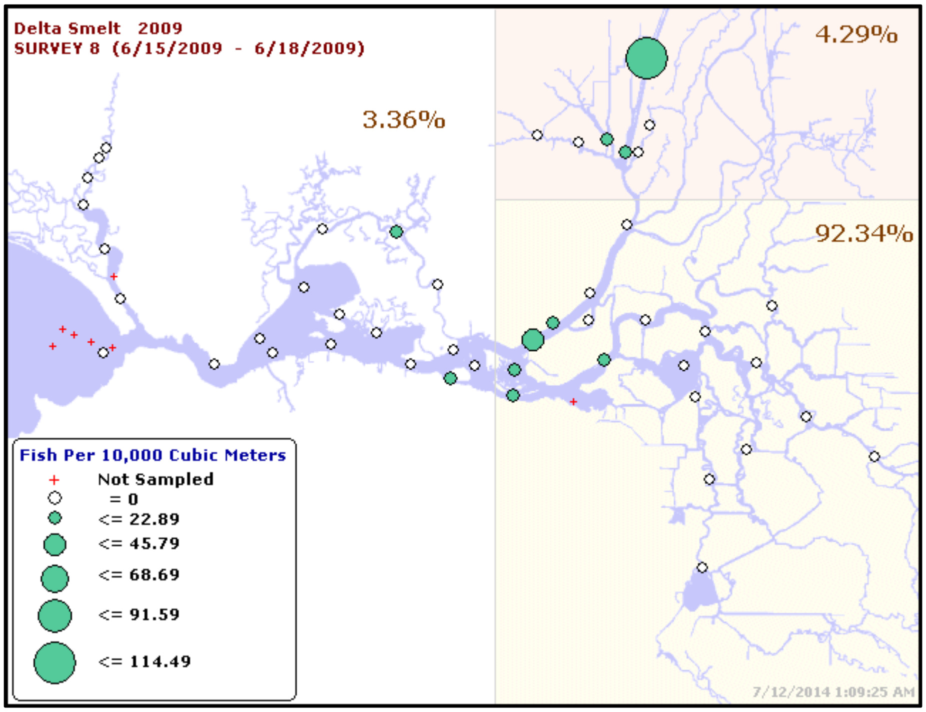
2012 Water Year: Sacramento = Below Normal; SJR = Dry



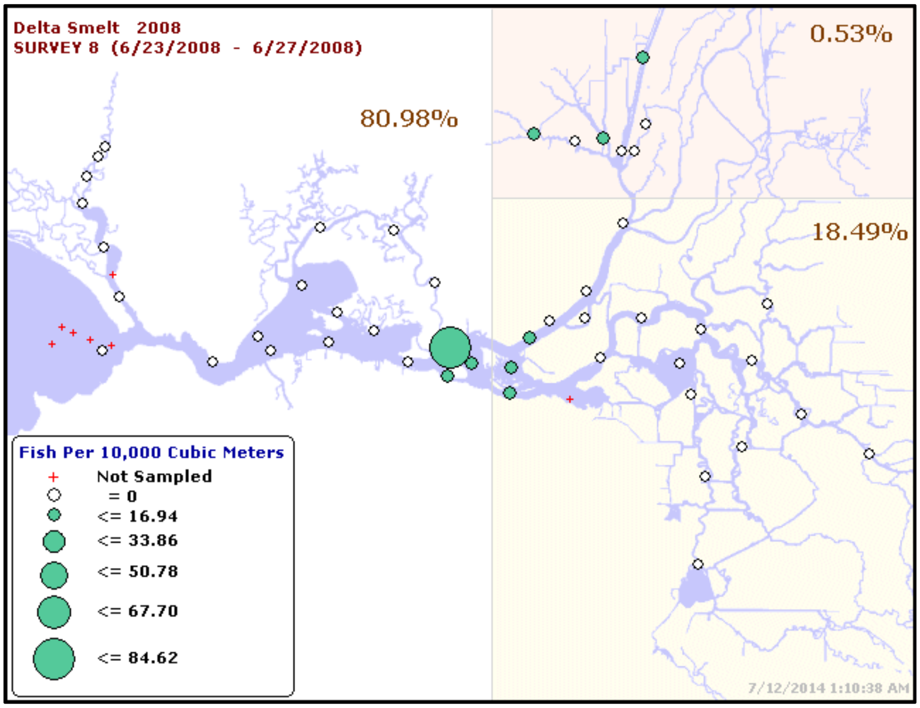
2011 Water Year: Sacramento = Wet; SJR = Wet



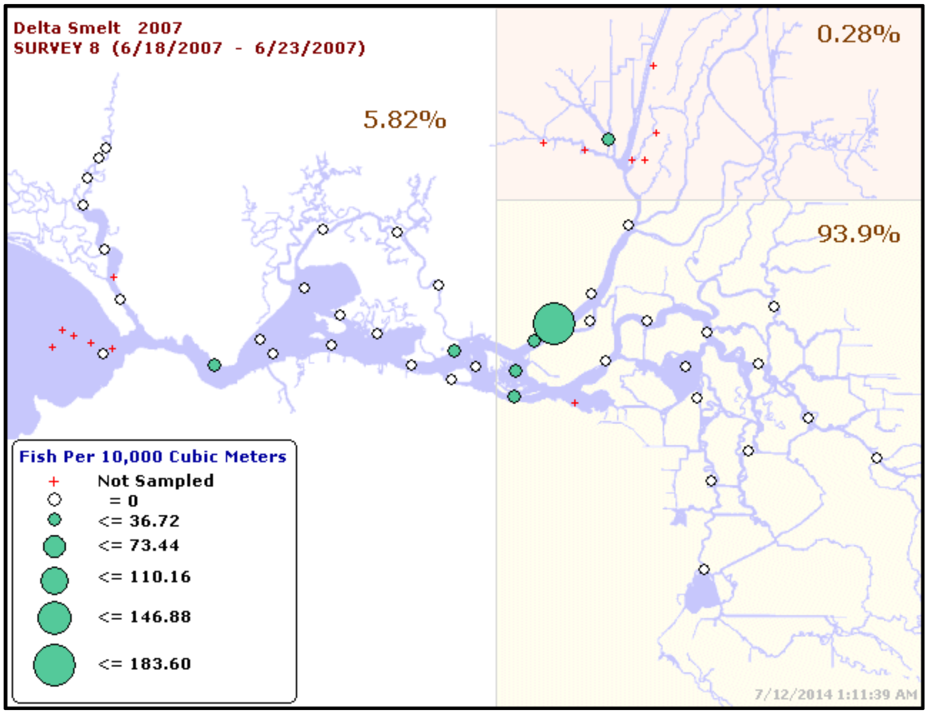
2010 Water Year: Sacramento = Below Normal; SJR = Above Normal



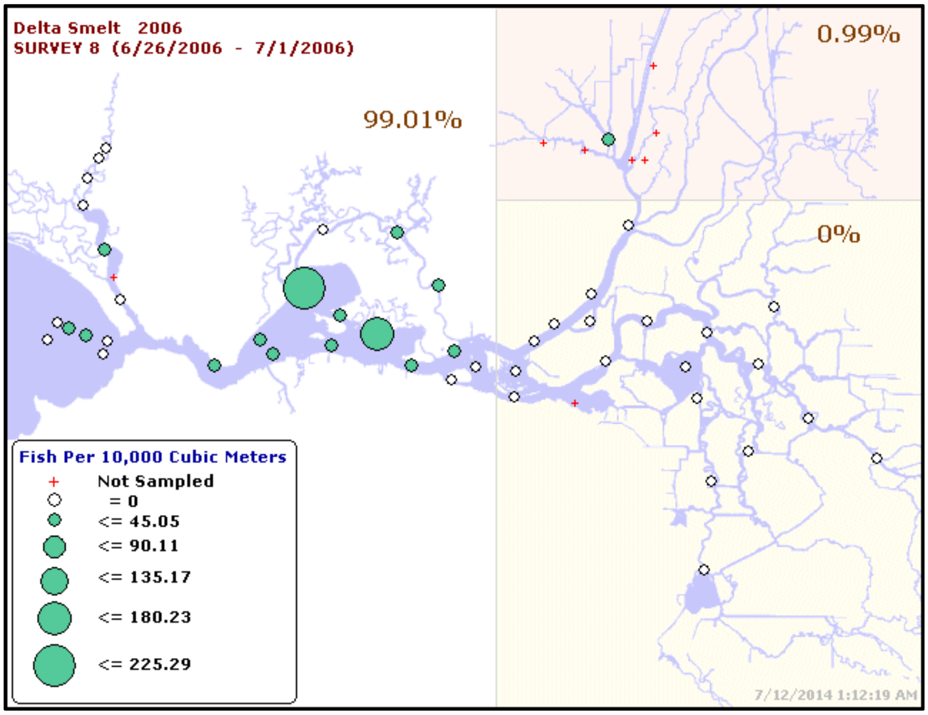
2009 Water Year: Sacramento = Dry; SJR = Dry



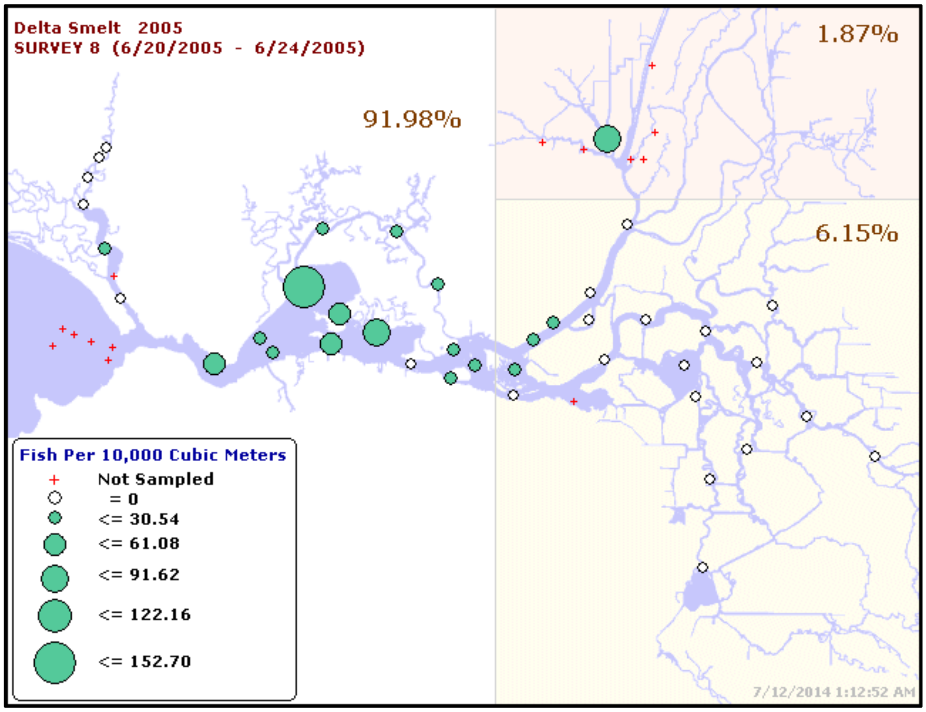
2008 Water Year: Sacramento = Critical; SJR = Critical



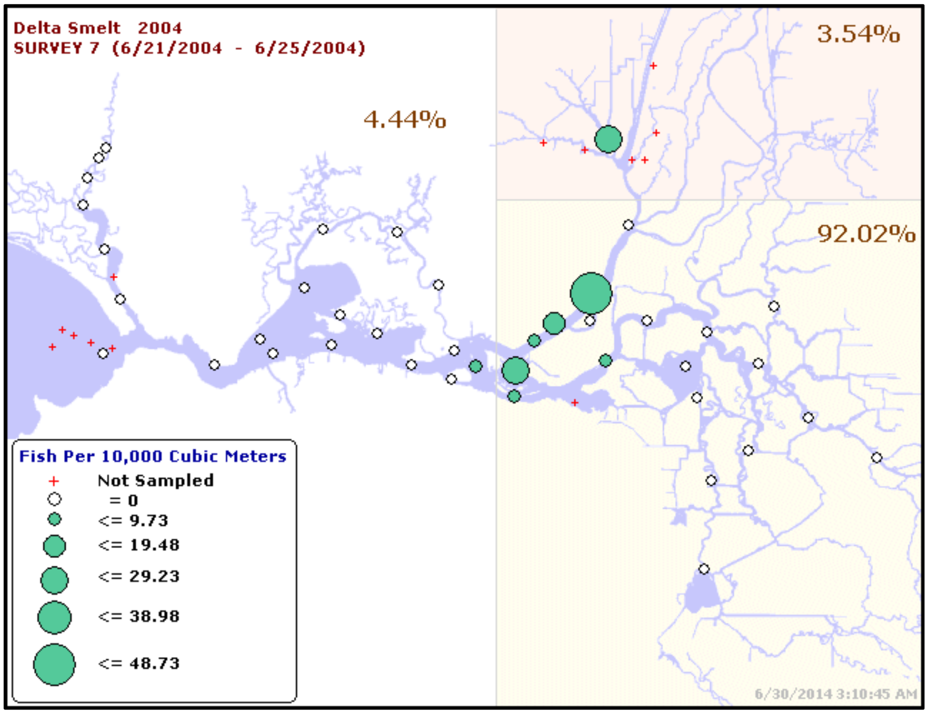
2007 Water Year: Sacramento = Dry; SJR = Critical



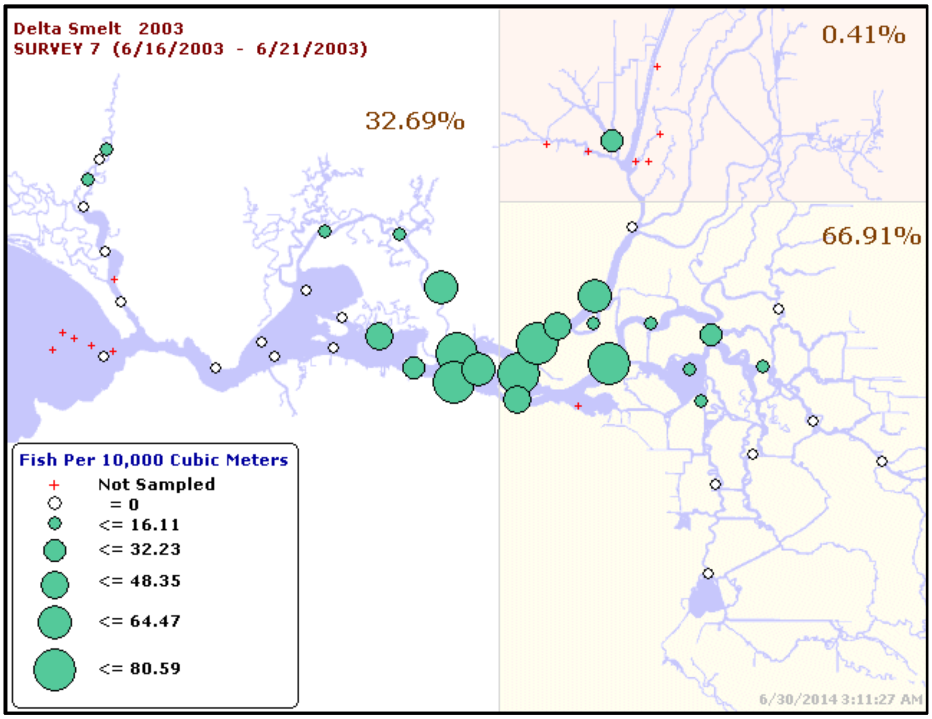
2006 Water Year: Sacramento = Wet; SJR = Wet



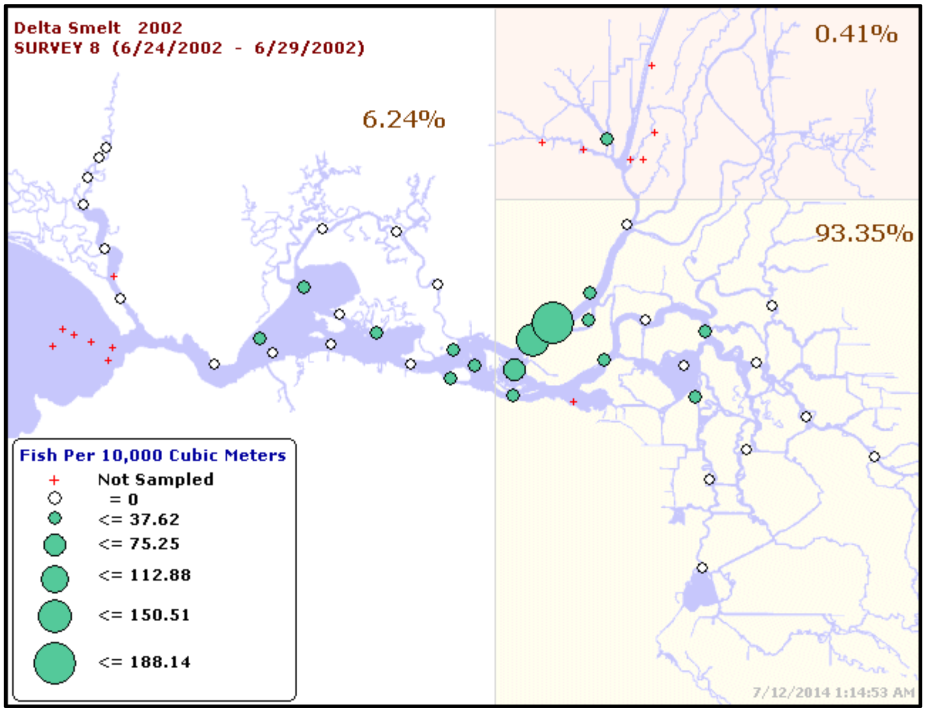
2005 Water Year: Sacramento = Above Normal; SJR = Wet



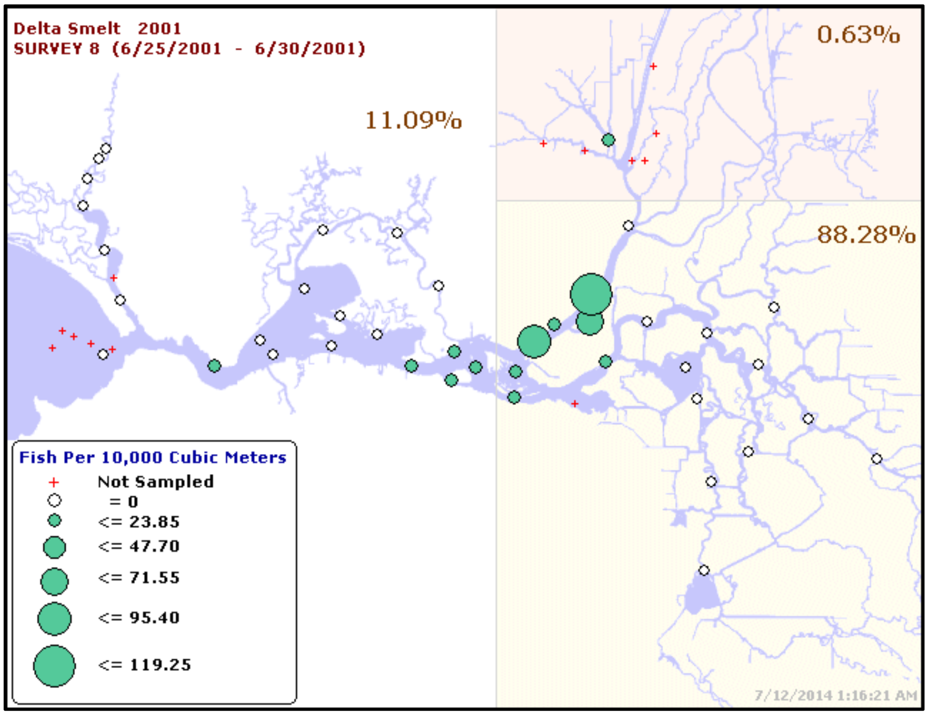
2004 Water Year: Sacramento = Below Normal; SJR = Dry



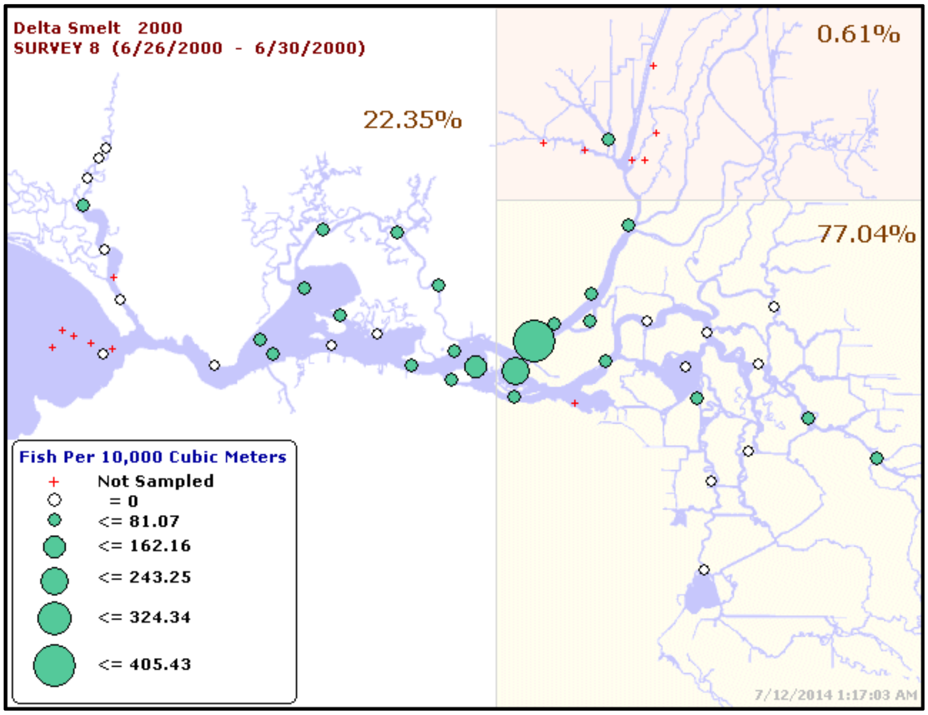
2003 Water Year: Sacramento = Above Normal; SJR = Below Normal



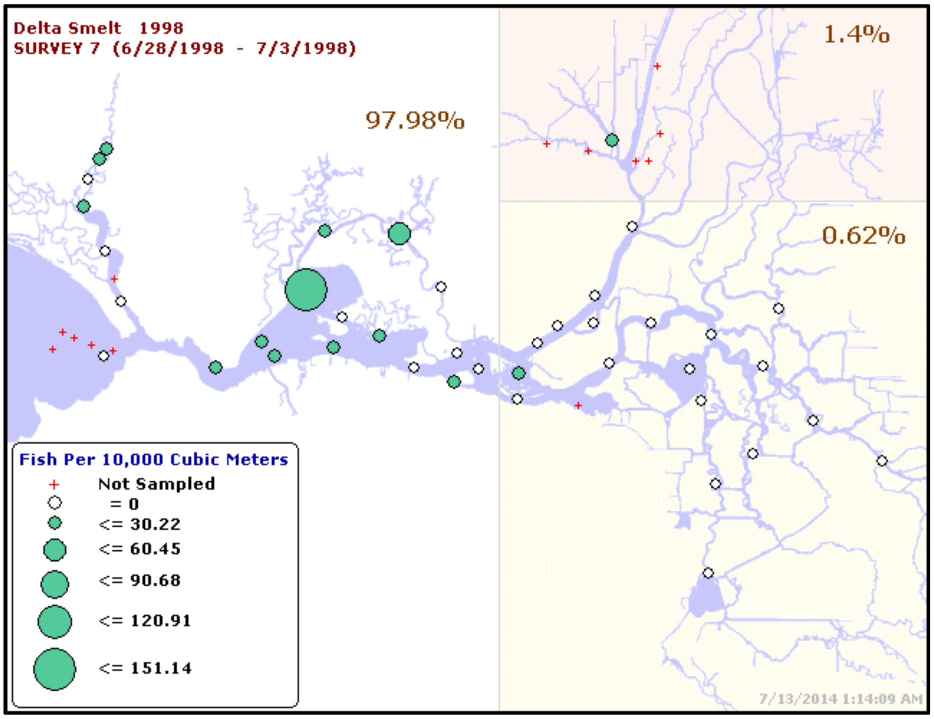
2002 Water Year: Sacramento = Dry; SJR = Dry



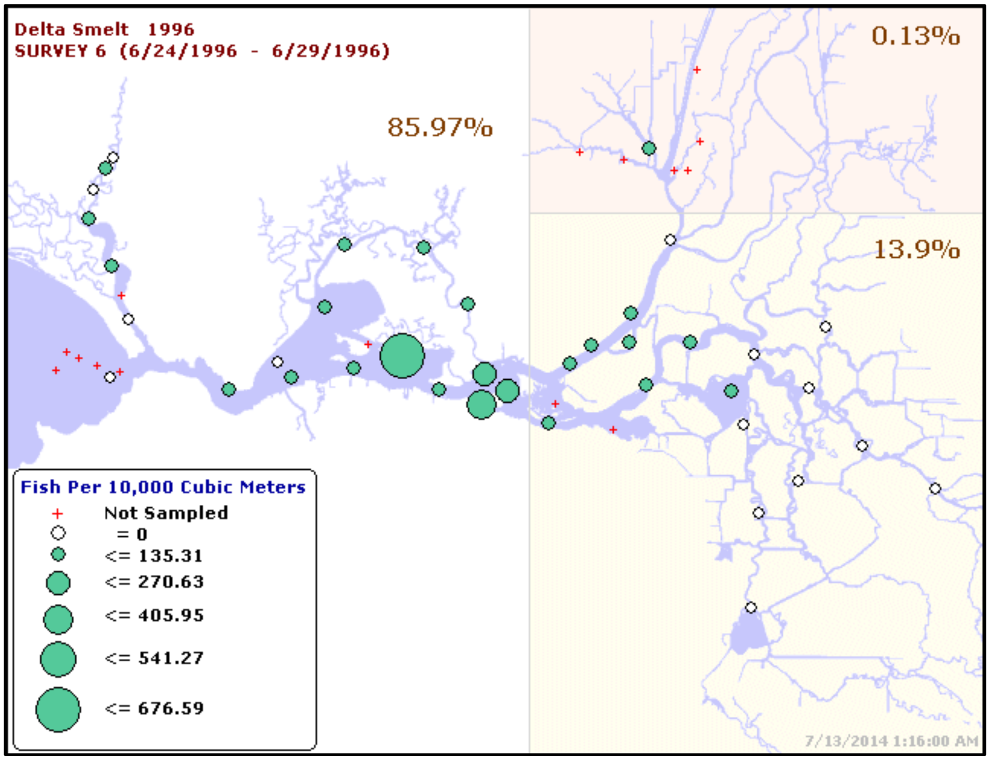
2001 Water Year: Sacramento = Dry; SJR = Dry



2000 Water Year: Sacramento = Above Normal; SJR = Above Normal



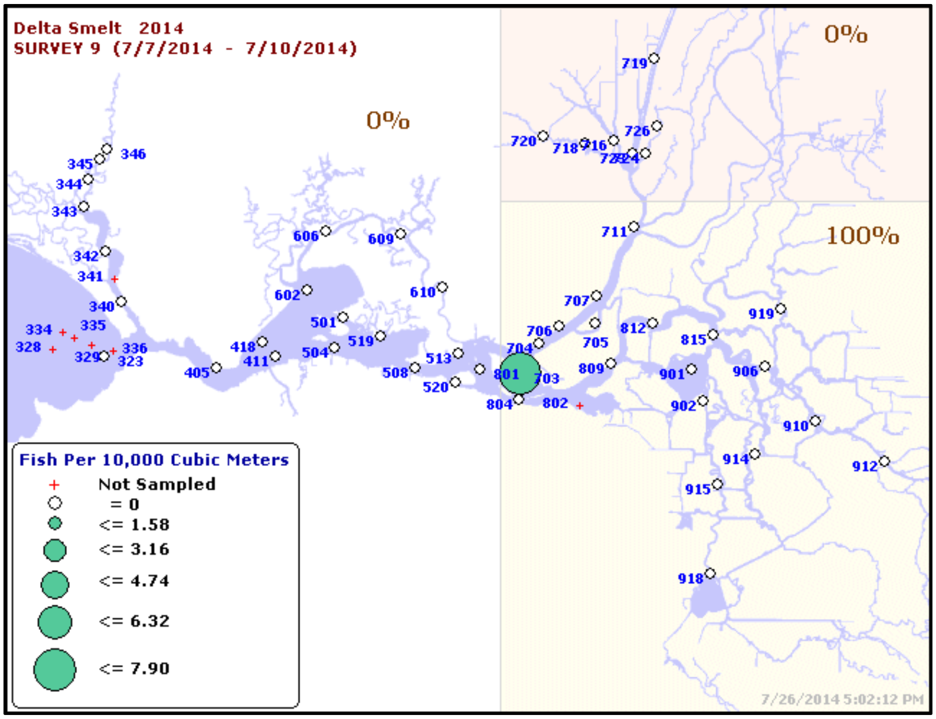
1998 Water Year: Sacramento = Wet; SJR = Wet



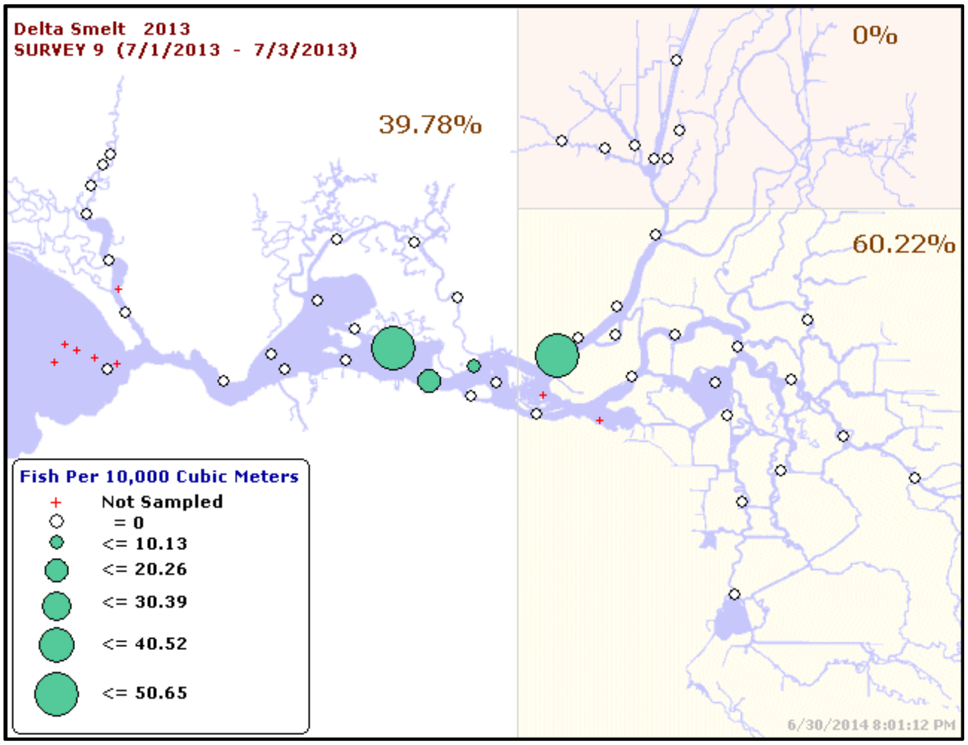
1996 Water Year: Sacramento = Wet; SJR = Wet

CDFW: 20mm Delta Smelt Surveys, Early July 1996-2013

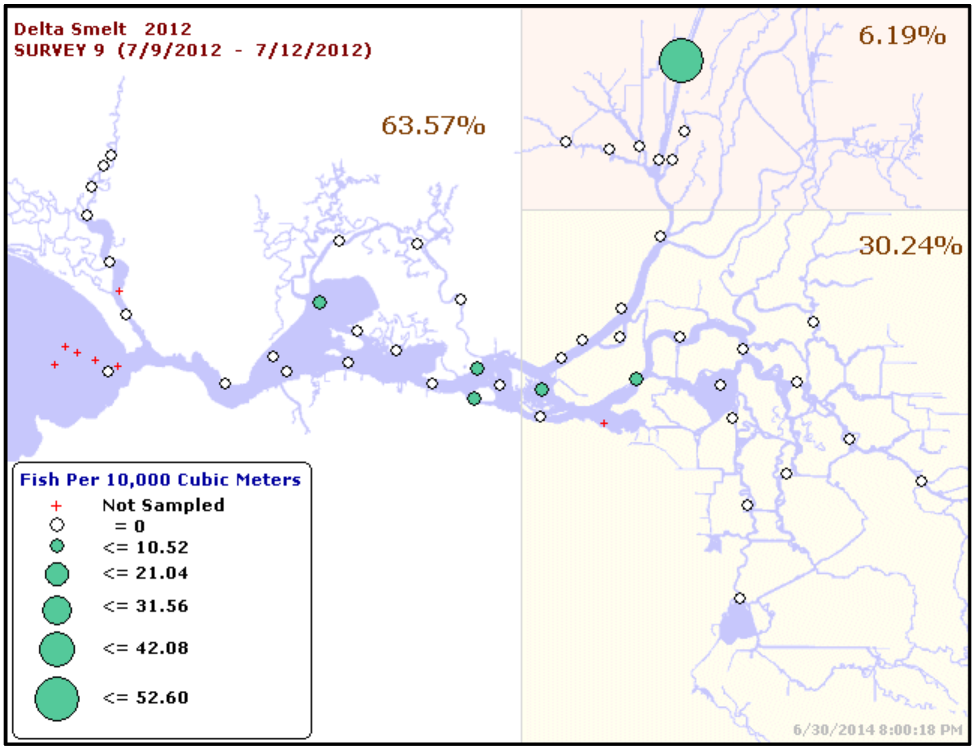
(with percentages)



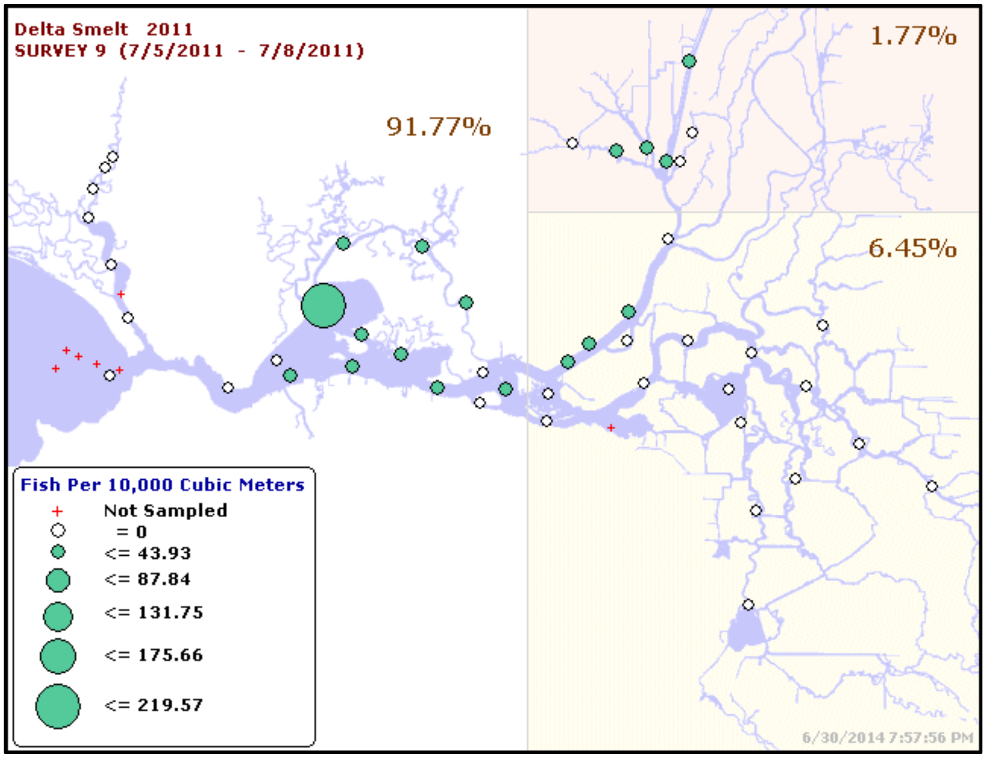
2014 Water Year: Sacramento = Critical; SJR = Critical



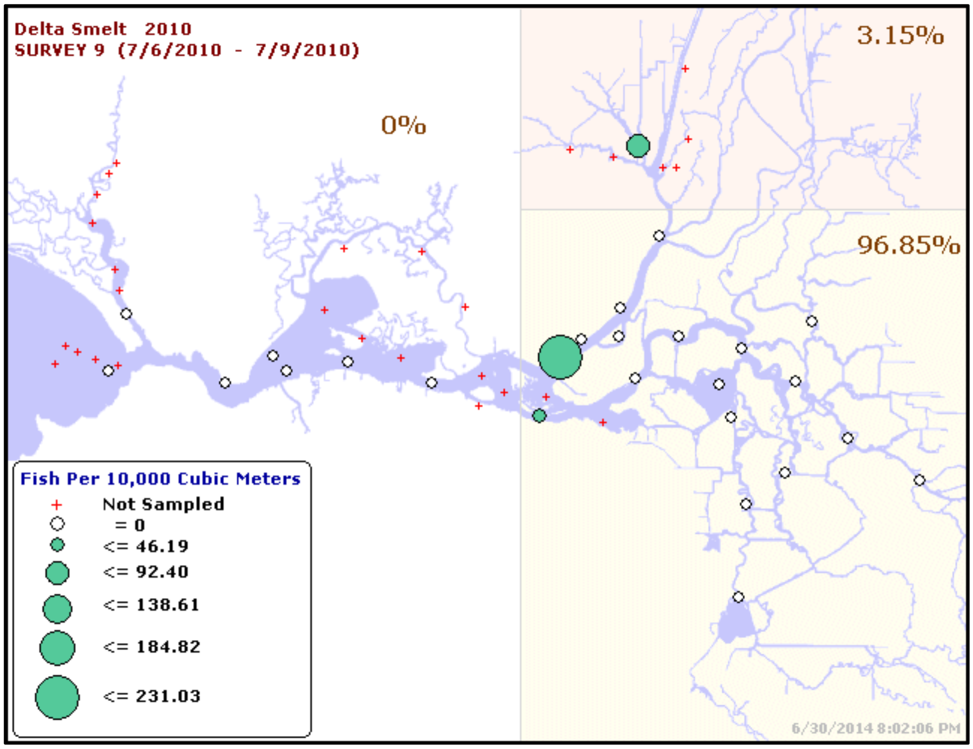
2013 Water Year: Sacramento = Dry; SJR = Critical



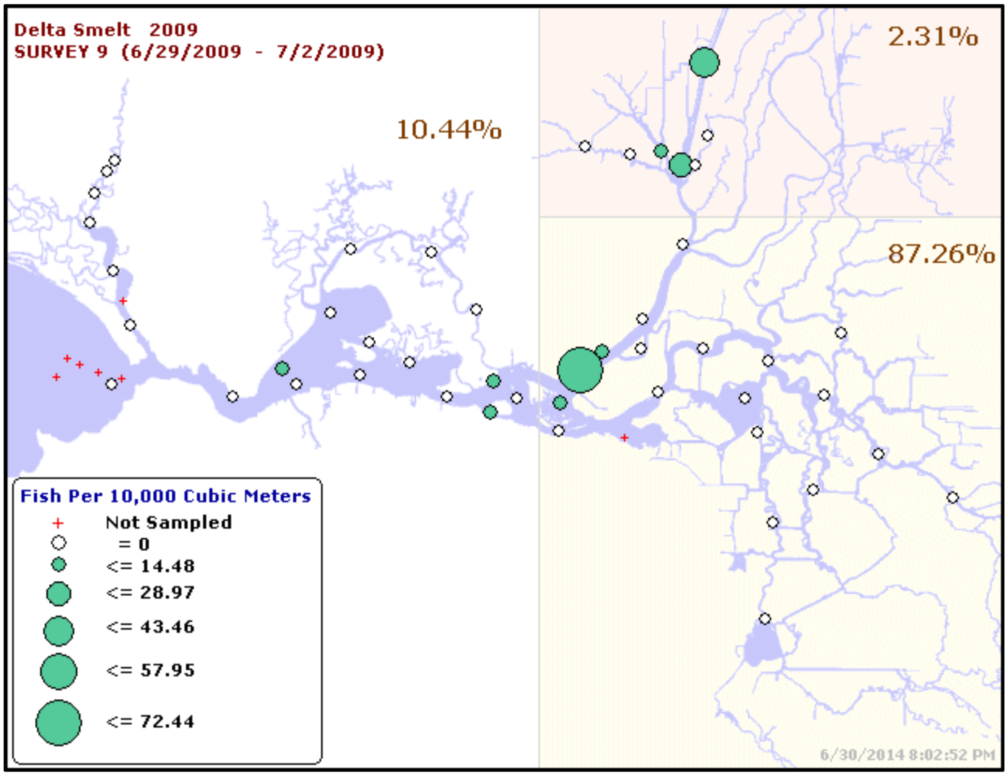
2012 Water Year: Sacramento = Below Normal; SJR = Dry



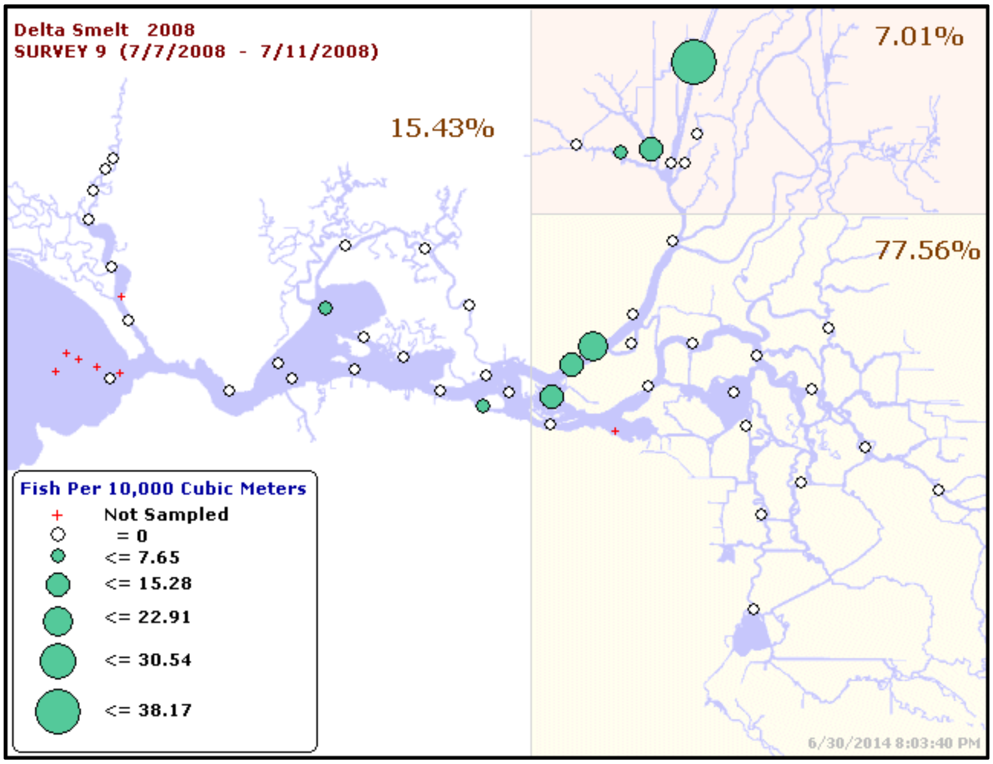
2011 Water Year: Sacramento = Wet; SJR = Wet



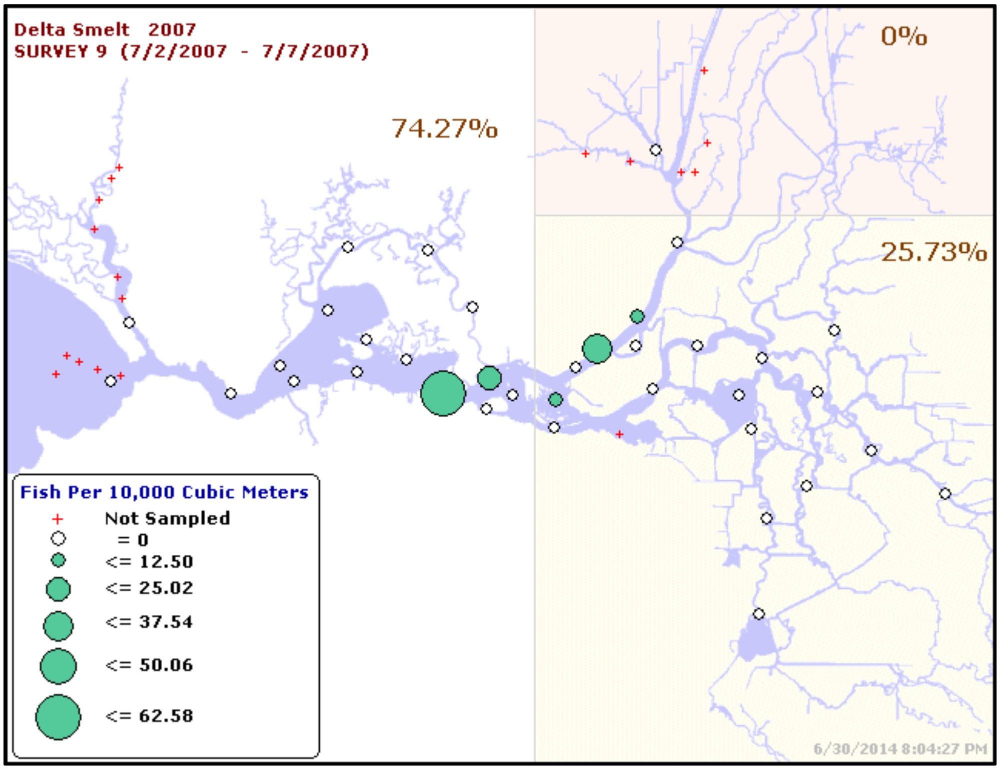
2010 Water Year: Sacramento = Below Normal; SJR = Above Normal



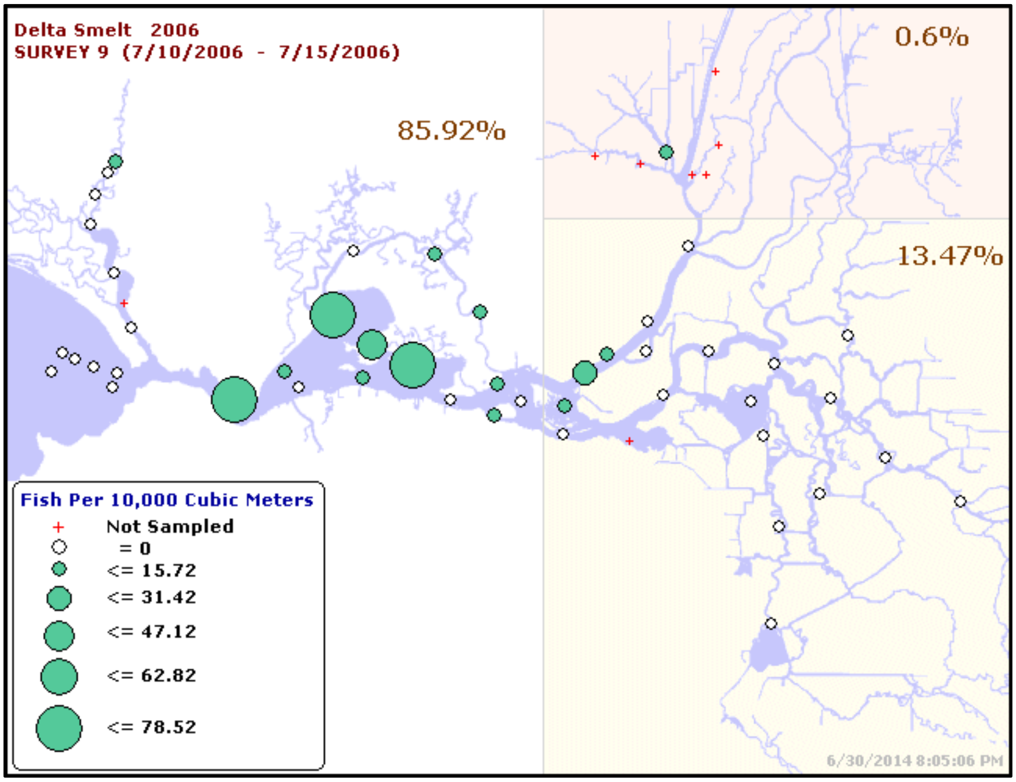
2009 Water Year: Sacramento = Dry; SJR = Dry



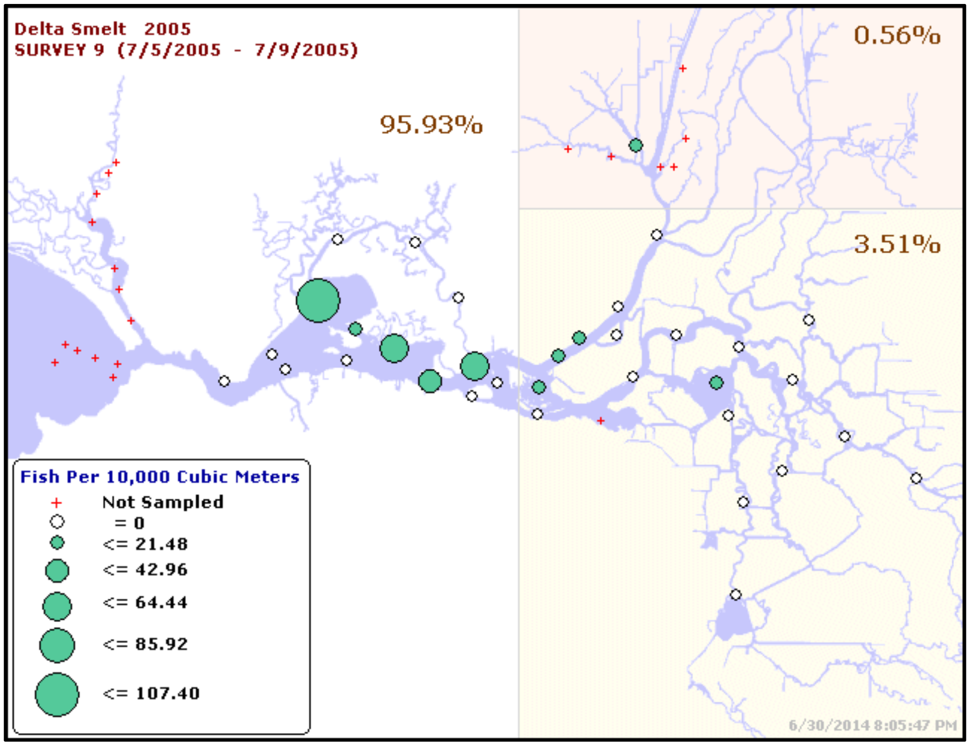
2008 Water Year: Sacramento = Critical; SJR = Critical



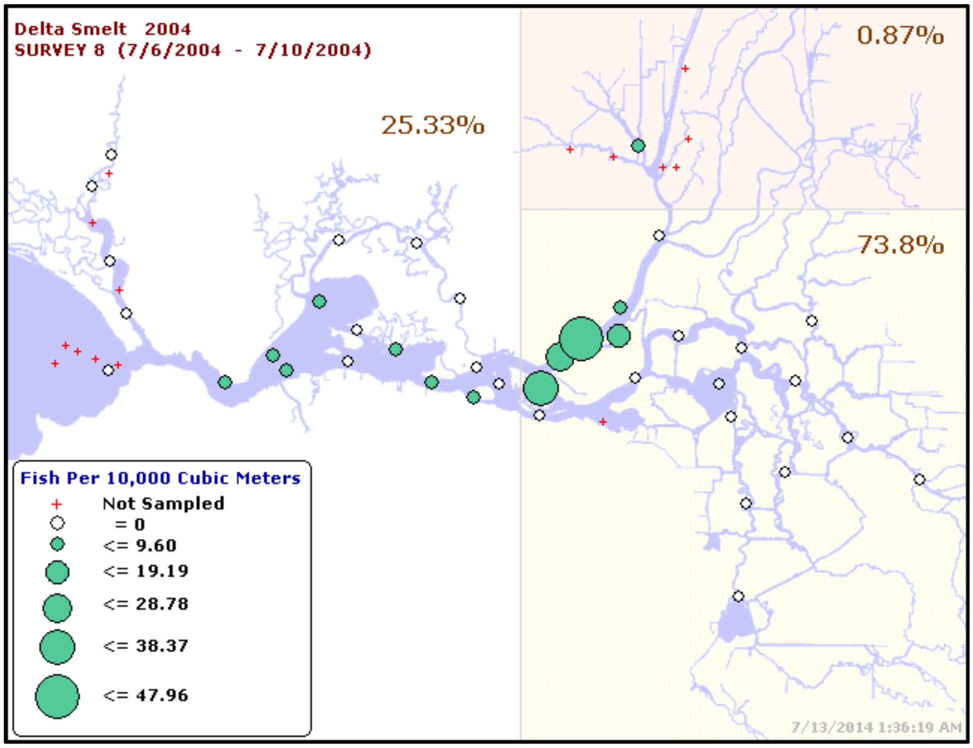
2007 Water Year: Sacramento = Dry; SJR = Critical



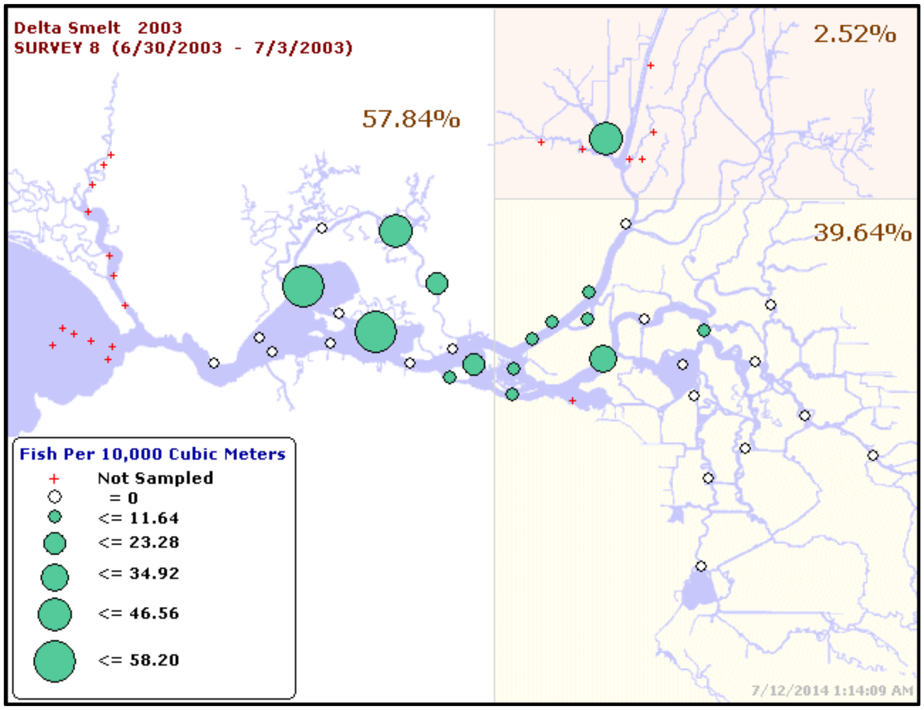
2006 Water Year: Sacramento = Wet; SJR = Wet



2005 Water Year: Sacramento = Above Normal; SJR = Wet

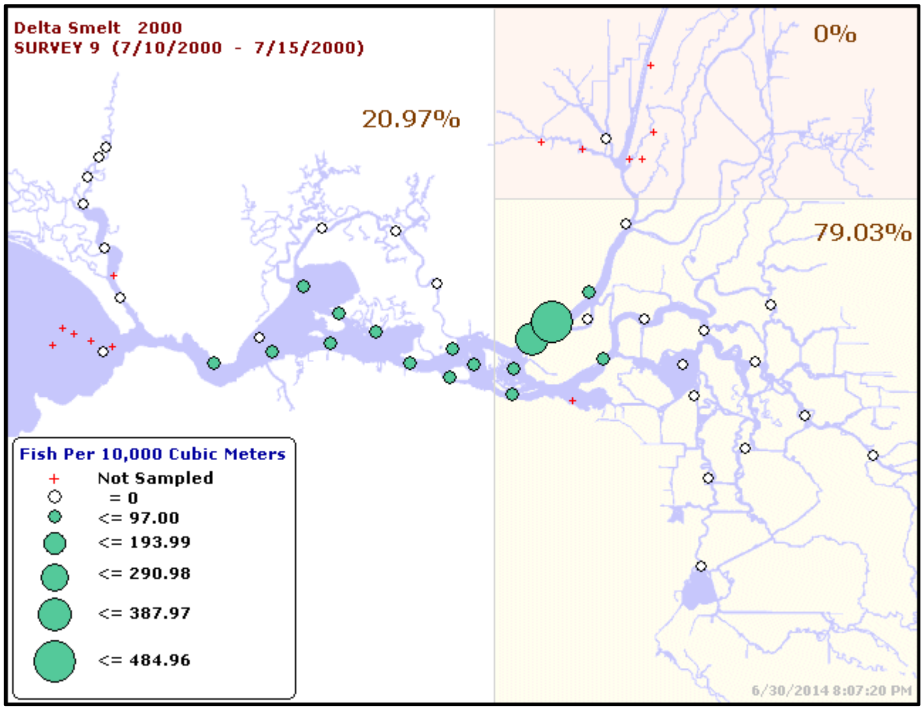


2004 Water Year: Sacramento = Below Normal; SJR = Dry

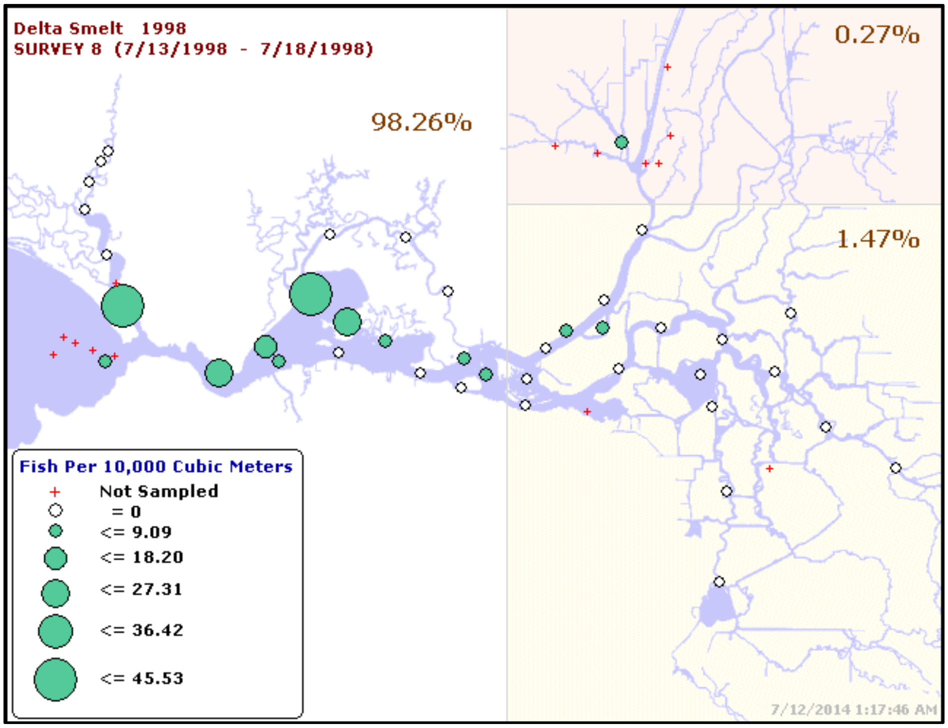


2003 Water Year: Sacramento = Above Normal; SJR = Below Normal

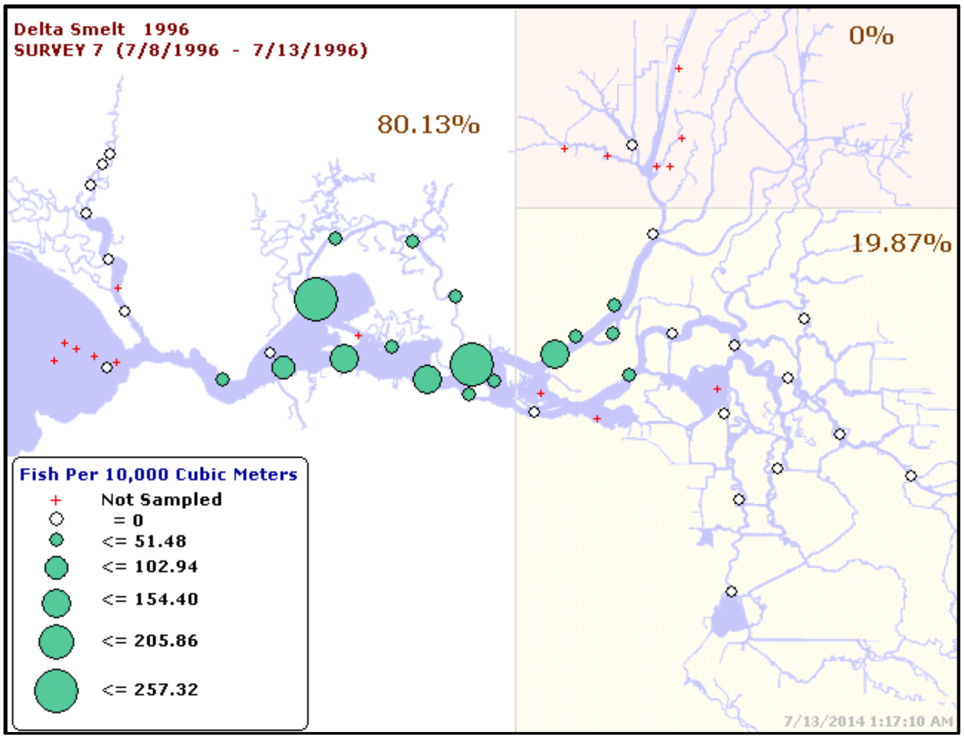
There Were No Early July Surveys in 2001 and 2002



2000 Water Year: Sacramento = Above Normal; SJR = Above Normal



1998 Water Year: Sacramento = Wet; SJR = Wet



1996 Water Year: Sacramento = Wet; SJR = Wet

Delta Smelt on the Scaffold

To summarize: during the summer of 2013, reductions in outflow, coupled with increased water exports, drew the LSZ and Delta smelt eastward into the Delta where smelt encountered lethal water temperatures. That situation was chronicled in a CSPA report titled *The Summer of 2013, the demise of Delta smelt under D-1641 Delta Water Quality Standards*, which predicted that the smelt population would plunge.[17] As predicted, the following Fall Midwater Trawl's Delta smelt abundance index was the second lowest level on record, statistically indistinguishable from the absolute lowest.

DFW conducts a series of 20-mm Delta smelt trawls monitoring post-larval-juvenile smelt. DFW does not publish their 20-mm Delta smelt indices, which are based on the initial surveys that begin in March of each year. CSPA took DFW 20-mm data and developed a series of indexes focused on the critical late June early July, when Delta smelt are drawn into the Delta be a combination of low outflow and export pumping. Those smelt are at risk of encountering lethal water temperatures. In 2014, juvenile Delta smelt were hammered by a combination of critically low outflow, water exports and lethal water temperature, as they were in 2013. The CSPA Delta

The previous low in 2009 was followed by a slightly better water year (below normal on the Sacramento and above normal on the San Joaquin) and smelt populations experienced a small rebound. This year, Delta smelt are being subjected to another year of critically dry conditions on both rivers. And this year, the State Water Board seriously weakened Delta flow and water quality standards. Delta outflow is below levels in recent memory and Delta smelt populations are at historic lows. Yet exports continue and water transfers are being approved with little environmental review.

The next Fall Midwater Trawl will almost surely find Delta smelt populations at new record lows. Population abundance levels over the last few years make the numbers of Delta smelt during the Pelagic Organism Decline (POD) in the early 2000s look robust. The POD years generated an enormous outcry. Myriad meeting were conducted, numerous studies funded and an array of programs launched. Today, the agencies that were so concerned about the POD are silent and have embraced measures they know will be disastrous for the species.

The point of no return, i.e., the level where the population cannot recover, is unknown. But, that point is likely approaching. A species that existed in this estuary for thousands of years and was the most abundant fish in the Delta is on the scaffold. Perhaps, the greatest tragedy is that our trustee agencies charged with the protection of Delta smelt; the USFWS, CDFW and the State Water Board have escorted it there.

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[17] http://calsport.org/news/wp-content/uploads/CSPA-Cannon-Summer-2013-6.pdf

SUMMER 2013

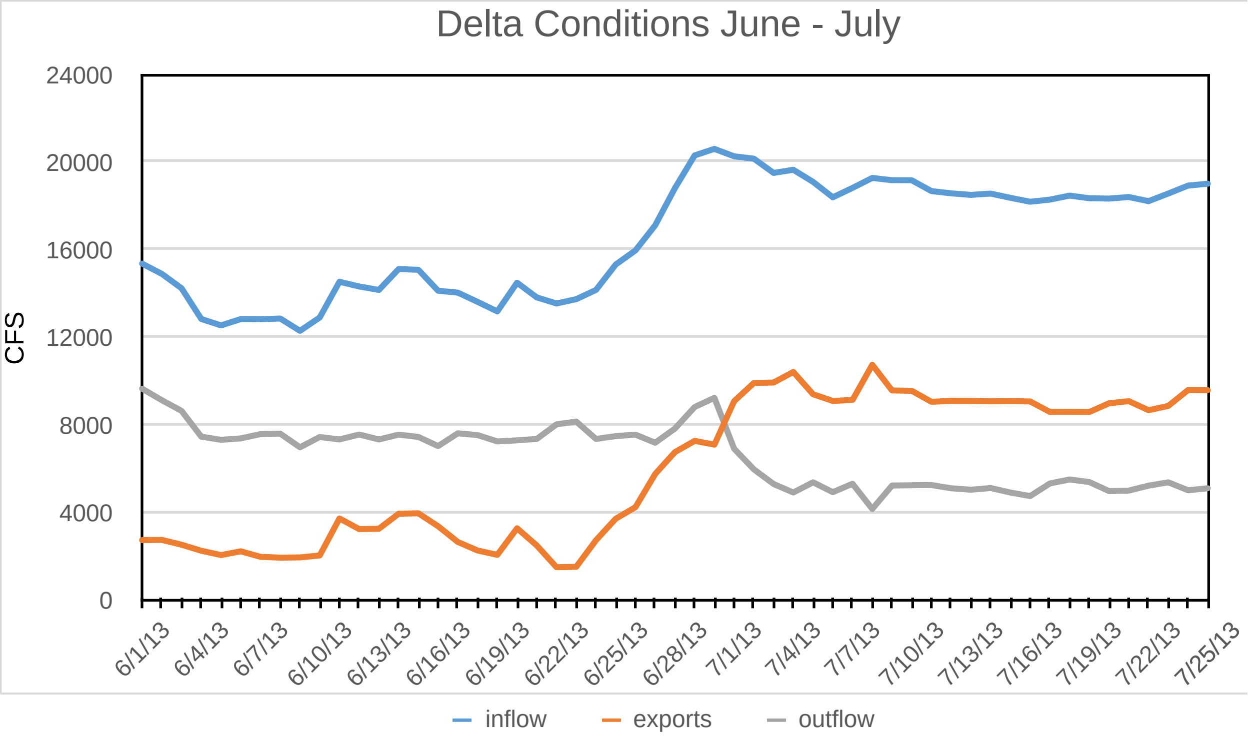
The demise of Delta smelt under D-1641 Delta Water Quality Standards

Thomas Cannon
Consultant

Representing
California Sportfishing Protection Alliance

August 2013

Summer 2013



Dry Year Standards Relaxed?

Despite near record low precipitation in the Central Valley in the spring of 2013, the water year remained classified as "dry," pursuant to D-1641. The "dry year" standards for EC at Emmaton were violated in April, May and June and the EC standard at Jersey Point was violated in June. These standards were established to protect agricultural beneficial uses in the Delta.

The Department of Water Resources and the Bureau of Reclamation, fearing that water exports from the State and Federal Water Projects (Projects) would lead to violations of Delta outflow and western Delta EC standards and depletion of cold water storage in Shasta Reservoir, asked the State Water Resources Control Board on 24 May to reclassify the water year to "critically dry" and requested permission to move the temperature compliance point on the Sacramento River upstream from Red Bluff to Anderson to save the cold-water pool supply in Shasta Reservoir. The Department of Fish and Wildlife, NOAA Fisheries and US Fish and Wildlife Service submitted letters supporting the request.

While the State Board had no authority to arbitrary change a water year classification, it informed the agencies that it "will not object or take any action if the Bureau and Department operate to meet critically dry year salinity objectives for Western and interior Delta."

On or about June 22, the Projects began substantially increasing exports and Delta inflows, and shortly thereafter significantly reducing Delta outflow per the Delta Standards.

The D-1641 standards for a dry year (Figure 1) already allowed salinity to encroach into the West Delta at Emmaton and Jersey Point. Earlier violations of those standards in the spring had already exacerbated conditions by summer (it should also be noted that South Delta EC standards were also violated in June and July through August 15).

This report reviews conditions in the summer of 2013, the inadequacy of D-1641 dry year standards and the adverse impacts to Delta smelt caused by violation of those already inadequate standards.

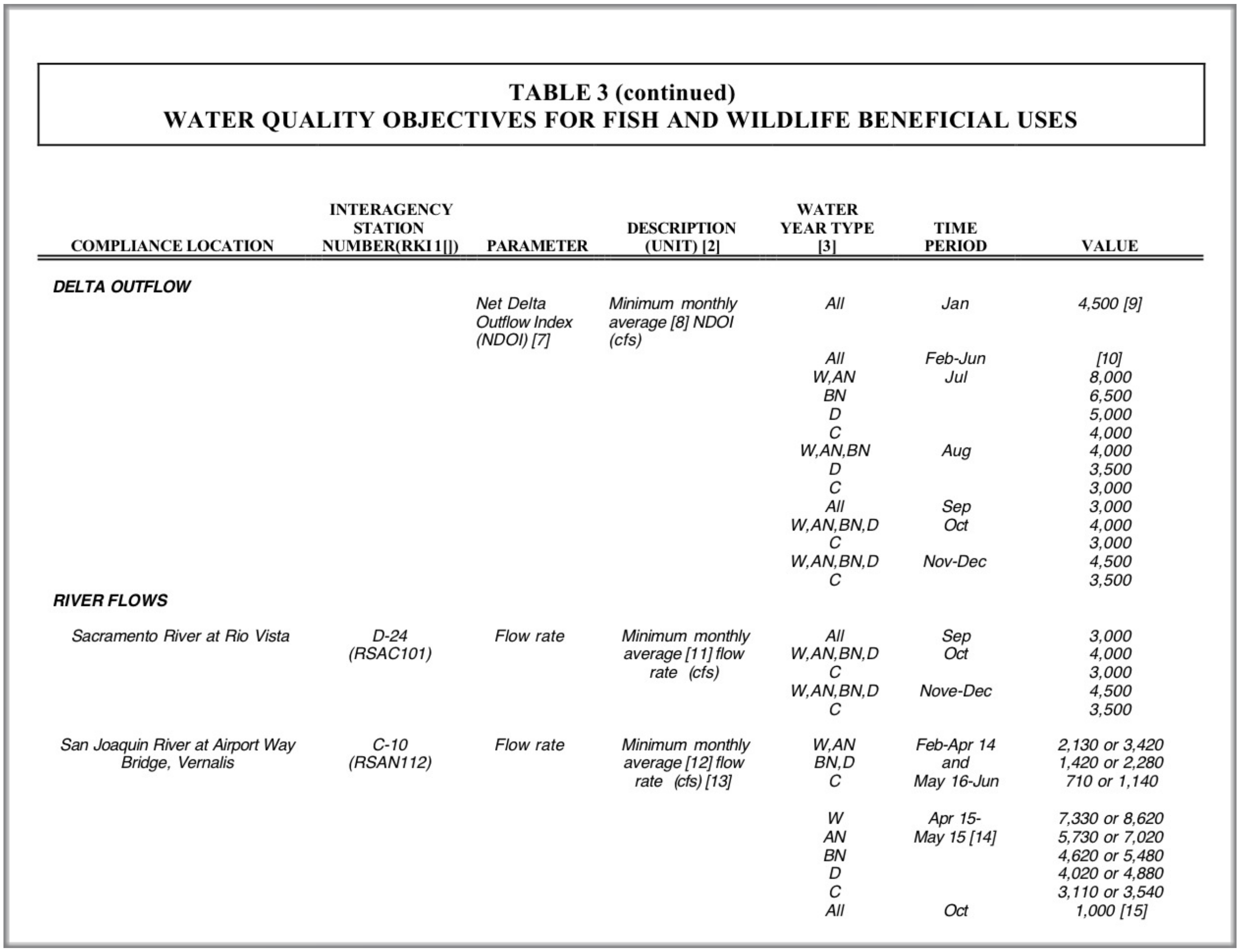


TABLE 3 (continued)
WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENEFICIAL USES

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER(RKI1[])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
DELTA OUTFLOW						
		Net Delta Outflow Index (NDOI) [7]	*Minimum monthly average [8] NDOI (cfs)*	*All*	*Jan*	*4,500 [9]*
				All	*Feb-Jun*	*[10]*
				W,AN	*Jul*	*8,000*
				BN		*6,500*
				D		*5,000*
				C		*4,000*
				W,AN,BN	*Aug*	*4,000*
				D		*3,500*
				C		*3,000*
				All	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nov-Dec*	*4,500*
				C		*3,500*
RIVER FLOWS						
Sacramento River at Rio Vista	*D-24 (RSAC101)*	*Flow rate*	*Minimum monthly average [11] flow rate (cfs)*	*All*	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nove-Dec*	*4,500*
				C		*3,500*
San Joaquin River at Airport Way Bridge, Vernalis	*C-10 (RSAN112)*	*Flow rate*	*Minimum monthly average [12] flow rate (cfs) [13]*	*W,AN*	*Feb-Apr 14 and May 16-Jun*	*2,130 or 3,420*
				BN,D		*1,420 or 2,280*
				C		*710 or 1,140*
				W	*Apr 15-May 15 [14]*	*7,330 or 8,620*
				AN		*5,730 or 7,020*
				BN		*4,620 or 5,480*
				D		*4,020 or 4,880*
				C		*3,110 or 3,540*
				All	*Oct*	*1,000 [15]*

Figure 1a. D-1641 EC Water Quality Objectives Table 2.

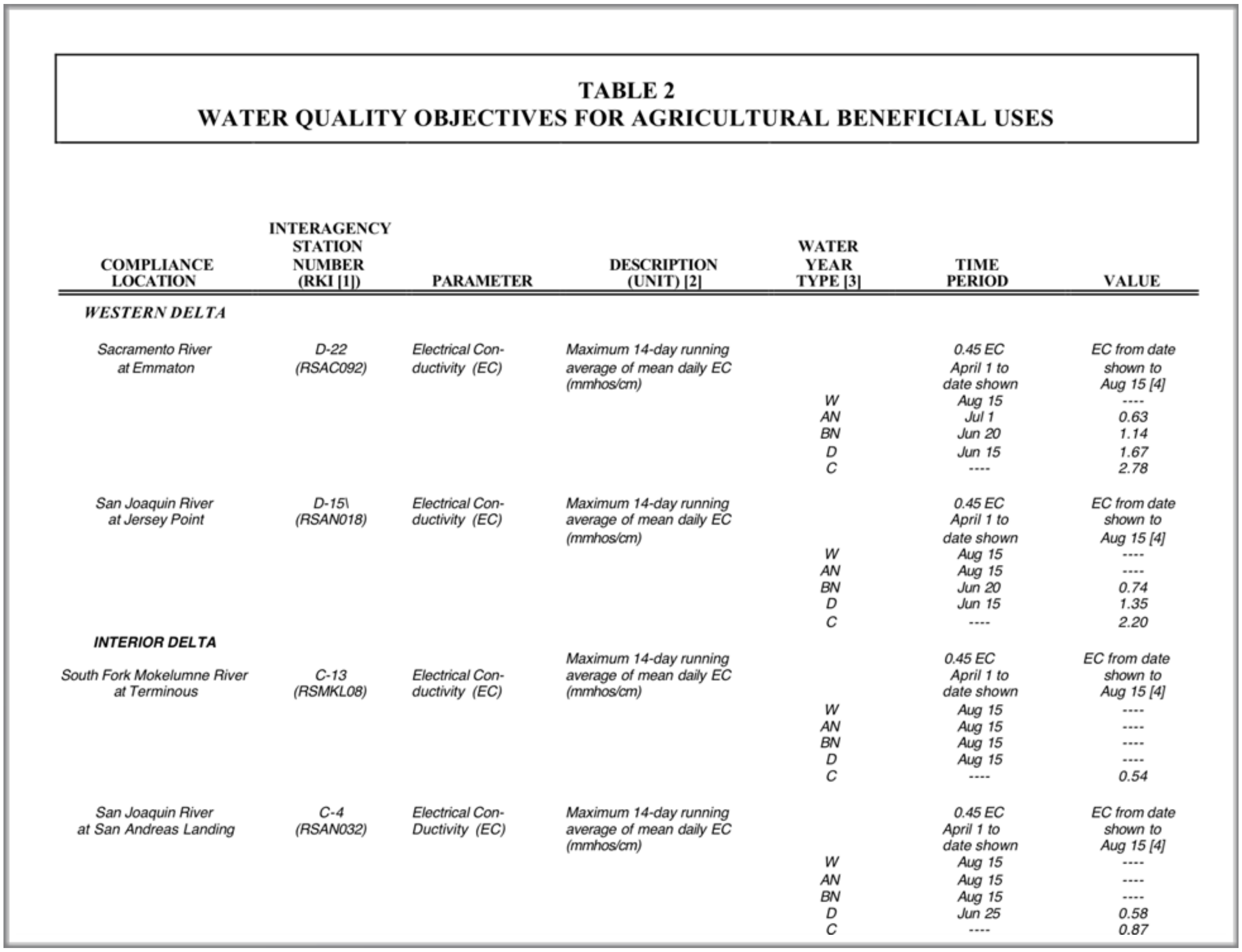


TABLE 2
WATER QUALITY OBJECTIVES FOR AGRICULTURAL BENEFICIAL USES

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
WESTERN DELTA						
Sacramento River at Emmaton	*D-22 (RSAC092)*	*Electrical Conductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Jul 1*	*0.63*
				BN	*Jun 20*	*1.14*
				D	*Jun 15*	*1.67*
				C	*----*	*2.78*
San Joaquin River at Jersey Point	*D-15\ (RSAN018)*	*Electrical Conductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Jun 20*	*0.74*
				D	*Jun 15*	*1.35*
				C	*----*	*2.20*
INTERIOR DELTA						
South Fork Mokelumne River at Terminous	*C-13 (RSMKL08)*	*Electrical Conductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Aug 15*	*----*
				C	*----*	*0.54*
San Joaquin River at San Andreas Landing	*C-4 (RSAN032)*	*Electrical Con-Ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Jun 25*	*0.58*
				C	*----*	*0.87*

Figure 1b. D-1641 Flow Water Quality Objectives Table 3.

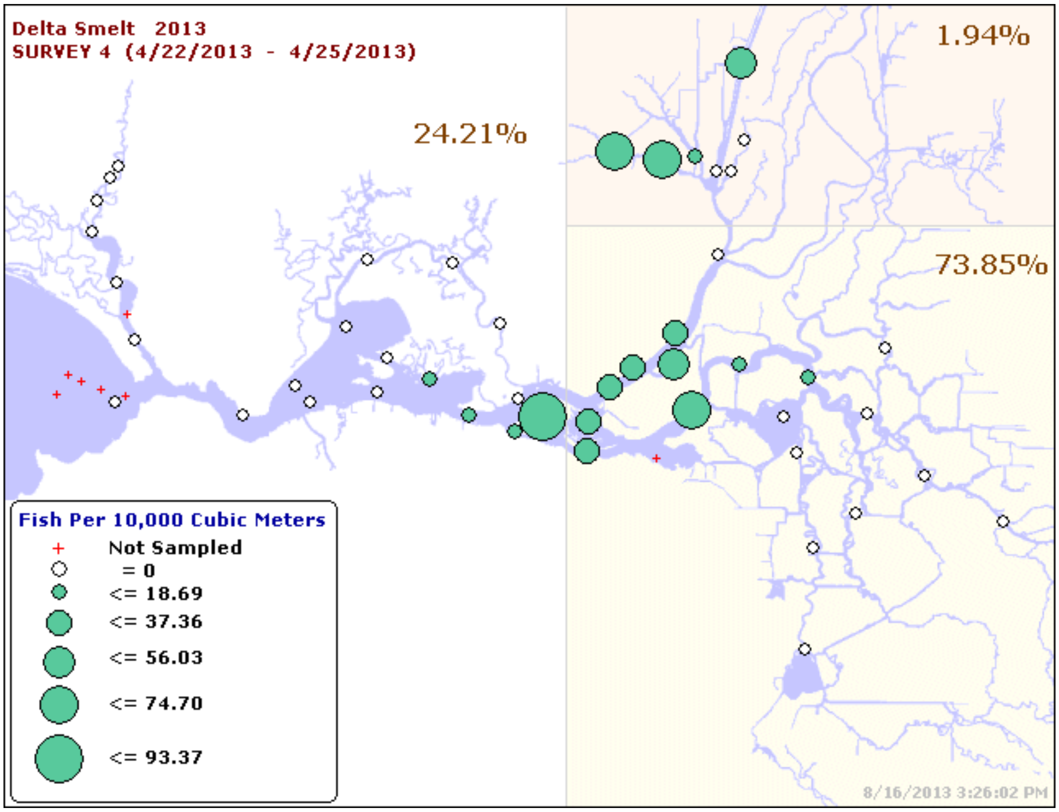


Figure 2. Late-April 2013, 20-mm Smelt Survey results. (Source: http://www.dfg.ca.gov/delta/data/20mm/)

Delta Smelt in April

Although not the subject of this report, spring conditions set the stage for summer. April 2013 was a tough time for smelt. Sacramento River inflow to the Delta dropped to only 6,000 cfs, San Joaquin inflows were 1500-3000 cfs, exports were up to 2,500-3,000 cfs, and outflow was as low as 6,000 cfs. Old and Middle River OMR flows were -1000 to -4000 cfs. The Delta Cross Channel was closed.

Over the past 20 years, the late April – early May period had been under the protection of VAMP (Vernalis Adaptive Management Program) experiment, but these protections ended in 2010. This year, without these protections, late April exports climbed to 2,500-3,000 cfs reaching 4,000 cfs in early May (from 1500 cfs cap under VAMP). This increase in exports without the VAMP export cap occurred under lower inflows, outflows, and negative OMR flows. Nearly three quarters of the Delta smelt population was in the Central and Western Delta (20-mm survey, Fig. 2) and thus subject to being exported (especially with negative OMRs with the DCC closed). Most of the smelt were not of salvageable size (they were only 10-25 mm), so they were entrained in the export water likely in large numbers (hundreds of thousands per day were moving into Old River toward pumps).

Despite these horrible conditions many still survived in the western Delta under the modest outflows and thus became subject to summer conditions.

Delta Smelt in Mid June

In mid June 2013 the small remnant population of delta smelt surviving in the San Francisco Bay-Delta after the below-normal water year of 2012 and poor spring conditions described above were spread through their usual dry-year habitats in the western Delta, eastern Suisun Bay, Montezuma Slough, and the Cache Slough/Bypass/Ship Channel complex in the north Delta (Figure 3).

Other than the north Delta group, most of the smelt were in their summer low-salinity zone (LSZ) home where salinities are low (0.5-5 ppt) and water temperature optimal (about 20C). With the protective dry-year EC standard of 0.45 through June 15, the LSZ was in eastern Suisun Bay west of the Delta.

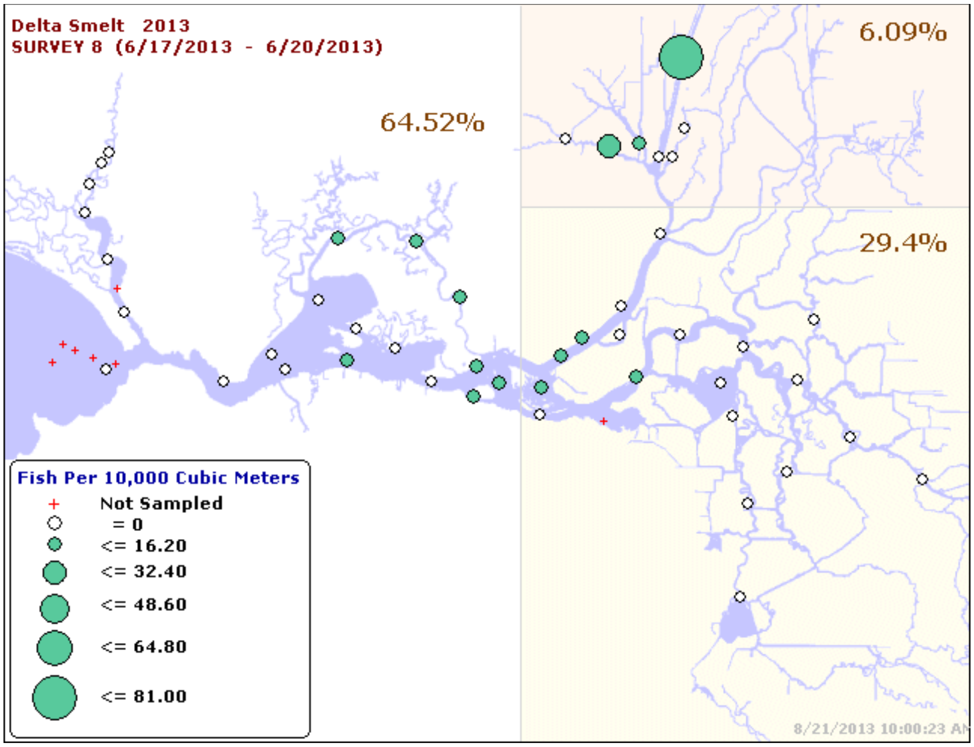


Figure 3. Mid-June 2013, 20-mm Smelt Survey results. (Source: http://www.dfg.ca.gov/delta/data/20mm/)

Summer Flow and Salinity Conditions

Beginning in the third week in June, inflow increase from the 12,000-14,000 cfs level to 20,000 cfs and exports increased from 2,000 to 10,000 cfs (Figure 4). A week later Delta outflow was reduced to 5,000 cfs.

West Delta

The effect is seen in the EC patterns at Emmaton and Jersey Point in the west Delta (Figures 5a and 5b). As outflow declines, salinities (EC) increase. The LSZ with its 500-6000 EC signature moved upstream into the West Delta with each incoming tide. In contrast, in wet year 2011, outflow was maintained at 8000 cfs and the LSZ did not move upstream into the Delta (Figure 5c).

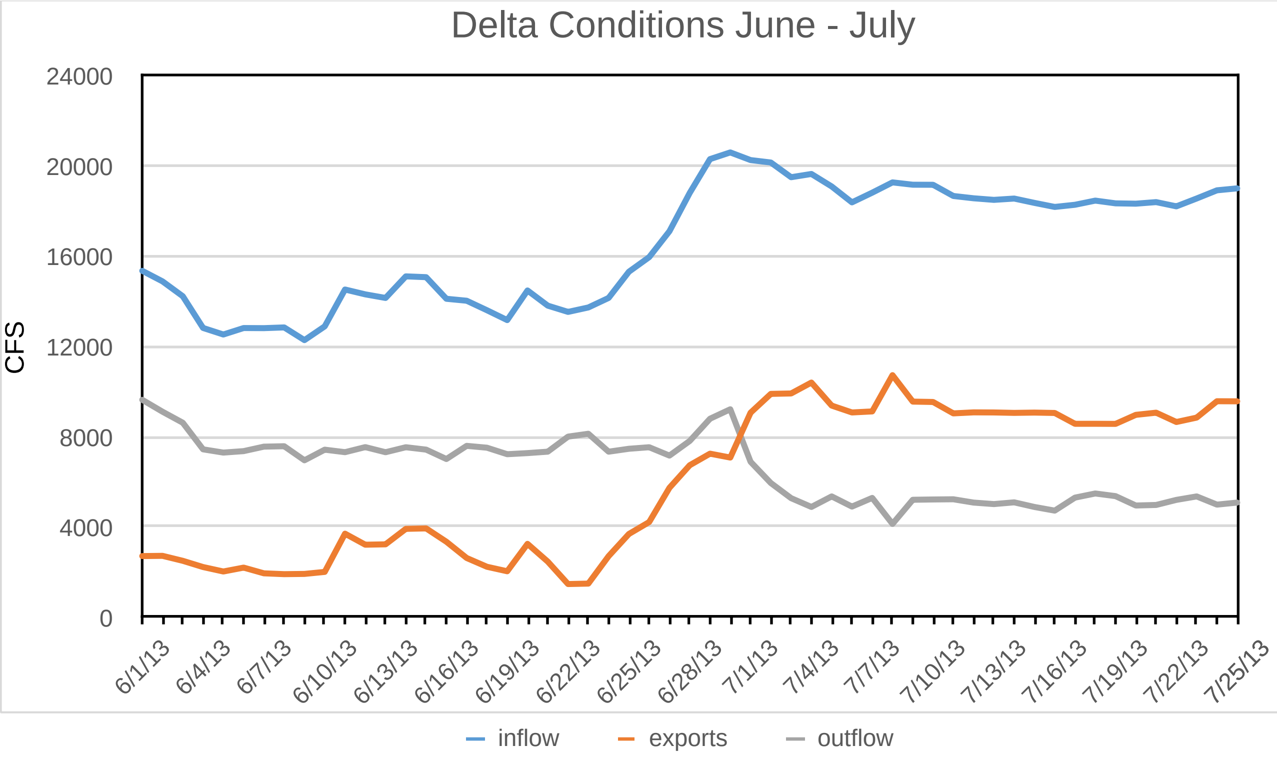


Figure 4. June through July 2013 Delta inflow, outflow, and exports. Summer EC standards kick in after mid June.

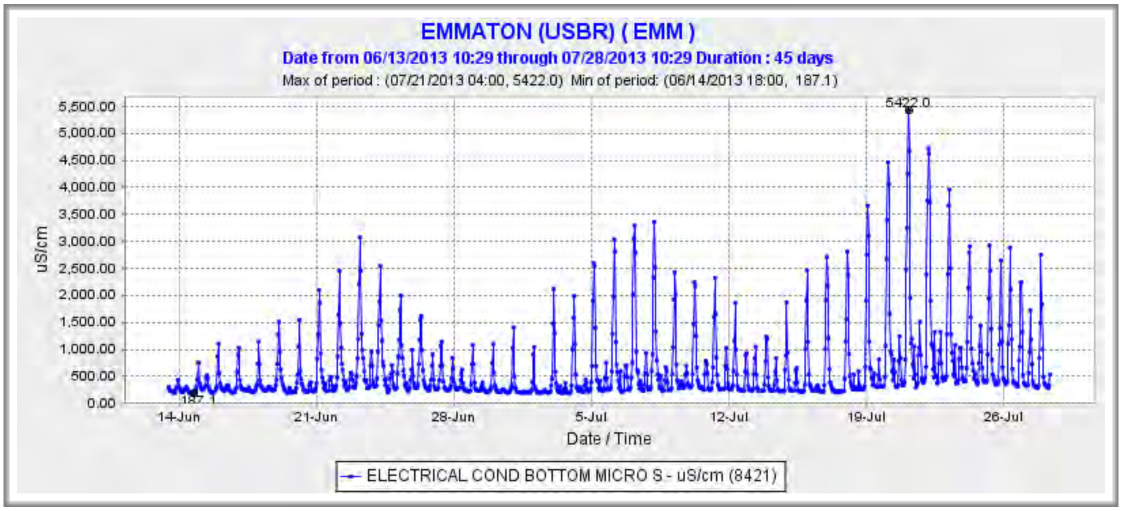


Figure 5a. Conductivity (EC) at Emmaton on lower Sacramento River in West Delta after mid June 2013. (Source: CDEC)

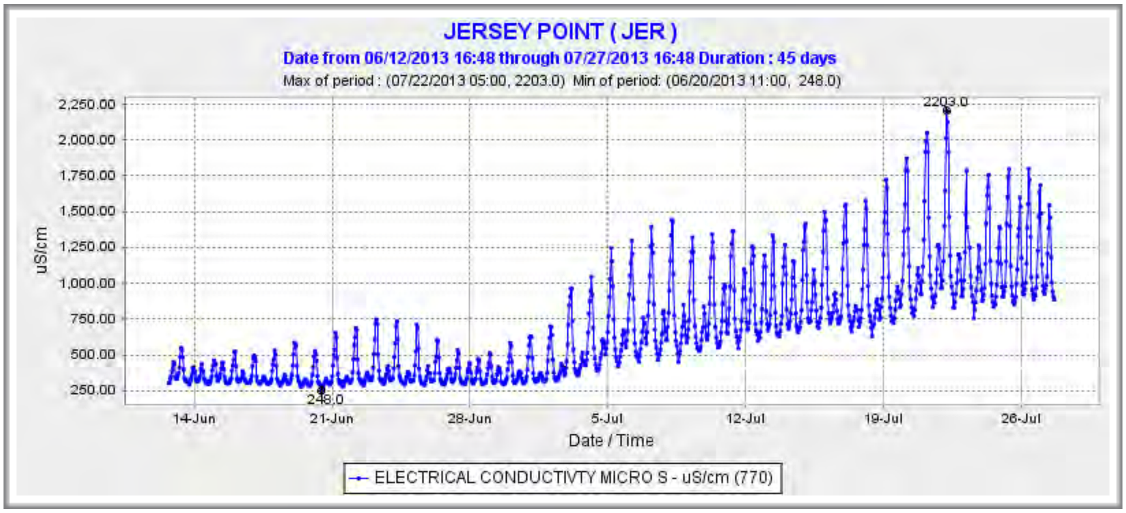


Figure 5b. Conductivity (EC) at Jersey Point on lower San Joaquin River in West Delta after mid June 2013. (Source: CDEC)

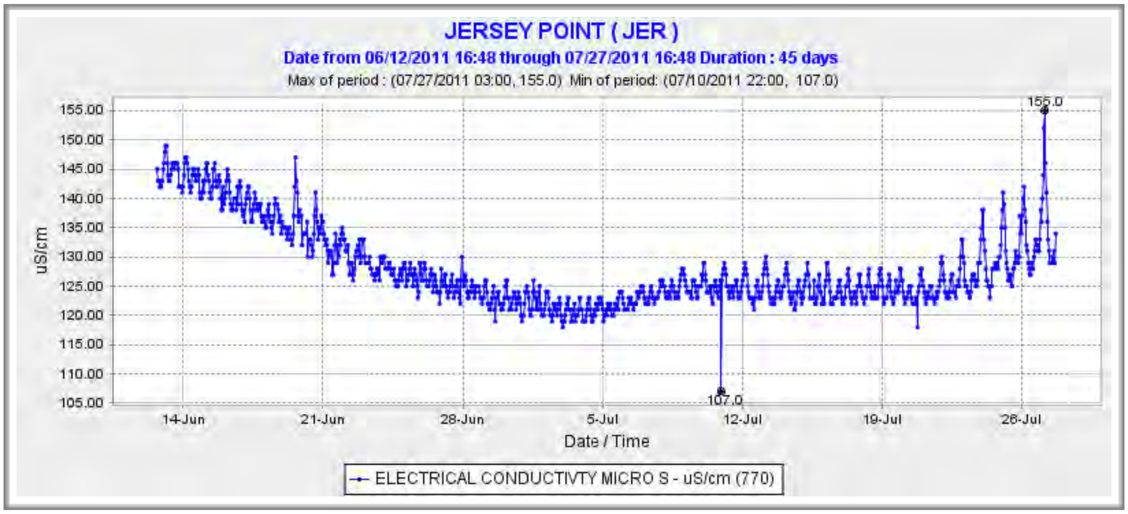


Figure 5c. Conductivity (EC) at Jersey Point on lower San Joaquin River in West Delta after mid June 2011. (Source: CDEC)

Eastern Suisun Bay

Salinity (EC) in Eastern Suisun Bay at Collinsville on the north and Pittsburg on the south also increased at the beginning of July with the decrease in outflow (Figures 6 and 7). At high tide the LSZ was well upstream of the two locations by early July. The lower end of the LSZ did extend downstream to these locations during low tides through July.

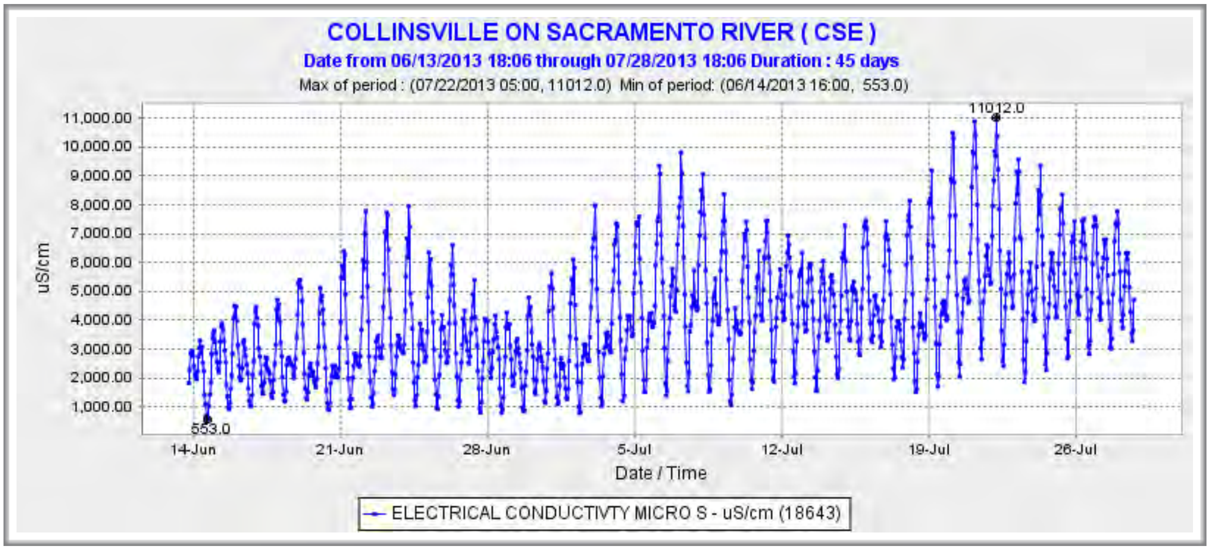


Figure 6. Conductivity (EC) at Collinsville in Eastern Suisun Bay after mid June 2013. (Source: CDEC)

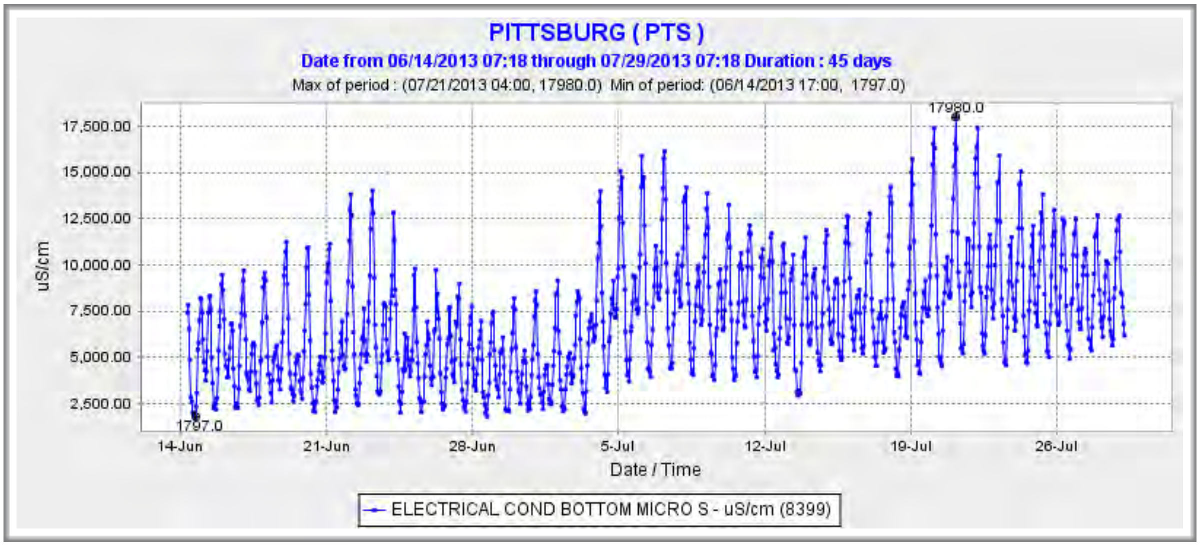


Figure 7. Conductivity (EC) at Pittsburg in Eastern Suisun Bay after mid June 2013. (Source: CDEC)

Central Delta

Central Delta EC as measured Threemile Slough on the San Joaquin River (Figure 8) and False River (Figure 9) also shows the movement of the LSZ upstream coincident with the reduction in Delta outflow at the beginning of July.

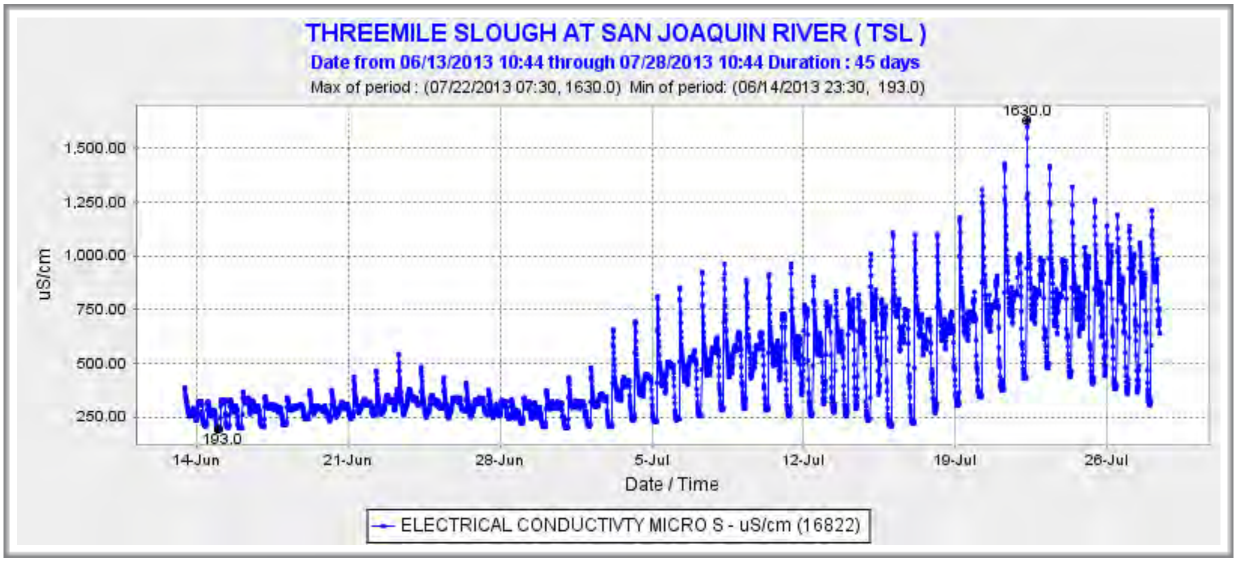


Figure 8. Conductivity (EC) at Threemile Slough in the Central Delta after mid June 2013. (Source: CDEC)

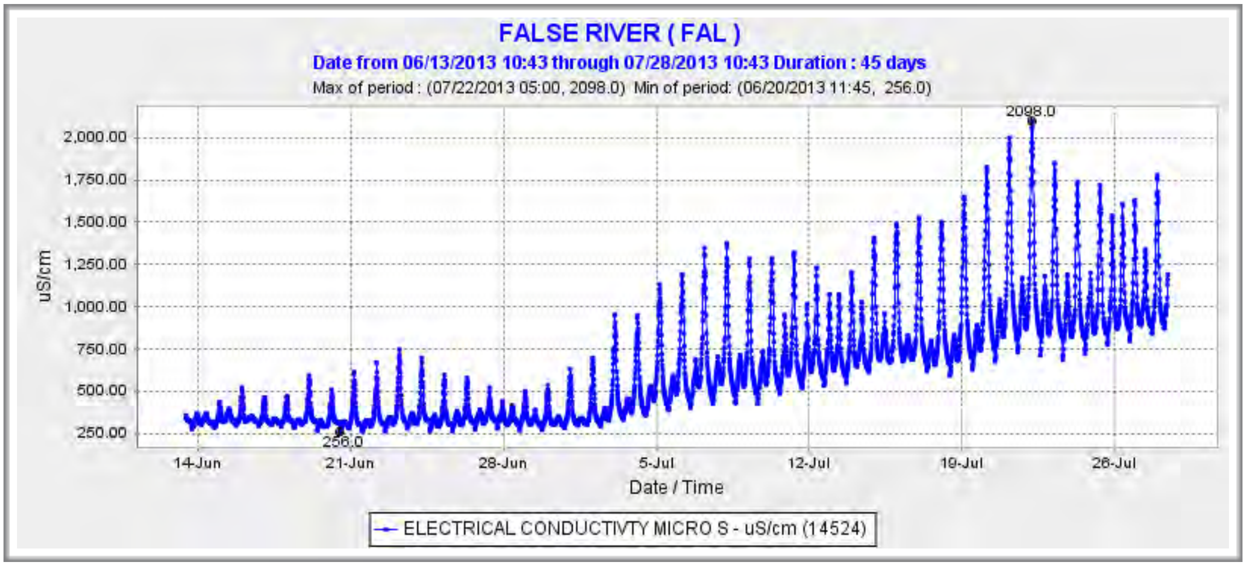


Figure 9. Conductivity (EC) at False River in the Central Delta at Franks Tract after mid June 2013. (Source: CDEC)

South Delta

South Delta EC also increased as the upper portion of the LSZ was mixed with cross Delta moving freshwater Sacramento River on the way to the export pumps. Salinity gradually increased in Old River as the head of the LSZ actually moved into the South Delta toward the export pumps (Figure 10).

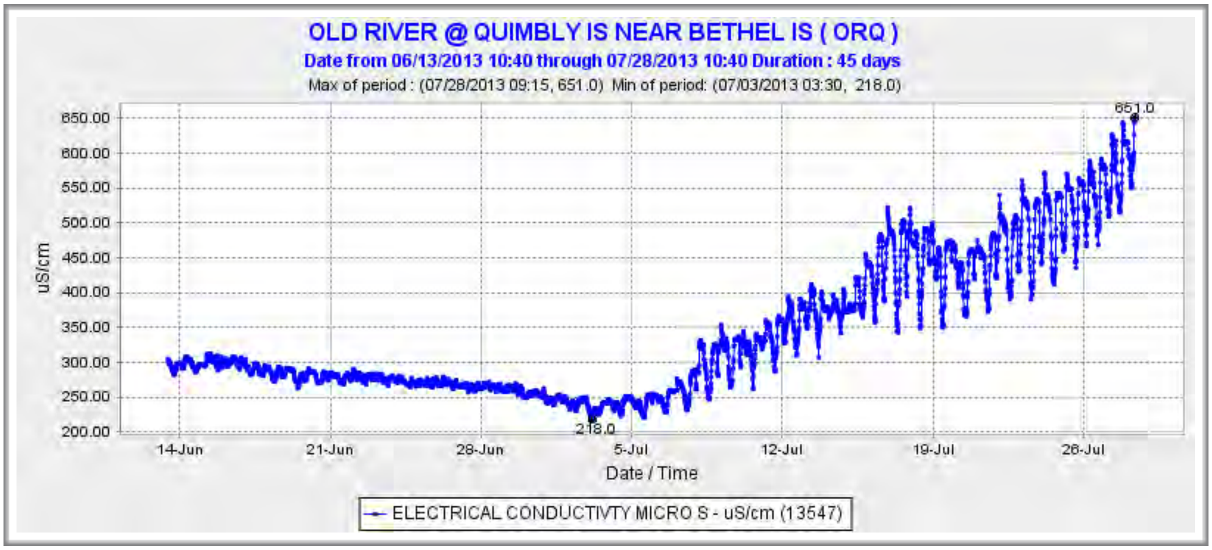


Figure 10. Conductivity (EC) in Old River in the Central Delta near Bethel Is after mid June 2013. (Source: CDEC)

Salinity in Clifton Court Forebay was slightly less as Forebay water is a mixture of Old River, Middle River, and East Delta waters of lower salinity (Figure11).

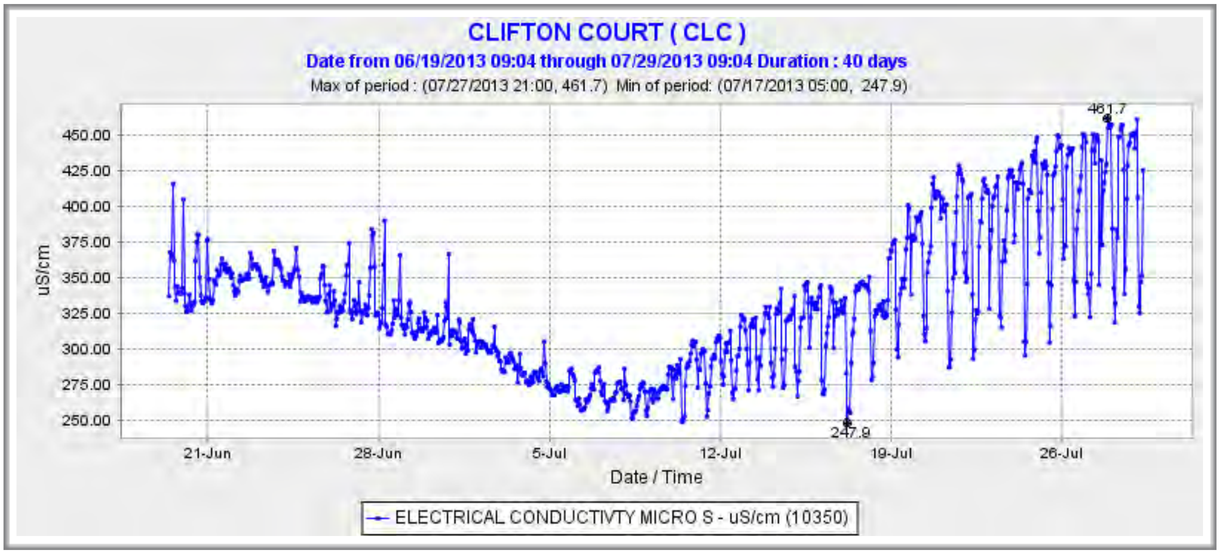


Figure 11. Conductivity (EC) in Clifton Court Forebay after mid June 2013. (Source: CDEC)

Summer Water Temperatures

Western Delta

Water temperatures reached near lethal levels for smelt (75-77F) in the western Delta by the beginning of July (Figures 12-14). Water temperatures rose sharply in late June due to the combination of warm air temperatures and sharply higher Delta inflows. Water temperatures declined thereafter through mid July with lower air temperatures, lower Delta inflows, and cooler waters moving upstream from Suisun Bay with lower outflows.

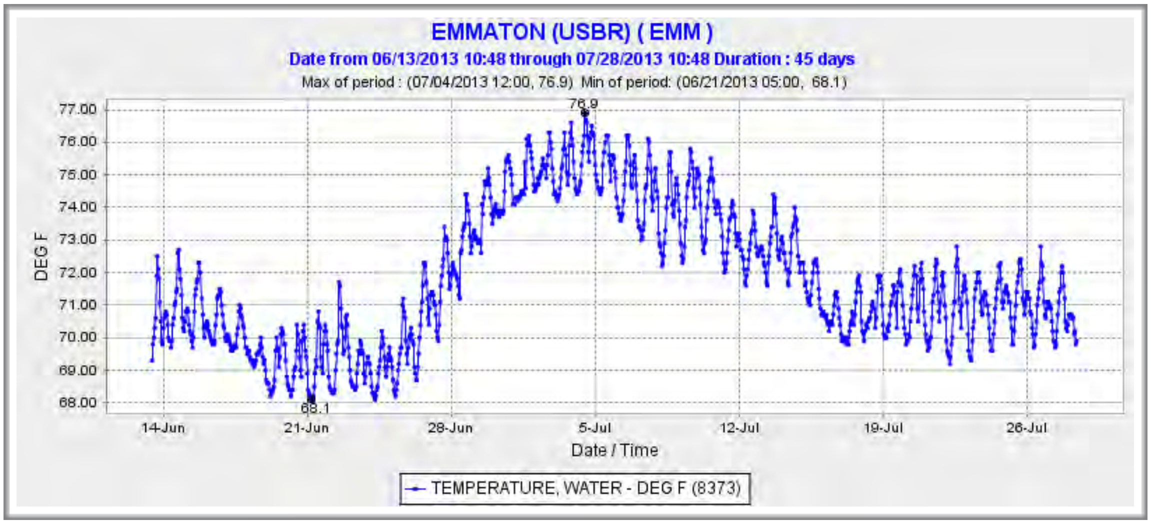


Figure 12. Water temperature at Emmaton mid June through July 2013. (Source: CDEC)

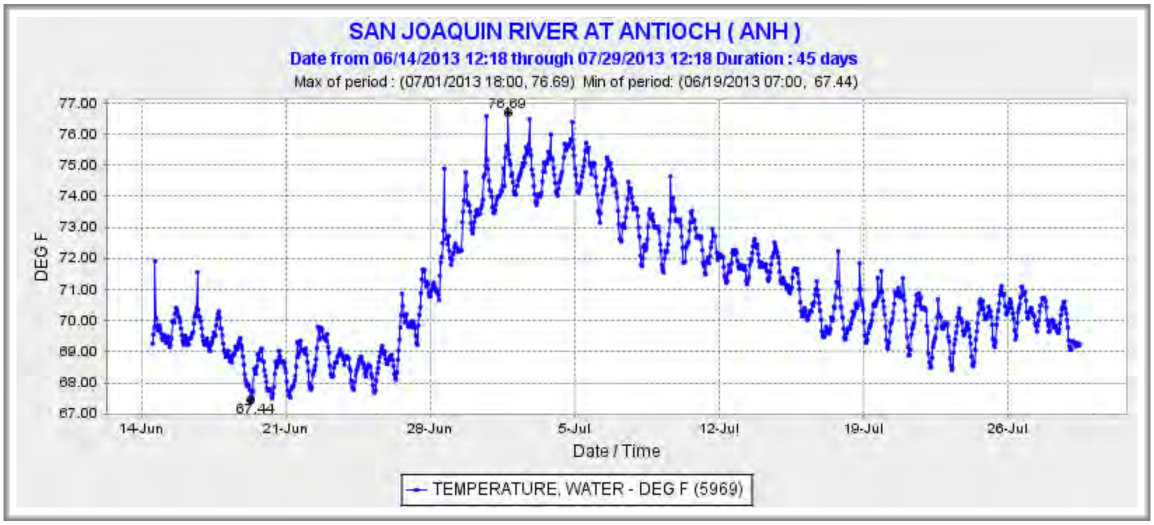


Figure 13. Water temperature at Antioch mid June through July 2013. (Source: CDEC)

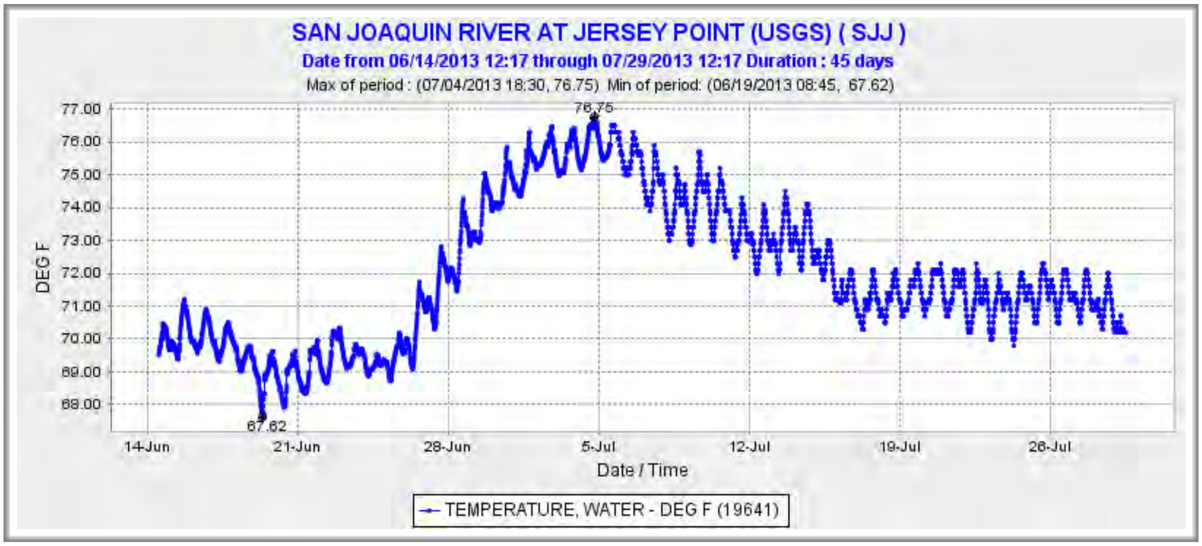


Figure 14. Water temperature at Jersey Point mid June through July 2013. (Source: CDEC)

Central Delta

Water temperatures reached near lethal levels for smelt (75-77F) in the Central Delta by the beginning of July (Figures 15 and 16). Water temperatures rose sharply in late June due to the combination of warm air temperatures and sharply higher Delta inflows. Water temperatures declined thereafter through mid July with lower air temperatures, lower Delta inflows, and cooler waters moving upstream from The West Delta with lower outflows.

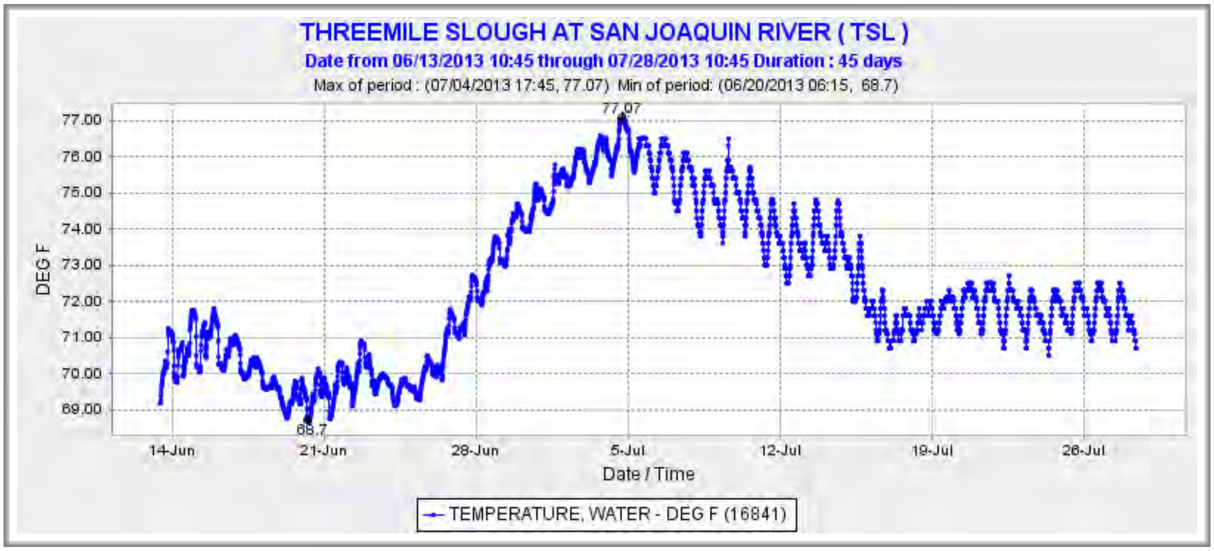


Figure 15. Water temperature at Threemile Slough mid June through July 2013. (Source: CDEC)

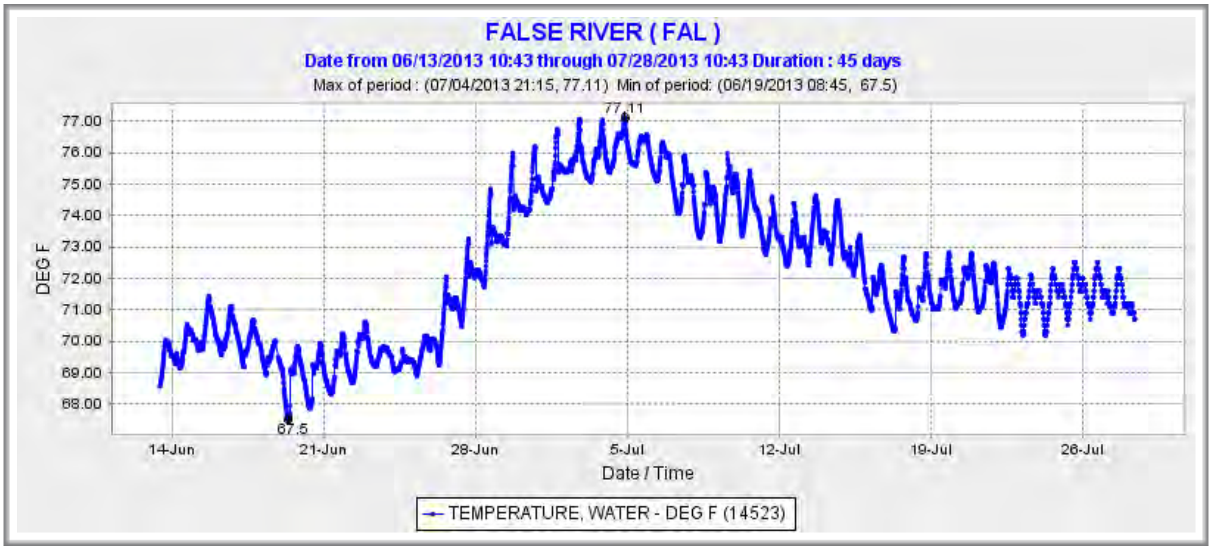


Figure 16. Water temperature at False River mid June through July 2013. (Source: CDEC)

South Delta

Water temperatures reached lethal levels for smelt (78-80F) in the South Delta by the beginning of July (Figures 17-18). Water temperatures rose sharply in late June due to the combination of warm air temperatures, sharply higher Delta inflows, and higher exports drawing warm water into the South Delta. Water temperatures declined thereafter through mid July with lower air temperatures, lower Delta inflows, and cooler waters moving into the South Delta from the western and central Delta with lower outflows.

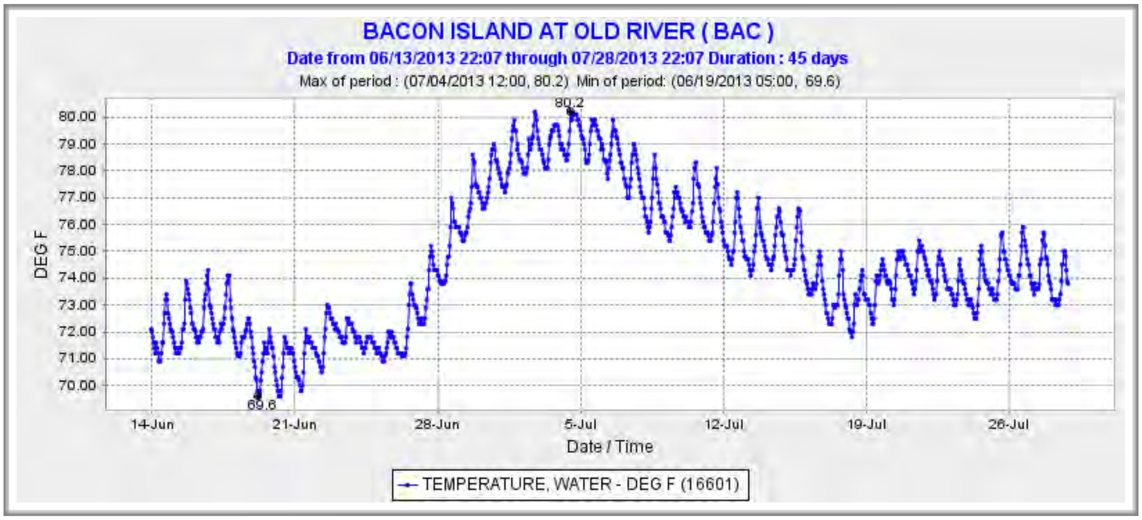


Figure 17. Water temperature in Old River near Bacon Is mid June through July 2013. (Source: CDEC)

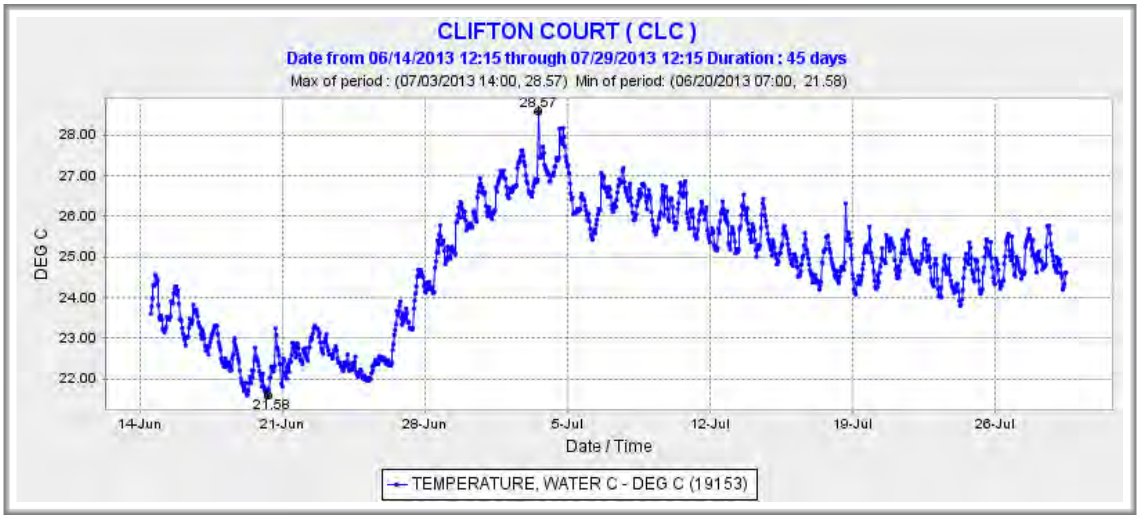
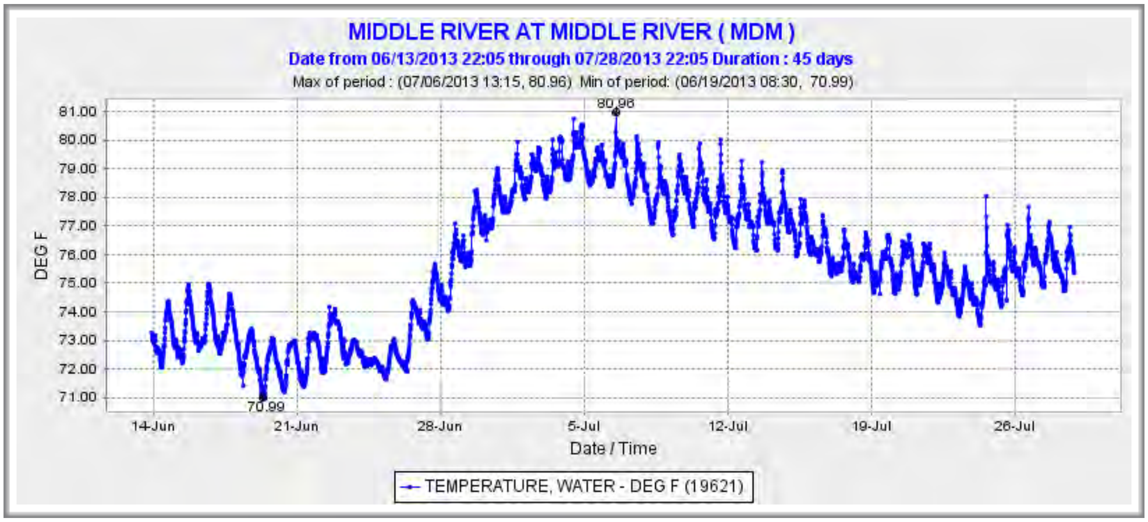


Figure 18. Water temperature in Clifton Court Forebay near Byron mid June through July 2013. (Source: CDEC)

Eastern Delta

Water temperatures in the eastern Delta also reached lethal levels of 80-81F (Figures 19 and 20).

Figure 19. Water temperature in Middle River mid June through July 2013. (Source: CDEC)



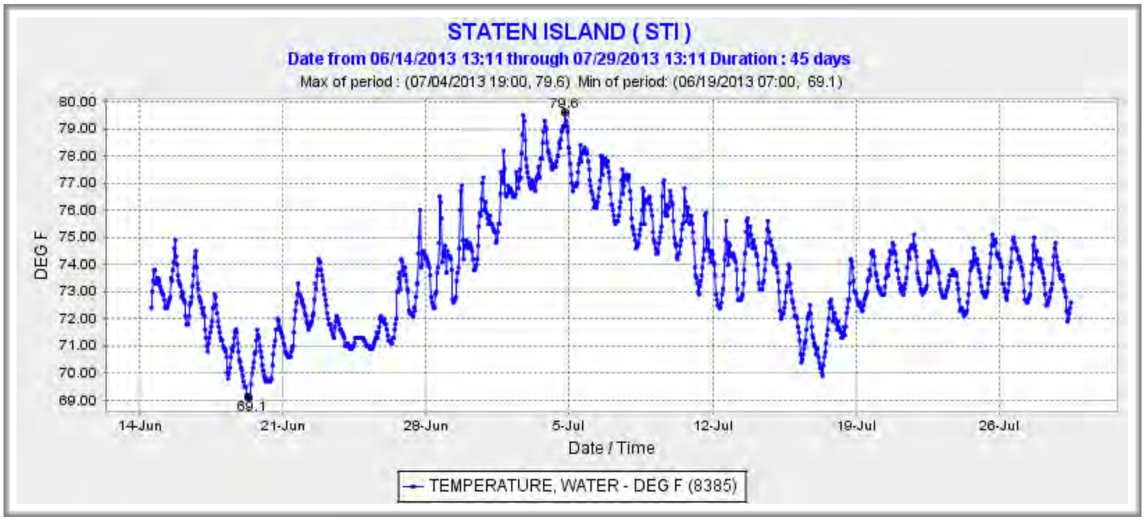


Figure 20. Water temperature near Staten Island mid June through July 2013. (Source: CDEC)

Delta Smelt Vulnerable

With the LSZ reaching into the Central and South Delta at high tides at a greater frequency through July than in wetter years it begs the question as to why were not more smelt salvaged. Clearly small salvage events occurred through mid June coincident with small pulses of exports (Figure 21). But, why not after mid June?

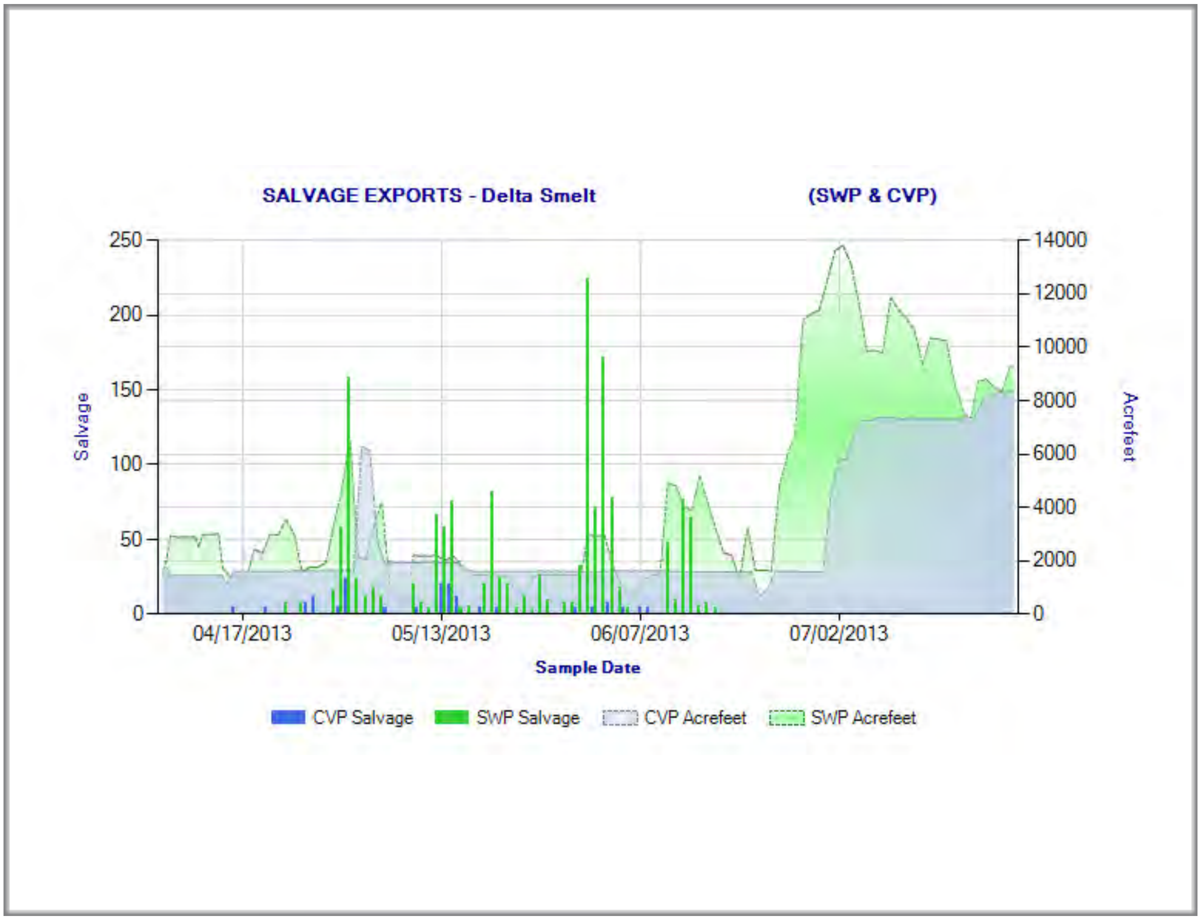


Figure 21. Delta exports and smelt salvage In spring and summer 2013. (Source: USBR MP)

First, the high inflows, low exports and high outflows kept the LSZ away from the influence of the pumps toward the end of June. Until about 8 July export demand was satiated by the pool of freshwater left over in the Delta from prior high inflows as observed in Clifton Court Forebay EC (Figure 11). But soon thereafter evidence of the LSZ being drawn to the pumps was apparent.

So why were no smelt salvaged after exports picked up and the LSZ entered the Central Delta? The answer is high water temperatures by early July. No smelt were able to survive passage to the

South Delta export salvage facilities because of lethal water temperatures in the Central and South Delta.

The high exports and high inflows at the end of June and beginning of July not only pulled the LSZ upstream into the Central Delta and under influence of the South Delta pumps at Clifton Court Forebay, but it also lead to a sharp increase in water temperature throughout much of the LSZ that was lethal to delta smelt (77-80F or 25-27C). Warm weather occurred at the beginning of July throughout the Delta (but reaching over 100F to the north and east), along with nearly a week of 20,000 cfs inflow (from the north and east) with high ambient water temperature, and near 10,000 cfs exports resulted in near lethal or lethal water temperatures in the North, Central, West, and South Delta. Smelt were able to survive only in the western portion of the LSZ of eastern Suisun Bay and extreme western Delta (Figure 22) where water temperatures remained sub-lethal at 22-24C.

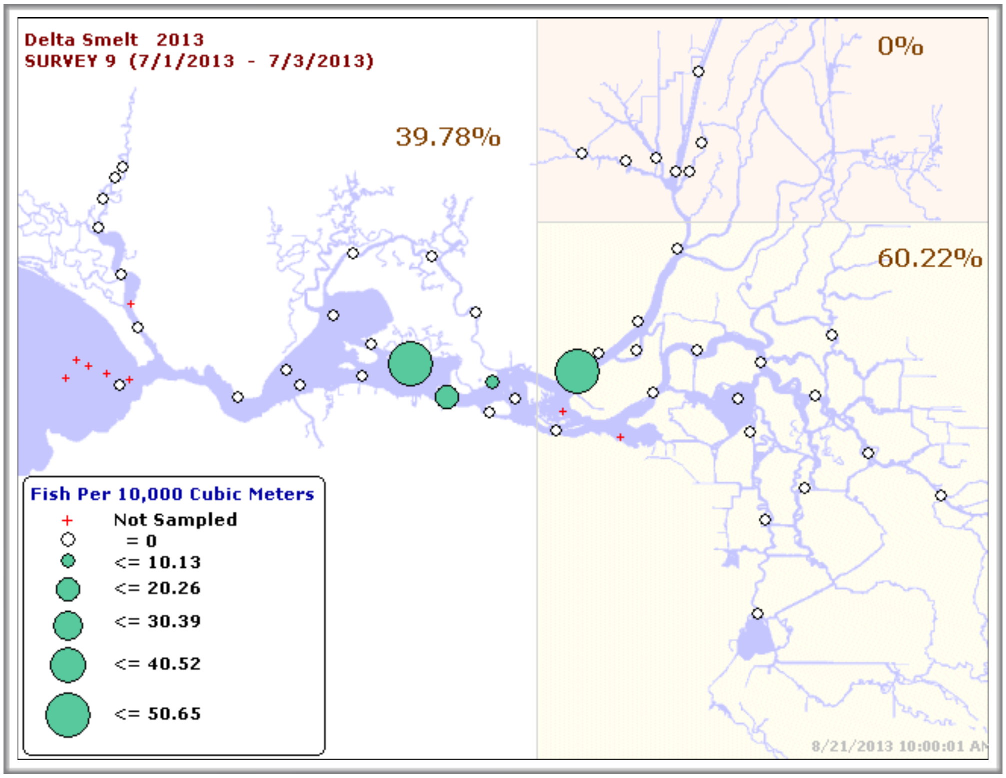


Figure 22. Early July 20-mm Smelt Survey results. (Source: http://www.dfg.ca.gov/delta/data/20mm/)

This ninth and last of the Department of Fish and Wildlife's 2013 20-mm Survey shows that the majority of smelt were in the Delta at the beginning of July. The Summer Townet Survey that began in mid June (unpublished CDFW data) has provided a Delta smelt abundance index based upon its first two surveys (weeks of June 10 and 24). The preliminary 2013 index is 0.7, down from last year's 0.9. The results from the remaining Summer Townet Survey and the Fall Mid-

Water Trawl Survey will help reveal the full extent to which Delta smelt were harmed by Project operations this summer. Based upon my decades of experience, I suspect that summer 2013 parallels the conditions during the Pelagic Organism Decline (POD) and record low smelt indices early in the last decade.

Solution

The problem remains that neither the D-1641 Water Quality Objectives for the Delta or the OCAP Biological Opinions have protections for Delta smelt after June. The demise of VAMP's limit on exports in the late spring has exacerbated the problem. The D-1641 dry and critical year standards for outflow are simply too low to protect delta smelt and their important habitats. Even with higher outflows, excessive exports remain a problem. The inflows necessary to sustain high exports reduce reservoir storage and cold-water pools, and bring warmer, low-productive reservoir water into the Delta and LSZ. Cooler, more productive, more turbid water, critical to delta smelt growth and survival is first exported from the Delta and then replaced with warm, low turbidity, low productivity reservoir water. Higher summer outflow and reduced exports (and a minimum of inflow necessary to sustain reduced exports) in drier years are fundamentally necessary for delta smelt recovery. A minimum of inflow and exports will increase residence time and productivity, allow higher productivity waters and smelt to remain in the Delta, and allow Delta waters to remain cooler to sustain smelt.

An Overview of Habitat Restoration Successes and Failures in the Sacramento-San Joaquin Delta

Thomas Cannon

Bill Jennings

California Sportfishing Protection Alliance

July 2014

Table of Contents

Executive Summary

The Bay Delta Conservation Plan (BDCP) proposes to create or restore approximately 150,000 acres of aquatic, riparian and terrestrial habitat in the Delta. Given the astonishing lack of specific details in BDCP's programmatic restoration plan, this report briefly reviews historical habitat restoration projects in the 222,902 acres of existing conservation lands within the Delta in an effort to evaluate the likely success of BDCP's conceptual restoration plan.

Despite numerous restoration projects, there have been few documented successes in the Delta. Many proposed projects failed to move beyond a conceptual stage because of a lack of funding. A number of projects succeeded in acquiring property but failed to secure the funding necessary for implementation. Other restoration projects were constructed but failed because they were poorly conceived or lacked sufficient funding to maintain or adaptively manage the habitat. Even relatively successful projects have too often experienced mixed results and unintended consequences. Cumulatively, the myriad restoration projects have failed to slow or reverse the precipitous decline in the estuary's native pelagic and anadromous fisheries.

The consistent flaw of previous restoration efforts in the Delta has been a failure to adequately meet the habit requirements of native fish. The estuary's native species evolved over many thousands of years in response to existing habitat conditions. And that habitat included adequate physical (flow, residence time, variability, etc.) and chemical parameters (salinity, temperature, turbidity, chemical constituents, etc.), as well as the nutrients necessary for primary production to support renewable fisheries. Upstream diversions and Delta exports have radically altered the Delta's hydrodynamics, which has resulted in a loss of critical flows, less variability, degraded water quality and reduced primary productivity. The yearly export of phytoplankton, the foundation of the aquatic food web, is equivalent to more than 30% of net primary production.

The Delta's altered hydrology has allowed numerous invasive non-native species to become entrenched to the detriment of native communities. A number of fishery scientists have observed that a variable freshwater Delta has been transformed into something resembling an Arkansas lake. Creating more Arkansas lake habitat will simply create more Arkansas lake fish.

Successful restoration of native species requires restoring the conditions under which they evolved and prospered. This entails increasing outflows, mimicking the natural hydrograph, improving water quality, protecting the critical low salinity zone (LSZ) and reducing export of primary productivity. However, these are the essential elements BDCP cannot provide.

Construction and operations of BDCP's north Delta diversion facilities will exacerbate existing poor conditions by decreasing outflow, moving critical LSZ pelagic habitat eastward, degrading water quality and exposing sensitive life stages of listed species to massive new water diversions. As mitigation, BDCP proposes a conceptual and highly speculative plan to restore habitat with uncertain public funding.

Our review of the habitat needs of native species and the history of habitat restoration projects in the Delta reveals that BDCP's optimistic projections of success are unrealistic and not likely to restore native Delta fisheries.

Introduction

The Bay Delta Conservation Plan (BDCP) proposes to increase water supply reliability by diverting the Sacramento River through twin 40-foot tunnels under the Delta for export to the San Joaquin Valley and Southern California. It also proposes creation of approximately 150,000 acres of new habitat in the Delta to restore the estuary and offset adverse impacts from diverting vast quantities of water around the Delta. The costs of tunnel infrastructure will be paid by the state and federal water contractors while the vast majority of habitat restoration costs will be borne by the general public.

The BDCP EIR/EIS analyzes the tunnels to a project specific level, while habitat restoration has only been analyzed at a programmatic level. There are few details on specific habitat restoration projects. Fishery agencies and scientists have bluntly questioned the likelihood that habitat creation will be as successful as claimed by BDCP proponents or whether habitat restoration can realistically offset the projected adverse consequences from increased exports and reduced outflow to San Francisco Bay.

For example, the Delta Independent Science Board, in its review of the Draft BDCP EIR/EIS and Draft BDCP Plan, observed, "Many of the impact assessments hinge on overly optimistic expectations about the feasibility, effectiveness, or timing of the proposed conservation actions, especially habitat restoration"[1] and "Positive and timely benefits of habitat restoration are highly uncertain. Failure to realize these benefits will invalidate the final conclusion of no net negative effect."[2] Likewise, the Panel Review of the Draft Bay Delta Conservation Plan, prepared for the Nature Conservancy and American Rivers said, "BDCP is too optimistic about benefits of tidal marsh and floodplain restoration for smelt, particularly the extent of food production."[3]

The National Marine Fisheries Service, in comments on the Draft EIR/EIS said, "There is too much benefit to steelhead smolts assumed from habitat restoration in the Delta."[4] The U.S. Fish and Wildlife Services wrote, "Scientific literature cited in the plan, new analyses provided by DWR, and conclusions of the independent scientific review panel have reinforced our concern

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[1] Delta Independent Science Board, Review of the Draft BDCP EIR/EIS and Draft BDCP, May 2014. Page 3.

[2] *Id.* Page A-25.

[3] Mount J., et al., Panel Review of the Draft Bay Delta Conservation Plan, prepared for the Nature Conservancy and American Rivers, September 2013, page 109.

[4] National Marine Fisheries Service, Federal Agency Comments on Consultant Administrative Draft EIR-EIS, July 2013, Page 8.

that the BDCP restoration plan has not been carefully thought out and has uncertain prospects for benefiting native aquatic estuarine species, particularly delta smelt and longfin smelt." [5]

Can habitat restoration offset the loss of flow due to diversion of massive quantities of fresh water around the estuary and restore severely degraded fisheries? The U.S. Environmental Protection Agency wrote in commenting on the Administrative Draft EIR/EIS, "There is broad scientific agreement that existing Delta outflow conditions are insufficient for protecting the aquatic ecosystem and multiple fish species, and that both increased freshwater flows and aquatic habitat restoration are needed to restore ecosystem processes in the Bay Delta and protect T & E fish populations. This includes statements from lead federal agencies."

Indeed, as the U.S. Fish & Wildlife Service testified during the State Water Resources Control Board's 2010 flow hearing, "flow in the Delta is one of the most important components of ecosystem function." Habitat is more than the spatial extent of acreage, and increases in habitat area doesn't ensure increases in habitat quality or functionality. Habitat requires adequate physical (flow, residence time, variability, etc.) and chemical parameters (salinity, temperature, turbidity, chemical constituents, etc.), as well as the nutrients necessary for primary production to support renewable fisheries. Yet, BDCP's principle strategy for fixing the Delta is based on the hypothesis is that increased habitat restoration acreage can substitute for flow.

The BDCP Conservancy Strategy identifies some 222,902 acres of existing conservation lands in the plan area. These include properties managed by conservancies and land trusts, agency restoration sites, designated biological mitigation sites, wetlands owned or managed by agencies or private parties, conservation easements, parks, and lands associated with implementation of HCPs and NCCPs.[6]

Since both the BDCP Plan and EIR/EIS contain few specific details of proposed habitat restoration, this report examines the history of habitat restoration in the Delta in order to provide some guidance on the likely success of future habitat restoration efforts. It summarizes our review of the habitat restoration that has taken place in the Delta over the past several decades with emphasis on habitat values for young Delta and longfin smelt as well as Chinook salmon.

Delta Habitat

Delta native fish species depend heavily on the Delta habitats, especially in drier years when flows are insufficient to move their young downstream to the Bay. Young smelt and salmon rear in brackish water in what is called the Low Salinity Zone or LSZ. This zone is typically defined as 0.5 to 6.0 ppt salinity (or roughly 500-10,000 EC conductivity). Another term referred to as X2 is defined as the center of the LSZ at 2 ppt salinity. After spawning upstream in freshwater, smelt tend to concentrate at X2 by summer. In drier years the LSZ and X2 are found mainly in the Delta in the main rearing period of young of both smelt species from late winter into early

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[5] U.S. Fish and Wildlife Service Staff BDCP Progress Assessment, 2013, Page 7.

[6] Public Draft, Bay Delta Conservation Plan: Chapter 3, Conservation Strategy, Table 3.2-2, page 3.2-20.

summer. The LSZ is important because it provides slightly brackish water, frequently suitable water temperatures, and abundant prey for the young fish. The smelt are pelagic species found predominantly in shoal and open water, and beaches near the open water. It is critically important that habitat be restored and developed within or near the LSZ if the expected benefits to smelt and other pelagic fishes are to be achieved.

Young salmon begin entering the Delta as fry soon after emerging from river spawning gravels from late winter to early spring. Fry and fingerlings (25-75 mm) concentrate in shoreline areas and adjacent margin habitats including tidal marshes, sloughs, and channels. Smolt salmon (80 mm +) are often collected in open channels migrating westward toward the ocean generally in winter and early spring, but are also found feeding in margin habitats. It is important that habitats be restored and developed along their Delta migration pathways to ensure successful passage from the river to the Bay. BDCP proposes to restore only about twenty miles of channel margin habitat over a span of thirty years.

Delta aquatic habitat has been greatly altered by 150 years of reclamation. The majority of the tidal marsh, slough, and open water habitats were reclaimed or altered by a vast system of levees and connecting sloughs by the second decade of the last century. More recently, two major ship channels were carved through the Delta. It should be noted, however, that the recent precipitous decline in pelagic and anadromous species and the listing of numerous species pursuant to state and federal endangered species acts only occurred after construction of the Central Valley Project (CVP) and State Water Project (SWP) and the diversion of massive quantities of water to the San Joaquin Valley and Southern California.

Between 1930 and 1943, an average of 82% of estimated unimpaired flow reached San Francisco Bay. That has declined to less than 50% in recent years,[7] well below the 75% level identified by the State Water Resources Control Board as necessary to protect public trust resources and estuarine health.[8] The State Board's conclusions on needed flows followed a comprehensive proceeding, mandated by the State Legislature, involving agency and independent scientists, academia, water agencies and pubic interest groups. The California Department of Fish and Wildlife, under a similar legislative mandate, reached similar conclusions.[9]

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[7] Swanson, C., WATER-Freshwater Inflow Indicators and Index, Technical Appendix, State of San Francisco Bay 2011, Appendix B, page 73.

[8] State Water Resources Control Board, Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem, 2010, page 5.

[9] CDFG, Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta, 2010.

A number of fishery scientists now refer to the Delta as being in a state of perpetual drought. The number of years of critically low inflow to the Bay has more than tripled to 62% of the time since the 1930s.[10]

The BDCP proposes upwards of 150,000 acres of habitat restoration, focusing primarily on tidal marsh restoration. Tidal marsh is proposed to provide direct and indirect benefits to Delta fish through the food web and as habitat for various fish species or specific life stages. One measure of the potential benefits of this large-scale restoration is to review the past history of restoration in the Delta. Have the various efforts to restore Delta aquatic habitats proved successful? This overview summarizes these restoration efforts and explains how that experience relates to habitat restoration efforts prescribed in the BDCP. But before examining historical habitat restoration efforts, we should consider a few of the inherent uncertainties of restoration efforts.

Uncertainties of Habitat Restoration

Much of the historical and BDCP habitat restoration has been focused on restoring tidal marsh. Recent scientific debate has focused on the relative merits of tidal marsh restoration on the shallow water and pelagic food web of the Delta. The key questions are whether smelt and salmon young use the tidal marsh habitats, whether tidal marshes contribute to food production in the preferred smelt and salmon open water (pelagic) and channel margins (shoreline) habitats of the Delta, whether restoration projects themselves create deleterious effects, and the uncertainties of funding and actual implementation.

One key BDCP hypothesis is that tidal marshes export nutrients and food web production to adjoining pelagic habitats. However, recent scientific reports question that hypothesis; “Tidal marshes can be sources or sinks for phytoplankton and zooplankton. Most appear to be sinks, particularly for zooplankton” and “ Even under the most highly favorable assumptions, restored marshes would have at best a minor contribution of plankton production in smelt rearing areas.” [11] Also, “Movement of plankton from a tidal marsh (beyond the immediate area of tidal exchange) is likely to be limited and to decrease strongly with distance. Even under ideal circumstances, plankton in water discharged from tidal marsh cannot greatly affect the standing crop of plankton in large, deep channels. Feeding by clams and other introduced species can further reduce contributions of marsh plankton to open-water food webs.” [12] As the Delta Independent Science Board recently wrote, “Whether or not any increases in primary production

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[10] Swanson, C., The Power of Measurement, Part II: Projected Freshwater Inflow to the San Francisco Bay Estuary with the Bay Delta Conservation Plan, Swanson’s Blog, NRDC Switchboard, 17 December 2013, page 2.

[11] Mount J., et al., Panel Review of the Draft Bay Delta Conservation Plan, prepared for the Nature Conservancy and American Rivers, September 2013, page 109.

[12] Herbold, B. et al., The Role of Tidal Marsh Restoration in Fish Management in the San Francisco Estuary, 2014, page A-11. http://www.escholarship.org/uc/item/1147j4nz

will be transferred to zooplankton and on to covered species that may reside in the restored area or outside of it is largely unknown."[13]

There is also the looming question of whether the proposed habitat can be created without exacerbating methylmercury problems. As the National Marine Fisheries Service (NMFS) put it, "There is no indication that the kinds of habitat restoration that can meaningfully contribute to estuarine fish viability can be created or restored without also methylating the ubiquitous mercury in the system because the management tools available conflict with these fishes' habitat needs. Minimization of water depth and reduction of turbidity to control mercury methylation conflict with the direct habitat needs of delta and longfin smelt and will in some locations favor invasive species such as sunfishes and water hyacinth. However, minimization of water depth and turbidity will maximize the potential for algal production and algal production will generate dissolved organic carbon (DOC). If, as the ADEIS implies, restoration sites will also be designed to minimize the export of DOC from restoration sites to minimize anoxic conditions (reducing methylation opportunities) these designs will also reduce their potential food web benefits."[14] BDCP found that the preferred alternative would increase mercury concentrations and exceed tissue toxicity thresholds in largemouth bass in the Delta.[15] Increases in mercury loading resulting from habitat restoration projects would exacerbate the problem.

This issue is not limited to mercury. Marshes are often sinks for organic contaminates like PCBs, PAHs, organochlorine compounds and organophosphate and pyrethroid insecticides. Selenium is a serious problem. NMFS commented on the BDCP EIR/EIS, "An expected increase in contribution of San Joaquin River water to the Delta will increase selenium loading in the Delta, especially in the southern Delta and Suisun Bay where bioaccumulation by bivalves is assured (Stewart et al. 2004). This in turn represents an increased risk of deleterious reproductive effects caused by selenium accumulation in fish and wildlife."[16] BDCP found that the preferred alternative would increase annual average selenium concentration in sturgeon over the existing conditions and no action alternatives.[17]

There is also a serious concern that diverting flow around the Delta and reducing outflow will expand the range of overbite clams, "Finally, only adverse effects are indicated resulting from conservation measures in the context of invasive mollusks. CM1 may increase *Corbula* habitat by moving X2 upriver, assuming greater freshwater diversion. Given that *Corbula* is the more effective trophic competitor with covered planktivorous fish, this suggests degradation of habitat characteristics due to CM1. Restoration involved in CM4 (tidal wetland), CM5 (seasonally

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[13] Delta Independent Science Board, Review of the Draft BDCP EIR/EIS and Draft BDCP, May 2014. Page B-39.

[14] National Marine Fisheries Service, Federal Agency Comments on Consultant Administrative Draft EIR-EIS, July 2013, Page 10.

[15] Bay Delta Conservation Plan, Appendix 8I, Mercury, Tables I-7a, I-15Aa, I-11Ba, I-11Ca, I-11Da.

[16] *Id.*

[17] Bay Delta Conservation Plan EIR/EIS, Appendix 8M, Selenium in Sturgeon, Tables 8M-2, 8M-3, Page 8M-9.

inundated floodplain), and CM6 (channel margin habitat) may increase potential benthic habitat for *Corbula* and *Corbicula*, overall exacerbating the impacts of these competitors. Tidal and shallow water habitat restoration, if invaded by *Corbula* or *Corbicula* may result in phytoplankton sinks actually worsening circumstances for fish.[18]

Another example of uncertainties in habitat restoration is the effect on tidal energy. As the Independent Science Board observed, "Tidal energy coming from outside the Golden Gate is another limited resource in the development of habitat in the Delta and its larger estuary. A major effect of many of the proposed habitat restoration activities (as well as potential island failures in the future) is likely to be the changes in tidal amplitude and mixing. This will affect the suitability of certain characteristics for restoration." [19] A number of agencies have expressed concerns that changes in tidal amplitude caused by creation of more open tidal habitat will increase salt intrusion in the Delta.

Given the programmatic level analysis of proposed habitat restoration, there is significant uncertainty that large-scale restoration projects will actually be implemented or implemented in a timely manner. The Independent Science Board acknowledged these concerns in saying, "Construction and flow operations may have impacts immediately, whereas the restoration impacts and benefits may lag a decade or more after construction" and "If proposed habitat restoration actions are not implemented in a timely fashion or are not as effective as assumed in the DEIR/DEIS, then the positive impacts of those actions would no longer be present, and the final assessment of a net positive or no net negative effect would not be valid." [20] They also noted, "The literature strongly suggests, however, that there are significant time lags between construction of a new habitat and its full functionality. This means that the benefits of habitat restoration may not occur for a long time and that the benefits may be too late for some species if negative impacts come first" and "Even if all acres are acquired and restoration actions are taken in a timely manner, whether those actions will deliver the anticipated benefits or not is also uncertain." [21]

The lack of funding commitments for BDCP's proposed restoration projects creates major uncertainties. Habitat restoration is extremely expensive. As we discuss below, many proposed restoration projects were unable to move beyond a conceptual stage because of a lack of funding. A number of projects were able to acquire property but couldn't secure the funding necessary for implementation. Other projects were constructed but failed because they lacked sufficient funding to maintain or adaptively manage the habitat.

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[18] Delta Science Program, Review Panel Summary Report, Bay Delta Conservation Plan (BDCP) Effects Analysis, May 2012, page 60.

[19] Delta Independent Science Board, Review of the Draft BDCP EIR/EIS and Draft BDCP, May 2014. Page B-17.

[20] *Id*, page B-38.

[21] *Id*, page B-39.

What is clear is that populations of native species like salmon, steelhead, Delta and longfin smelt, splittail, threadfin shad, native phytoplankton and zooplankton, and several species introduced in the 1800s like striped bass and American shad are collapsing. In contrast to the rapid decline of native species: populations of recent invasive predatory species like inland silversides, bluegill, largemouth bass and overbite clams; troublesome invasive plants like water hyacinth, arundo, Brazilian waterweed, parrots feather and potamogeton; and less nourishing non-native copepods and mysids are flourishing.

Many scientists have observed that the state and federal project's massive water diversions and altered hydrograph have transformed the Delta into something resembling an Arkansas lake. In fact, the Delta is now home to a number of trophy bass fishing tournaments and Bass Master magazine recently ranked the Delta as the ninth best largemouth and smallmouth bass fishing spot in the entire nation. Creating additional Arkansas lake habitat will not restore the iconic native species of the Bay-Delta estuary.

The preceding examples are only a few of numerous critical comments by independent scientists and agencies regarding the highly speculative and questionable assertions by BDCP that habitat restoration is a magical bullet that will not only mitigate adverse impacts of diverting additional water around the estuary but will also restore seriously degraded fisheries. But these are not the subject and purpose of this review.

Instead, this report focuses on whether historical habitat restoration has met the physical goals and objectives of restoration. The following observations are focused primarily on the direct benefits to salmon and smelt based on four decades of sampling fish in Delta habitats. Are the altered habitats after levee breaching, channel digging, and vegetation planting functioning? Has water quality been sufficient to support fish? Have non-native invasive plants and fish taken over these new restored habitats? Are the habitats right for smelt and salmon?

History of Aquatic Habitat Restoration in the Delta

There are dozens of "restoration" sites around the Delta dating back several decades or more. There are even more in San Francisco Bay, which are not discussed in this report. As noted above, BDCP has identified almost 223,000 acres of existing conservation lands in the Delta. The majority of these lands were acquired in the last few decades.

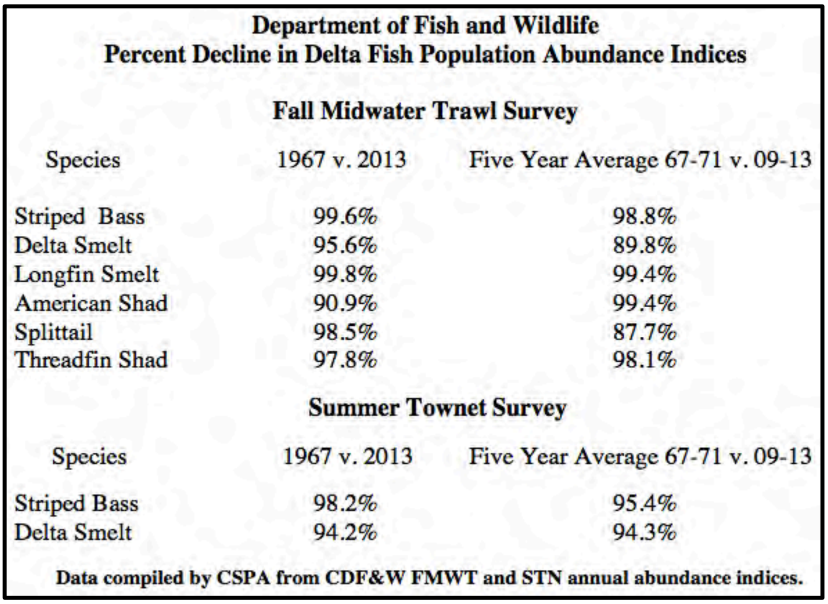
Delta restoration has occurred as mitigation for many large and small development projects throughout the Delta. Levee repair, dredging, dock construction, sand mining, new water intakes, bridges, flow barriers, and the large federal and state water projects have undertaken some form of habitat mitigation.

In the recent decade, restoration has been larger and more formal under directed water project mitigation, multi-agency programs such as the Central Valley Project Improvement Act, Corps Central Valley Flood Control Levee Program, Sacramento and Stockton Port Programs, Delta Wetlands Program (private), the state Delta Levees Program, and the CALFED program. Under the State Water Project, Delta Wetlands Project, Montezuma Wetlands Project, PG&E Delta Power Plant Mitigation Program (HCP), and CALFED programs monies were available for government and non-profits to purchase large-acreage projects such as Sherman Island, West Sherman Island, Twitchell Island, Yolo Bypass Wildlife Area, Big Break, Staten Island, Cosumnes River Preserve, Liberty Island, Stone Lakes NWR, Little Holland Tract, and many other significant areas.

In recent years, water districts have acquired large tracts of property in anticipation of future mitigation needs. The most notable is a 5000-acre portion (including 1,100 acres of wetlands) of the lower Yolo Bypass north of Liberty Island called the Lower Yolo Restoration Project.

However, habitat restoration projects have failed to achieve their stated purpose. They have neither slowed nor reversed the collapse of Delta fisheries. We see little on which to base any optimism that more of the same will lead to different results.

The California Department of Fish and Wildlife has conducted surveys of the Delta's pelagic species since 1959. The Fall Midwater Trawl (FMWT) survey was initiated in 1967, the year the State Water Project began exporting water from the Delta. It samples 122 stations each month from September to December, and the data is used to calculate an annual abundance index of pelagic species. These stations range from San Pablo Bay upstream to Stockton on the San Joaquin River, Hood on the Sacramento and the Sacramento Deep Water Ship Channel.[22]



Department of Fish and Wildlife
Percent Decline in Delta Fish Population Abundance Indices

Fall Midwater Trawl Survey

Species	1967 v. 2013	Five Year Average 67-71 v. 09-13
Striped Bass	99.6%	98.8%
Delta Smelt	95.6%	89.8%
Longfin Smelt	99.8%	99.4%
American Shad	90.9%	99.4%
Splittail	98.5%	87.7%
Threadfin Shad	97.8%	98.1%

Summer Townet Survey

Species	1967 v. 2013	Five Year Average 67-71 v. 09-13
Striped Bass	98.2%	95.4%
Delta Smelt	94.2%	94.3%

Data compiled by CSPA from CDF&W FMWT and STN annual abundance indices.

The Summer Townet Survey was begun in 1959 and samples striped bass and Delta smelt at 32 stations, ranging from eastern San Pablo Bay to Rio Vista on the Sacramento River and to Stockton on the San Joaquin River. Surveys begin in early June and continue on alternate weeks through August, and the data is used to calculate an abundance index.[23]

The annual abundance indices document the continued one to two orders of magnitude decline of the entire spectrum of native pelagic species in the estuary. The same magnitude declines hold true for the native lower trophic orders that comprise the base of the food web.

Central Valley anadromous fisheries have also not fared well and are far below the doubling levels mandated some 22 years ago by the Central Valley Project Improvement Act, California

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[22] http://www.dfg.ca.gov/delta/projects.asp?ProjectID=FMWT

[23] http://www.dfg.ca.gov/delta/projects.asp?ProjectID=TOWNET

Water Code and California Fish and Game Code.[24] For example, winter-run, spring-run, Sacramento fall-run and San Joaquin fall-run Chinook salmon are at 5.7, 20, 31 and 25.5 percent, respectively, of legally mandated levels.

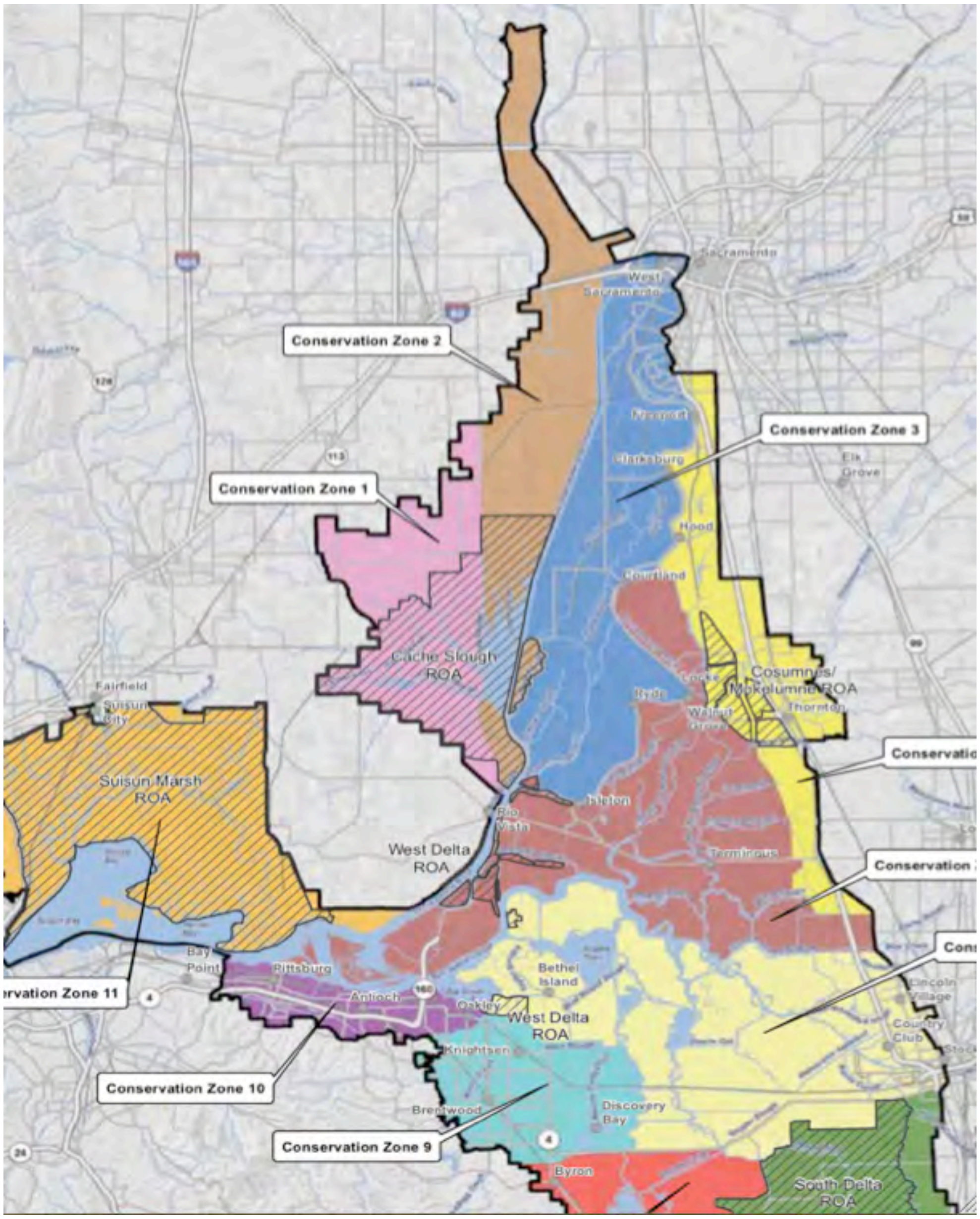

Figure 1. Delta habitat regions as defined in the Bay Delta Conservation Plan. Restoration sites included in the BDCP are shown by cross-hatching.

Geographic Coverage

The focus of this review is on restoration sites in the West, Central, East, and North Delta where habitats are potentially used by smelt and salmon. The South Delta is not addressed primarily

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[24] http://www.fws.gov/stockton/afrp/Documents/Doubling_goal_graphs_020113.pdf

because there are few restoration sites and what there is may be of minimal benefit to smelt and salmon. There is discussion of lower San Joaquin River habitat in the discussion of the East Delta, as it is important habitat for salmon and splittail originating from the San Joaquin River system. For consistency, the BDCP Restoration Opportunity Areas (ROAs) are used for the various portions of the Delta. The areas are generally consistent with the BDCP designations (Figure 1), which include more area than the BDCP's Cache Slough ROA. The West Delta region includes the area from Collinsville to Rio Vista, Pittsburg to Antioch, including eastern Chipps Island.

Benefits, Successes, and Failures

This review discusses individual sites including benefits, successes, and failures. Failures include simply doing nothing with the specific properties and letting them deteriorate over time. Failures are common even for active restoration sites where what was built or constructed did not work or actually provided poor habitat. Given the large amount of overall effort and expense, there has been a disturbing lack of progress and overall success. There have been a few successes in protecting or restoring specific sites and considerable research on several of these sites has produced a wealth of restoration and ecological science.

However, what some characterize as new "paradigms" for Delta habitat restoration are, in reality, disasters in the making that jeopardizes both restoration success and the expenditure of billions of dollars. Fish cannot be coerced into thriving under conditions radically different than those in which they evolved over millennia. Restoration projects that fail to provide habitat that reflects conditions under which native species evolved cannot succeed in restoring native species.

West Delta

The West Delta has a rich history of failed habitat "restoration" and missed opportunities. Many of the habitats are managed as part of Suisun Bay/Marsh habitats and are described in the Suisun Marsh Habitat Management, Restoration and Preservation Plan.[25]

Figure 2. Chipps Island at the western boundary of the Delta on Suisun Bay is a failed mitigation site.

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[25] http://www.fws.gov/sacramentøoutreach/2010/10-29/Documents/Tidal_CM_Chapter_1_Phys_Proc.pdf

Chipps Island

Chipps Island is a classic example of failed mitigation habitat. The roughly 700 acre "Delta island," at the west boundary of the Delta, has three main parcels: north, west, and east (Figure 2). Each has its own history and habitat characteristics. Today they are duck clubs. The north parcel was once purchased with mitigation funds by a non-profit but was eventually sold to a duck club for lack of restoration funds. The north and east parcels are muted tidal marshes that are flooded periodically during high tides. But, these are basically managed as freshwater marsh preferred by duck clubs in the Suisun Marsh area. The west parcel would be best described as brackish marsh, as the levees have long been breached and its channel network is fully tidal. The southern boundary of the island on the main ship channel is slowly eroding from ship wakes. Levees have been repaired in recent decades on the north parcel and have gates to allow water to enter the property when needed. Large numbers of native fishes including young salmon have been observed trapped within this parcel's ponds and channels. The island is in need of management and restoration, and the duck club owners have unsuccessfully attempted to sell the property. The island could potentially serve as important winter-spring rearing habitat for salmon and as Delta and Longfin smelt habitat in all but the driest years. However, Chipps Island is a restoration failure in that it should have been restored a decade after it was purchased with oil-spill mitigation funds.

Figure 3. The Collinsville site along the north shore of the lower Sacramento River channel. Collinsville is left center with Montezuma Island to its right.

Collinsville/Montezuma

Collinsville is at the west boundary of the Delta (Figure 3) and has a rich history. The two islands and most of the lowland shoreline (about 500 acres), at the base of the hills immediately east of Collinsville, were once PG&E property destined for a new Delta power plant.

After efforts to build a new plant failed, PG&E offered the property for restoration as part of the HCP permit mitigation to operate their two remaining power plants in the Delta. PG&E subsequently sold the two plants to Mirant/Southern. The plants are now included within the BDCP package of development actions to be permitted by the new BDCP-HCP process. The

Collinsville mitigation site remains in limbo having been once included in the original HCP permit.

However, it was never restored. Title to the property remains with the utility companies and was never transferred to the State, as intended under the original HCP permit. Once a navy base in World War II, the site's tidal channels have filled in with sediment and aquatic plants including invasive submergent aquatic vegetation (SAV) and water hyacinth.

The shoreline on the ship channel is eroding, along with its riparian vegetation. Invasive *Arundo* dominates the two islands. This area was once a designated mitigation site but was never restored as required under the utilities' permits. There is potential for restoration by creating tidal channels and shallow tidal marsh but only if intensive maintenance can control invasive weeds and insure adequate circulation. New permits are being sought under the BDCP without this site being included in the BDCP mitigation package. The BDCP, as an HCP/NCCP, would provide the power plants new ESA take permits, overriding the previous HCP that included the Collinsville site restoration. The new permits would not require the site to be restored. The hills adjacent to the site are now being developed by the utilities as wind farms.

West Sherman Area

The West Sherman area (Figure 4) includes Browns Island (far left), Winters Island (east of Browns), West Sherman (center) and West Island (southeast at right bottom corner).

Figure 4. West Sherman area with Browns and Winters Islands to west, West Sherman and Kimball in center, and Donlon and West Islands at lower right. All restoration opportunities of great potential value that were not included in BDCP. Cities of Pittsburg and Antioch are at lower left and right, respectively.

Browns Island

Browns Island is a 595-acre site generally referred to as "natural" and is part of the East Bay Regional Parks system. It was a reference site for the CALFED Breach study program. It has a dysfunctional tidal channel network with several large dead end channels and limited connection between its marshes and the nearby Bay waters. Its interior waterways are heavily impacted by water hyacinth and parrots feather. The occurrence and density of introduced fishes far exceeds native species. A 2007 report funded by CALFED found that Browns Island was a source of methylmercury production.[26]

Winter Island

Winter Island is a 453-acre private duck club managed as a freshwater marsh duck club with a functional levee system except for its northern tip, which is fully tidal brackish marsh. Its 4.7 miles of riprapped shoreline has unscreened manually operated tidal gates maintain water levels on the island's managed wetlands. Dredge materials from the Stockton Deep Water Ship Channel and various San Francisco Bay dredging projects have been placed on the island to strengthen the levees. As presently configured, the island provides little habitat to the estuary's pelagic or anadromous species and is somewhat of a missed opportunity to restore tidal marsh. Winter Island is 400 acres of "missed opportunity" to restore tidal marsh.

West Sherman Island

West Sherman Island comprises several thousand acres immediately to the west of Sherman Island proper (center of Figure 4). It has large partially disconnected ponds and a slough (dark areas) and is dominated by invasive SAV and invasive floating aquatic vegetation (green areas). It is considered "restored" and is now a state wildlife area. Ship channels are on the north, west, and south sides and its shorelines and remnant levees are slowly eroding from wakes.

The Lower Sherman Island Wildlife Area Land Management Plan states, *"In summer, extensive growth of blue-green algae and aquatic plants can contribute a considerable quantity of organic matter to shallow, dead-end sloughs; this may reduce the level of dissolved oxygen in these locations. Most channels at the wildlife area are clogged with such plant growth." And "Submerged aquatic vegetation within the open water area of Sherman Lake is dominated by the nonnative species egeria. Egeria also dominates submerged vegetation along the shallower margins of the Sacramento and San Joaquin rivers. Large expanses of open water at Sherman Lake are dominated by the invasive nonnative species water hyacinth. This plant readily forms dense, interconnected mats that drift along the water's surface."*[27] *"Mercury contamination is widespread in sediments and waters of the Delta, including at LSIWA.*[28]

The Goals for the wildlife area include, "*Pursue funding and develop plans for identified restoration projects. Cooperate with the development and implementation of local and regional restoration plans for upland and riparian ecosystems by the Ecosystem Restoration Program of*

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[26] http://mercury.mlml.calstate.edu/wp-content/uploads/2008/10/15_task5_3_browns.pdf

[27] DFW, Lower Sherman Island Wildlife Area Land Management Plan, page ES-5. http://www.dfg.ca.gov/lands/mgmtplans/lsiwa/docs/LSIWA_FinalLMP.pdf

[28] *Id*, page ES-4.

the California Bay-Delta Program and other programs that are consistent with the goals of this LMP."[29]

Lower Sherman Island was originally acquired to establish a public hunting and fishing area. The LSIWMP and CEQA document was finalized in 2007. The project was included as part of the CALFED Ecosystem Restoration Program Plan and Multi-Species Conservation Strategy. Given a lack of resources, restoration and maintenance have languished and the site is an example of failed restoration efforts. West Sherman Island is not included in the BDCP.

Kimball Island

Kimball Island is a 250-acre site on the south side of West Sherman. It is a "restored" tidal marsh, having been breached and channeled over a decade ago as a wetland mitigation bank. The original network of tidal channels has filled in with sediment and invasive aquatic plants and the SAV accelerate suspended sediment deposition and the reductions in turbidity. The lower turbidity water with abundant SAV is preferentially beneficial to non-native fishes including golden shiner, largemouth bass, sunfishes and silversides and detrimental to some native fishes. Constructed marshes like Kimball with limited tidal circulation are a recipe for backwater habitats dominated by invasive non-native aquatic vegetation and associated non-native fish community. While Kimball remains a somewhat functional tidal tule marsh, these subtidal backwater marshes also tend to have poor water quality in the form of low dissolved oxygen levels that also favor non-native fishes.

West Island to the southeast is a sandspit of dredge spoils with some channels and functional riparian shoreline. Its southern neighbor spoils island has nearly eroded away.

Donlon Island

Donlon Island a 200-acre site at the southeast corner of West Sherman is another "partially failed" restoration site. Its abandoned levee channels have long been clogged with invasive aquatic vegetation and associated non-native fish species. It was developed as a combination dredge spoils and mitigation site by the Corps of Engineers and the Port of Stockton in the 1980s.[30] Donlon Island is another example of a restored marsh with limited tidal circulation, which leads to backwater habitats dominated by non-native aquatic vegetation and fishes. It was in the CALFED Breach study and is not included in the BDCP.

West Island

West Island, to the southeast, is a sandspit of dredge spoils a few channels and some functional riparian shoreline. Its southern neighbor spoils island is nearly gone.

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[29] *Id*, page ES-17.

[30] http://www.fs.fed.us/psw/publications/documents/psw_gtr110/psw_gtr110_i_england.pdf

Central Delta

The Central Delta area includes portions of the lower San Joaquin River, Big Break, False River, Dutch Slough, and Old River (including Franks Tract) (Figure 5). These areas are included in the West Delta ROA (see Figure 1).

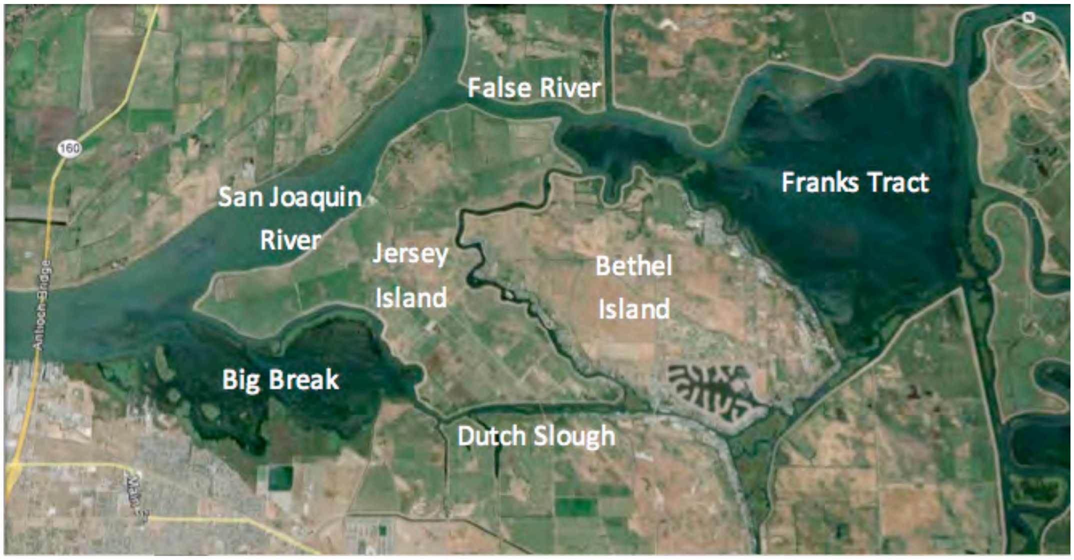

Figure 5. The Central Delta including Big Break at bottom left, Franks Tract at upper right, lower San Joaquin River at upper left, False River at upper center, and Dutch Slough at lower center. Old River runs along the eastern side of Franks Tract.

Big Break

East Bay Regional Park District’s Big Break Regional Shoreline Park is located along the south shoreline of Big Break. Once a leveed agricultural property, Big Break’s levees failed in 1928 and the 1500-acre shallow bay has remained open since. The bay was once reclaimed marsh along the south shore of Dutch Slough, which connected the central and south Delta with the lower San Joaquin River channel. Today the bay is clogged with non-native invasive aquatic plants with an ecological footprint more like an “Arkansas bass lake”. The oil company mitigation site at the west end of the Bay is also entirely dysfunctional, being clogged with invasive non-native submerged, emergent, and floating beds of aquatic vegetation (Figure 6). One of its two breaches is completely clogged with sediment and plants.

Big Break Regional Shoreline is on the northwest shoreline of the City of Oakley in Contra Costa County. In 1999 the U.S. Bureau of Reclamation purchased the 668-acre Lauritzen property that is situated along the west side of Big Break adjacent to the chemical company mitigation site as mitigation for the Rock Slough diversion project for the Contra Costa Canal in the Central Delta. This acquisition almost doubled the acreage of the Big Break Regional Shoreline. The site is described as “*a unique and valuable habitat area for several endangered fish and bird species”* in the East Bay Parks brochure.

The entire Big Break area is a prime example of establishing habitat that favors invasive non-native species over native species. It contains massive concentrations of non-native aquatic plants that dominate the shallow water habitat. Neither of the two mitigation sites at the west side of Big Break has been restored as promised. They remain typical of the "restored" habitats of the Delta that have failed in most respects. Not only are they failed habitats, but they enhance populations of non-native predatory fishes that compete with and prey upon Delta native fishes. The Big Break area is not included in the BDCP.

Figure 6. The west end of Big Break is a failed chemical company mitigation site. Some of the chemical waste facilities can be seen at the lower left. The site is virtually abandoned. Big Break Marina is located at the right.

Dutch Slough

The Dutch Slough Tidal Marsh Restoration Area (Figure 7) lies just to the east of Big Break. The 1,178-acre site is comprised of three parcels, partially separated by Emerson Slough and Little Dutch Slough. In the fall of 2003, the Department of Water Resources completed the purchase with funds from CALFED's now defunct Ecosystem Restoration Program. The project proposes to breech the levees to create large expanses on intertidal tule and/or cattail marshes plus areas of open tidal water, managed marsh and uplands. Construction was scheduled to begin in 2013.

However, when the levees are breeched, the site will likely end up similar to Big Break with poor aquatic habitats dominated by non-native invasive aquatic plants. Another fundamental problem with the site is its location on Dutch Slough. During most of the spring and summer, especially in drier years, Dutch Slough has a net flow to the east toward Old River and the state and federal export facilities in the south Delta. Fish in this area would tend to be drawn to the export pumps. Dutch Slough has been proposed for over a decade as mitigation for development projects in the Oakley area and now for the BDCP. It is not a good site and would provide poor habitat contiguous with Big Break and its non-native predatory fishes.

Figure 7. The Dutch Slough Project consists of breaching levees on the upper center tracts. Dutch Slough is located at top and upper right. Big Break is at upper left. The Contra Costa Canal at bottom center is the southern boundary of the project.

Franks Tract

Franks Tract is owned by the State and maintained as a State Recreation Area. It comprises nearly 4000 acres of tidal aquatic habitat with many of the features of an "Arkansas bass lake". It is infested with non-native invasive aquatic plants. The CALFED Record of Decision (August 2000) identified Franks Tract as a location for one of the programmatic Ecosystem Restoration Program (ERP) actions that was intended to provide improvements in ecosystem restoration, recreation, and Delta water quality.[31] "*The Franks Tract Project is one of several interim actions to address fish and water quality concerns in the near future*."[32]

One possible action was to block False River, its connection to the west with the Lower San Joaquin River. False River receives a strong tidal flood flow from the lower San Joaquin. The inflow of turbid San Joaquin water can be seen in Figure 8. Other options included isolating Franks Tract from the Delta channels, thus eliminating it as a refuge for non-native plants and fishes, and reducing the influx of native fish species from the lower San Joaquin River into Franks Tract and Old River (the eastern boundary of Franks Tract).

Native fishes do poorly in Franks Tract because of the low turbidity and high concentrations of non-native predatory fish that thrive in the clear aquatic plant infested habitat. Unfortunately, nothing has been done to date and Franks Tract restoration is not included in the BDCP mitigation.

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[31] Action 1: Restore Frank's Tract to a mosaic of habitat types using clean dredge materials and natural sediment accretion. Control or eradicate introduced, nuisance aquatic plants." Ecosystem Restoration Program Plan – Strategic Plan for Ecosystem Restoration – Final Programmatic EIS/EIR Technical Appendix July 2000.

[32] http://www.water.ca.gov/deltainit/action.cfm

View of Mildred Island looking south along Middle River with McDonald Island to left and Lower Jones Tract in the distance.

Mildred Island

Mildred Island is a small agricultural island of approximately 1,000 acres that was breached in 1983 and not reclaimed. Like Franks Tract, it is open water habitat dominated by SAV. Nobriga et al. (2005)[33] pointed out that non-native fishes dominate such habitat. Local fishermen have long recognized it as a bass hot spot. No attempt has been made to restore this habitat and the site is not included in the BDCP.

Twitchell Island

Twitchell Island is a 3,516-acre island bounded on the north by Seven Mile Slough, on the east and south by the San Joaquin River and on the west by Three Mile Slough. Eighty-five percent of the island is owned by the State of California. Currently, the island is primarily agricultural land with the major crop being corn. It is the site of a 15-acre experiment by the U.S. Geological Survey to study wherther growing tules and catttails can reverse the soil loss caused by farming. It was also the site of a CALFED funded mercury study where two experimental wetland ponds were created. It was found that both ponds were sources of methylmercury production.[34]

However, Twitchell Island does contain a success story. In 2005, the Twitchell Island Reclamation District (RD 1601) constructed and planted approximately 2,100 linear feet of setback levee to increase levee stability and provide 3,000 linear feet of shaded riverine aquatic habitat and 1.4 acres of emergent freshwater marsh habitat along both sides of a back channel off the San Joaquin River.[35] The site (Figure 9) has remained stable and functional after more than a decade. Though small, it is one of the few successes for restoring natural shoreline habitats along Delta levees. The small setback levee provides a small tidal slough with connections to the San Joaquin River, as well as prolific riparian plant community. No specific projects of this type were proposed in the BDCP.

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[33] http://www.dwr.water.ca.gov/aes/docs/Nobriga_etal_2005.pdf

[34] http://mercury.mlml.calstate.edu/wp-content/uploads/2008/10/12_task5_3a_twitchell_final.pdf

[35] http://www.water.ca.gov/floodsafe/fessrøenvironmentałdee/twitchellsetback.cfm

Figure 8. The Twitchell Island setback levee project is located along the lower San Joaquin River on the south side of Twitchell Island at the center of the photo. It consists of a small tidal channel and island connected at several locations with the river.

North Central Delta

The north-central Delta is also part of the BDCP's designated West Delta ROA. The north-central Delta is sometimes described as the north Delta, as it includes the north of the "interior" Delta in the lower Sacramento River on the north side of Sherman Island.

Decker Island

Decker Island is a 648-acre island that was created between 1917 and 1937 when the Sacramento Ship Channel was dredged out and more than 30 million tons of dredge spoils were placed on top of existing wetlands. The island retains much of the original dredged sediment and has a spoils easement for U.S. Army Corps of Engineering dredging material. D.I Aggregate management LLC owns approximately 473 acres and, as seen in Figure 10, operates a large sand-sediment mining operation on the island. The Port of Sacramento owns approximately 140 acres.

The California Department of Fish and Wildlife purchased 34 acres in 1999 and, in conjunction with the Department of Water Resources, created a 26-acre wetland.[36] The restoration site was constructed similarly to the Kimball Island site by digging out interior channels and connecting them to the Sacramento River via a single breach. This design fails as it creates a dead-end slough system that clogs with aquatic plants (Figure 11) and provides habitat for non-native fish species. By 2003, over 90% of the tidal channels were clogged with water hyacinth (Rockriver, 2003, p. 91).

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[36] http://www.water.ca.gov/floodsafe/fessrøenvironmentałdee/decker.cfm

Figure 9. Decker Island in the lower Sacramento River. The entrance to Three Mile Slough is at upper right.

Figure 10. Mosaic of Decker Island State Wildlife Area development at north end of island. Channels dug have eventually filled with sediment and non-native aquatic plants (light green areas are predominantly water hyacinth). (DWR figure)

Figure 11. The southeast portion of Decker Island. Dark areas are invasive Egeria, while the light green are non-native aquatic plants including water hyacinth. Light brown is interior muted tidal marsh. The light tan between marsh and shoreline is remnant sand levee. The channel at right is the original Sacramento River channel.

Dead end tidal channels like the Decker and Kimball (see Figure 4, above) projects fill with submerged aquatic plants that strain the fine sediments for the water resulting in clear water favored by non-native fishes and avoided by many native fishes including Delta smelt. The dark channels in Figure 11 indicate clearer water than the turbid river. The site also has riparian plantings along its river shoreline, which are generally functional sandy beaches.

The southeastern portion of the island consists about 200 acres of “natural” shoreline used for pasture grazing (Figure 12). This site was once slated for CALFED restoration as it has a low elevation and much potential for tidal marsh-slough habitat. The black areas seen in Figure 12 are nonnative submerged aquatic plants, probably egeria, with the lighter green being other invasive aquatic plants including water hyacinth inshore. Decker Island restoration is included in the BDCP (see Figure 1), although no specific design is provided.

Sherman Island Levee Setback Project

The Sherman Island Levee Setback Project was constructed a decade ago by the Sherman Island Reclamation District (RD 341). The project consists of approximately 6,000 linear feet of setback levee to increase levee stability and provide 6.87 acres of intertidal channel margin habitat and 1.68 acres of riparian scrub shrub along Mayberry Slough (adjacent to Donlon Island site). The project is another example of mitigation provided by the State for the Delta Levees Program. Like the Twitchell Island setback project, this project was successful in restoring a narrow band of riparian and intertidal shoreline habitat along a Delta channel that has been sustained for over a decade on what was otherwise 100% unvegetated rock riprap.

Figure 12. The Sherman Island Levee Setback Project is shown on the southwest shoreline of Sherman Island on Mayberry Slough across from Donlon Island as a narrow strip of green on a new near-white rock levee.

North Delta

The North Delta is the northern component of the North Delta Arc of fish habitat connecting Suisun Bay/Marsh ROA with the Cache Slough ROA via the lower Sacramento River (see Figure 1).[37] The Cache Slough ROA is the BDCP component of the North Delta. It includes Liberty Island, Little Holland Tract, Cache Slough, Lindsey Slough, Barker Slough, Prospect Island, and the Sacramento Deep Water Shipping Channel (Figure 14). This area is considered the new "paradigm" for Delta restoration and thus is a key focus of the BDCP mitigation package.

The area has several features that potentially make it "good habitat." Bypass floods wash it clean several times a decade; it is a back water with long residence time except in floods, and it is a perfect elevation for shallow turbid water and intertidal habitats preferred by many Delta native fishes.[38] The area also has several negative features: low freshwater inflow, high nutrient loadings, and warm summers. Much of the area generally reaches lethal water temperatures for Delta smelt (25C/77F) in summer, particularly in heat waves.

Liberty Island, Little Holland Tract, Little Hastings Tract, and Prospect Island were once leveed reclaimed agricultural lands in the lower Yolo Bypass/Cache Slough region of the Delta. Over the decades all the island levees failed and breached and were subsequently purchased by the government and left for Mother Nature's tides and Bypass floods. Liberty Island is the largest of the reclamations at about 5000 acres. The tides flood all but about 1000 acres of the northern portion of the island. The middle and lower portions of the island are subtidal. The lower

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[37] http://californiawaterblog.com/2013/10/26/north-delta-arc-lifts-hope-for-recovery-of-native-fish/

[38] http://www.water.ca.gov/aes/docs/Sommer_Mejia_SFEWS_Smelt_Habitat_2013.pdf

several thousand acres remain open water connected to Cache Slough. Tules invaded the intertidal habitats of the flooded islands early, but tule expansion has since been limited.

Figure 13. Cache Slough – Lower Yolo Bypass region of North Delta. Lindsey/Barker sloughs are at lower left. Upper Cache Slough is at upper left. Sacramento Deep Water Ship Channel is at right edge. The flooded islands including Liberty (center) and Little Holland Tract (upper center right) of the lower Yolo Bypass are at center right. Prospect Island is east of Ship Channel at lower right.

The shallow waters with long residence time with abundant nutrients and sunshine make the open waters around Liberty Island very productive. The areas relatively high turbidity, mainly from wind-wave erosion along with periodic flood scouring, limit invasive rooted aquatic plants. The aquatic habitat of the area including the Ship Channel appears ideal for Delta smelt and other native Delta fishes.[39]

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[39] http://www.water.ca.gov/aes/docs/Sommer_Mejia_SFEWS_Smelt_Habitat_2013.pdf

The 200 acres of northern Liberty Island have been "restored" as a Delta smelt conservation bank with credits being sold for Delta smelt mitigation (Figure 15). Channels have been dug in uplands area to create slough and marsh habitats. The channels are connected to Liberty Slough and the main open waters of Liberty Island.

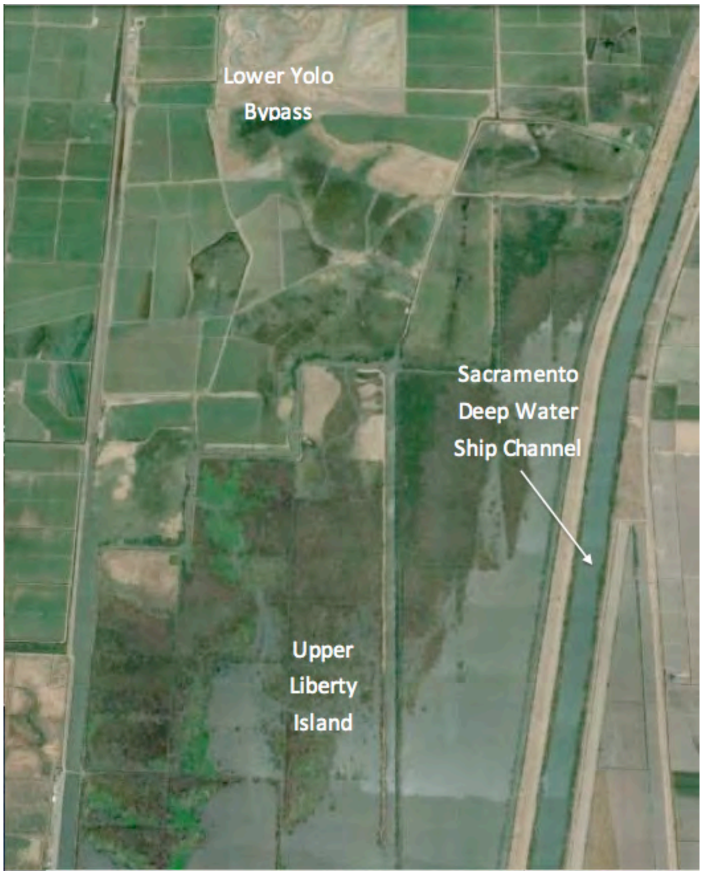

Figure 14. Upper Liberty Island (left center) and Little Holland Tract (right center). Ship Channel is at right. Stair-step levee remnants and Liberty Slough are north boundary of Liberty Island. Dark aquatic vegetation is tules. Light green is invasive non-native yellow primrose (able to take hold in the lee of high remnant levees). North staircase sections have brown upland habitats. Liberty Island Conservation Bank is upper right staircase with manmade channels and lowlands excavated from uplands. To the north of Liberty north or Liberty Slough is Yolo Ranch, which is also slated for BDCP mitigation.

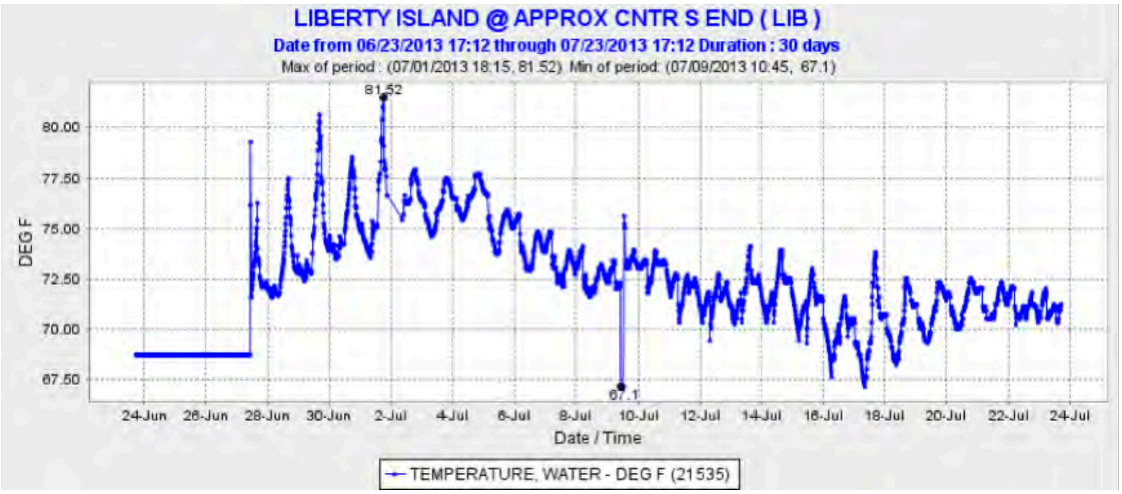

Figure 15. Water temperature during early summer 2013 at Liberty Island. (Source: DWR CDEC)

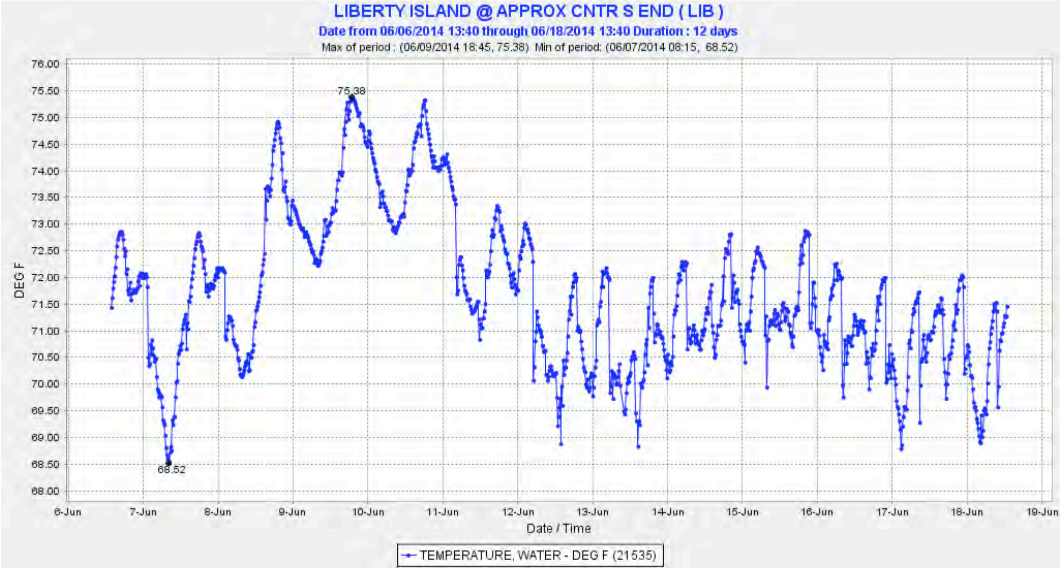

Figure 16. Water temperature during late spring 2014 at Liberty Island. (Source: DWR CDEC)

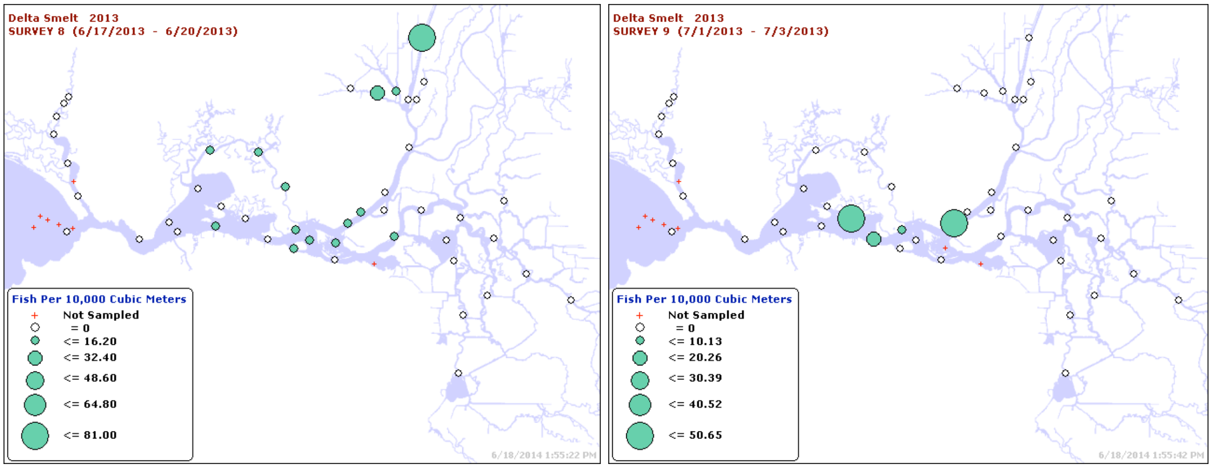

Figure 17. Comparison of Delta smelt distributions in early summer 2013 20-mm surveys before and after heat wave at beginning of July. Note the concentration of smelt in Cache Slough area before the heat wave and the lack of smelt in that area after the heat wave.

The main problem with the Cache Slough area is its periodic warm water temperatures as seen in Figures 16 and 17. With water temperatures generally considered lethal for Delta smelt above 75F, the area is basically inhospitable in summer for smelt. If not for the regular occurrence of the “Delta Breeze”, the entire area would only be suited for non-native catfish and carp. Though there may be periodic refuge for smelt in deeper channels of Cache Slough and the Sacramento Deepwater Ship Channel (SDWC), there has been little study of the ability of smelt to use these deep-water refuges and successfully survive the summer of warm dry years like 2013 (Figure

18). While Summer Townet Survey collected some Delta smelt in the Ship Channel in July surveys, none were collected in August surveys.[40]

Recent surveys of the Ship Channel by CDFW question the ability of Delta smelt to survive the summer: "*While the extent of SDWC usage by delta smelt is still unclear, these surveys have shown that delta smelt are limited in their ability to utilize the SDWC year round*." [41]

The Cache Slough complex experiences frequent toxicity from agricultural and urban discharges of chlorpyrifos and pyrethroid insecticides to copepods on which Delta smelt feed and to invertebrates in general. High temperatures tend to increase the toxicity of pyrethroids.[42]

Figure 18. Prospect Island is located between the Ship Channel and Miners Slough. The lower 300 acres are a Port mitigation area. The northern 1600 acres are owned by DWR and intended as a BDCP mitigation site.

Lower Yolo Restoration Project

The Lower Yolo Restoration Project is a proposed tidal restoration project by the State and Federal Water Contractors Water Agency to partially fulfill the habitat restoration requirements of the biological opinions for the Operations Criteria and Plan (OCAP) of the state and federal water projects. It would also help meet restoration objectives of BDCP. The project is located on a 3,795-acre site to the west of the Sacramento Ship Channel and to the north of Liberty Island and would result in the creation of approximately 1,226-acres of perennial emergent marsh (tidal) wetlands and 34-acres of non-tidal marsh.

The proposed enhancement of tidal wetlands at Yolo Ranch to the north of Liberty Island as well as breaching of leveed lands along Cache Slough (see Figure 15) would increase the area of shallow open waters that would warm in the summer sun to levels lethal to Delta smelt. This is a concern as the Sacramento Ship Channel and the general Cache Slough provides habitat for the northern spawning population of Delta smelt. The creation of

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[40] http://www.dfg.ca.gov/delta/data/townet/

[41] https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=30643

[42] Weston, DP. et al., Urban and agricultural pesticide inputs to a critical habitat for the threatened delta smelt (Hypomesus transpacificus), Environ Toxicol Chem, 2014.

additional open water will likely increase the amount of seawater that enters the Delta, leading to increased violations of salinity standards and expansion of the overbite clam and a resulting reduction in estuarine food availability. The site will also likely become a net sink for phytoplankton and zooplankton.

The project will likely become a net producer of methylmercury, and even if MeHg is not exported it will tend to bioaccumulate in resident and migratory species. Further, the area will be highly vulnerable to colonization by invasive weeds that will require extraordinary and expensive long-term management to control, something that has not been evidenced by the vast majority of habitat restoration efforts in the past.

Project implementation will likely go forward but, like numerous previous restoration projects, is likely to create unintended and detrimental impacts.

Prospect Island

Prospect Island is located between the Ship Channel and Miners Slough east of Liberty Island (Figure 19). Prospect Island was once a leveed farmland likes its neighboring tracts. Its lower end became a mitigation site for the Port of Sacramento. The upper portion failed in the recent decade and flooded, stranding thousands of fish. The island has since been purchased and levees repaired by the state with intention of the site being part of the BDCP mitigation package. DWR acquired the northern 1,300 acres from the U.S. Bureau of Reclamation in 2010, which had purchased the property in 1994 for restoration purposes that never occurred. The Port of West Sacramento owns the southern 300 acres and has used it for dredge spoil placement.

The Prospect Island Tidal Habitat Restoration Project is a component of the Fish Restoration Program Agreement (FRPA) comprised of a joint effort by the California Department of Water Resources (DWR) and the California Department of Fish & Wildlife (CDFW) to restore the property to freshwater tidal wetland and open water (subtidal) habitats to benefit native fish and improve aquatic ecosystem functions. "*Restoration will entail interior grading, vegetation management, possible clean fill import for subsidence reversal, possible weir installation, breaching of exterior levees, and addressing various property considerations. Monitoring will take place as part of a science- based adaptive management plan. The design of future restoration projects will incorporate knowledge gained through the implementation and monitoring of this project.*" [43] Planning and design is expected to be completed by late 2015, with construction commencing by early 2016.

Restoration of the site is complicated by local seepage problems for agricultural lands to the east of Prospect. Full tidal access to the northern portion of the island would result in extensive open water, not unlike Liberty and Little Holland Tract (Figure 20). However, without the scour provided by periodic Bypass floods, upper Prospect like lower Prospect would likely become infested with non-native invasive aquatic plants. Additionally, hydrodynamic modeling shows that open water restoration projects have the potential to increase seawater intrusion into the Delta. Flooding the island also has the potential to increase soil saturation and impact

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[43] http://www.water.ca.gov/environmentalservices/frpa_prospect_restoration.cfm

neighboring islands because of the horizontal sand lens that runs under the islands. Restoration might result in the island becoming a net exporter of methylmercury.

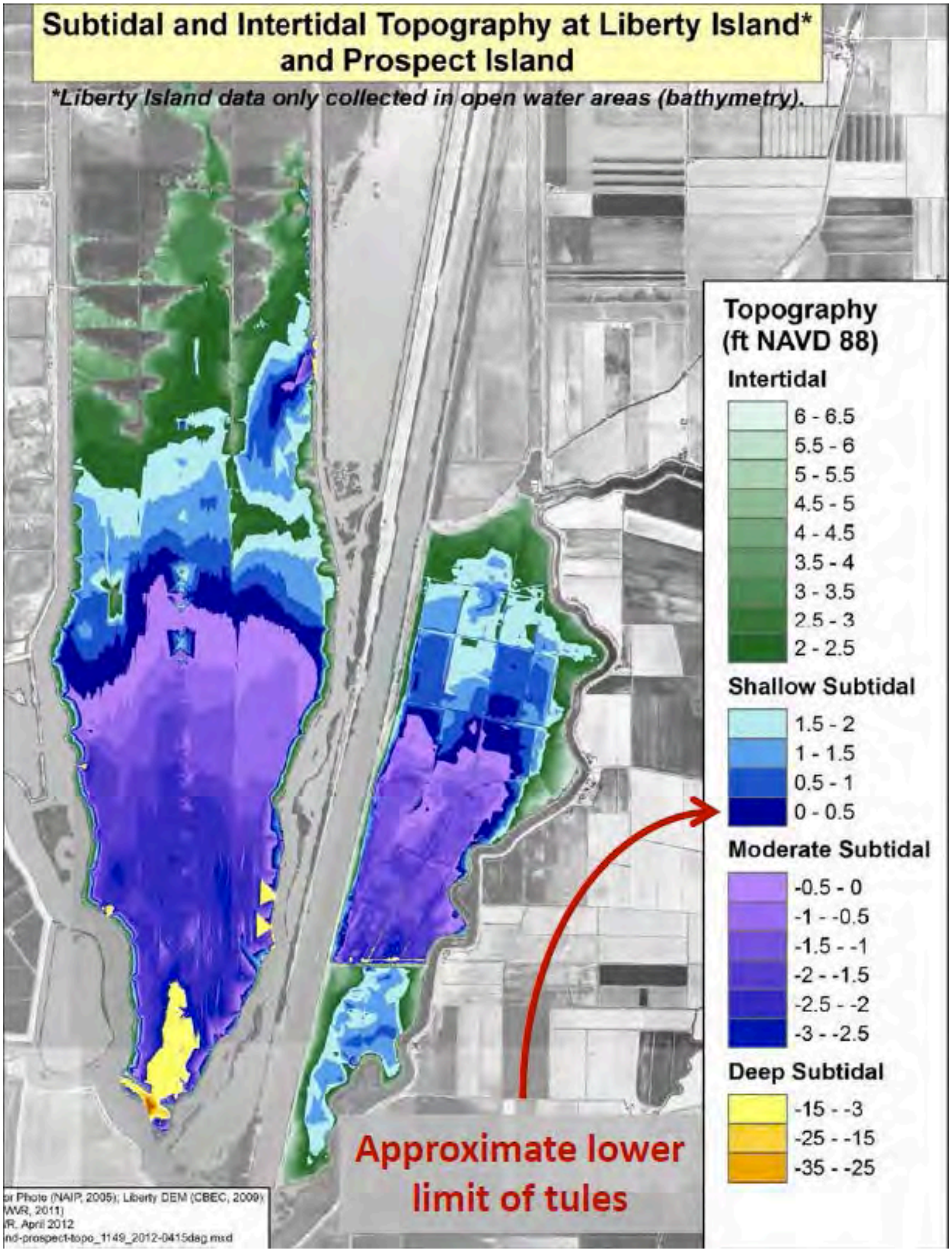

Figure 19. Liberty-Prospect area project water elevations.[44]

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[44] http://www.delta.ca.gov/res/docs/meetings/2013/2013%20DC%20Board%20Mtg_Prospect_FINAL.pdf

The lower island mitigation site is entirely dysfunctional as native Delta fish habitat because of the lack of circulation and dominance of invasive non-native aquatic plants. As seen in Figure 19, the open waters lack turbidity (dark color) and provide habitat more suited for non-native warm water fish species. Miners Slough reached 77F during the early July 2013 heat wave and early June 2014 heat wave. More shallow open water habitats would increase warming of the area.

Upper Yolo Bypass

An example of a restoration project that has been largely beneficial with significant unresolved and potential adverse impacts is the Yolo Basin Wetlands Project. And it should be kept in mind that this project, coupled with all of the other restoration projects implemented over the last 30 or 30 years in the estuary, has not reversed the precipitous decline of the Delta's pelagic and anadromous fisheries.

The Yolo Bypass is seasonal floodplain to the west of Sacramento that typically floods in about 60% of years, when winter and spring floodwaters enter from the Sacramento River and several small streams. The floodplain appears to be particularly good spawning and rearing habitat for splittail and young Chinook salmon. The Bypass supports 15 native and 27 non-native fish species. The Yolo Basin Wetlands Project comprises 2,223-acres of seasonal wetlands and 185-acres of perennial wetlands and was dedicated in 1997.[45] Potential enhancements that have been discussed include additional wetlands, fixing fish passage and stranding problems and increasing the frequency of floodplain inundation in drier years.

Measures to address fish stranding in the Bypass were proposed by the Anadromous Fisheries Restoration Program in 1995, by the CALFED Record of Decision in 2000 and the National Marine Fisheries Service OCAP Biological Opinion in 2009, but never occurred. In 2011, biologists documented the stranding of hundreds of listed green sturgeon, spring-run Chinook salmon and steelhead trout in the Bypass. In July 2013, National Marine Fisheries Service biologists estimated that the numbers of stranded endangered winter-run Chinook salmon could be as high as half of the year's returning population.[46] BDCP proposes to facilitate additional periods of inundation and address the stranding issue.

The area is a net producer and exporter of methylmercury. For example, The State Water Board has found that when the Yolo Bypass is flooded, it becomes the dominant source of methylmercury to the Delta.[47] Restoration actions that lead to an increase in wetting and drying

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[45] http://www.water.ca.gov/aes/docs/Yolo_Fisheries_Paper_2001.pdf

[46] http://calsport.org/news/?s=winter+run+stranding

[47] State Water Resources Control Board, 2009 Periodic Review of the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin River Delta Estuary, adopted resolution 2009-0065, page 29. http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/periodic_review/docs/periodicreview2009.pdf

periods could exacerbate existing mercury problems.[48] A 2010 report of a study funded by the Central Valley Regional Water Quality Control Board to evaluate methylmercury cycling and export from agricultural and natural wetlands in the Yolo Bypass found that periodic flooding of rice fields promotes the production of methylmercury beyond rates seen in naturally vegetated wetlands, whether seasonally or permanently flooded.[49]

A potential and unresolved issue of concern is the loading of urban and agricultural wastes into the Bypass, especially toxic concentrations of insecticides. Another potential issue is expansion of invasive aquatic plants in the perennial wetlands, without continual and costly oversight.

North East Delta

Planning for the Cosumnes/Mokelumne ROA habitat restoration has been going on for decades. Yet other than the lower Cosumnes Preserve, little has been done to restore tidal aquatic habitat in the East Delta. With federal and state grants, the Nature Conservancy has purchased much of the corridor from Walnut Grove east to the Cosumnes Preserve including most of the properties in Figure 1. Staten Island and McCormick Williamson Tract were purchased by the nature Conservancy more than a decade ago in the 1990s with CALFED funding. Invertebrates in the Cosumnes area have been found to have the highest concentrations of methylmercury in the Delta.

Aquatic habitat restoration in the area would be problematic considering the close association of the tidal channels with the Delta Cross Channel at Walnut Grove. Waters in the area are also warmer than other parts of the Delta and subject to warm summer inflows of the lower Sacramento River at the Delta Cross Channel. Restoration planning on projects such as the McCormick Williamson Tract is proceeding.[50]

Delta Meadows State Park was designed to preserve some of the original Delta habitats. The Park is now closed. The following is an excerpt from page 1 of the McCormack-Williamson Tract Restoration Planning, Design and Monitoring Program: *"The ultimate significance of these findings for the restoration is that regardless of careful design of a tidal gradient as has been done in other Delta projects, a restored upper Delta will be subjected to an unpredictable flood regime that will result in a spatially complex assemblage of geomorphic units that will defy conventional criteria for "success" in restoration. That is not inherently bad in that it is the natural condition of the system. However, the assumption of a well-ordered tidal geomorphic process as exists in other modern tidal freshwater wetlands is not appropriate for MWT (McCormick Williamson Tract). In addition, the presence of extremely high mercury*

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[48] Foe, C., et al., Task 2: Methyl mercury concentrations and loads in the Central Valley and Freshwater Delta, CALFED, 2008. http://mercury.mlml.calstate.edu/wp---content/uploads/2008/10/04_task2mmhg_Winal.pdf

[49] http://www.waterboards.ca.gov/centralvalley/water_issues/tmdłcentral_valley_projects/delta_hg/other_technical_reports/ybwa_hg_final_rpt.pdf

[50] https://watershed.ucdavis.edu/project/mccormack-williamson-tractnorth-delta-project-restoration-planning-design-and-monitoring

concentrations in both the Delta Meadows and MWT create significant uncertainty in the biogeochemical fate of wetland restoration of MWT, though the opportunity exists for experts to study the biogeochemistry of Delta Meadows and establish how such a wetland functions in the face of existing pollution."[51]

East Delta

The lower San Joaquin channel in the Delta from Mossdale downstream to Prisoners Point (Figure 20) is also part of the East Delta that has been largely ignored by Delta restoration programs. The corridor is important for many fishes including salmon and steelhead from San Joaquin tributaries, as well as Delta species such as splittail. It suffers in summer from low flows, high water temperatures, low dissolved oxygen, algal blooms and heavy pollution loads, but it is an important corridor for many species in winter and spring.

The Stockton or San Joaquin Deep Water Ship Channel dominates the area. The channel converted the once sinuous channel to a straight channel for shipping by cutting through many points creating a series of dredge-spoil islands. The Port of Stockton owns most of these created "islands." The lower San Joaquin channel from Mossdale downstream to Prisoners Point (Figure 21) has been largely ignored by Delta restoration programs.

Figure 20. South East Delta – San Joaquin River between Stockton and Prisoners Point. The ship channel can be seen cutting through a series of Delta islands at the center of the photo. Mildred Island is at the lower center and eastern edge of Franks Tract and Old River are at the upper left.

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[51] https://watershed.ucdavis.edu/pdf/crg/MCWTFinal.pdf

Conclusion

Research over the past several decades indicates that Delta native fishes, especially Delta smelt, have very refined habitat preferences that should be the focus of any habitat restoration projects. The main habitat features of importance include salinity, turbidity, tidal flows, productivity, and water temperature. Creating habitat that meets most or all of these criteria is extremely difficult but necessary. Very few of the restoration projects undertaken to date meet these criteria.

Many implemented and proposed projects have fatal flaws (e.g., Liberty Island - lethal water temperatures) and did not consider these basic needs when designed and built (e.g., Decker Island, Kimball Island). Many project areas have actually deteriorated after purchase and little actual restoration was implemented (e.g., PG&E's Collinsville property). Other projects failed because necessary funds to restore, maintain and adaptively manage the areas were never provided (e.g., Chipps Island, Franks Tract). Consequently, many of these restoration sites evolved into havens for an astonishing assemblage of invasive plants and fishes and adversely impacted native species (e.g., Big Break, West Sherman Island, Donlon Island). A number of projects that could be considered a success have had mixed results with unintended consequences (Yolo Bypass).

The blunt fact is that the cumulative effects of all of the myriad restoration project that have been constructed in the Delta have not reversed the continued decline of native fisheries. This is because few restoration projects have been designed with the needs of fish in mind. And there is nothing in BDCP's proposed habitat restoration scheme that indicates it can or will produce habitat that meets the needs of fish. Indeed, BDCP proposes to exacerbate existing habitat problems.

As we've observed, native species evolved over many thousands of years in response to habitat. And that habitat included adequate physical (flow, residence time, variability, etc.) and chemical parameters (salinity, temperature, turbidity, chemical constituents, etc.), as well as the nutrients necessary for primary production to support renewable fisheries. The export projects have radically altered the Delta's hydrodynamics, which has resulted is a loss of critical flows, less variability, degraded water quality and reduced primary productivity. The yearly export of phytoplankton biomass is equivalent to more than 30% of net primary production. And BDCP proposes to expand the export of primary production to the north Delta. It proposes to move the critical LSZ habitat further east where smelt will more frequently encounter lethal water temperatures and entrainment in project pumps. It proposes make Sacramento salmonids run a gauntlet past massive new diversion facilities.

The Delta's altered hydrology has allowed numerous invasive non-native species to become entrenched to the detriment of native communities. We have transformed a variable freshwater estuary into something resembling an Arkansas lake. Creating more Arkansas lake habitat will simply create more Arkansas lake fish.

The best options for meeting the necessary fish habitat criteria is to increase flow and variability, mimic the natural hydrograph, protect the LSZ, improve water quality and reduce the export of primary productivity. But, those are the things BDCP cannot offer. Instead, the EIR/EIS predicts less flow and variability, a less protective LSZ, reduced water quality and increased export of primary production. That is not a recipe for improved habitat.

BDCP even ignores or marginalizes the obvious habitat improvements that could be undertaken. Migrating young salmon fry and fingerlings tend to concentrate in shoreline areas and adjacent and adjacent margin habitats along channels. Salmon smolts are frequently collected in the open channels migrating westward but are also found feeding in margin habitats. The shoreline restoration efforts on Twitchell, Decker and other west Delta sites have been successful. Yet, BDCP proposes to restore only about twenty miles of channel margin habitat over a span of thirty years.

Franks Tract is a death trap for smelt. Once drawn into Franks Tract, Delta and longfin smelt are unlikely to survive lethal temperatures, predation or entrainment at the south Delta pumps. There have been numerous proposals to place a barrier across False River or to wall off Franks Tract from surrounding channels. BDCP is silent on the issue.

In closing, we offer a bottom line. Habitat restoration cannot be successful if it doesn't meet the flow and water quality needs of native species that evolved over millennia. The history of habitat restoration in the Delta is that it hasn't met those needs, and BDCP will not meet those needs.

Attachment A: Comparison of this Review with the Habitat Assessment in BDCP HCP Appendix 5E

Appendix 5E of the BDCP HCP discusses some of the above areas and specific sites in the context of the proposed Conservation Measures. Unfortunately, the BDCP assessments, which are predicated on a conceptual programmatic level with few specific details, are seriously over optimistic of both the results of past efforts and the potential benefits of future restoration projects.

For example: page 5E-iv; "*In this appendix we evaluate the potential of restored habitat to enhance productivity of the Delta based on a simple depth relationship (Lopez et al. 2006) while cautioning that the realities highlighted by Lucas and Thompson (2012) may limit the value of restoration in regard to phytoplankton production."*

The BDCP fails to consider the both the benefits and detriments of shallow water habitat, while focusing on water depth and phytoplankton. Shallow water provides key spawning and rearing habitat for most Delta native fish with its cover, turbidity, and food via aquatic and terrestrial insect and benthic invertebrate communities. However, shallow water can also contain lethal water temperature, harbor invasive plants and be detrimental to native fish.

CM5 Seasonally Inundated Floodplain Restoration

"*The proposed restoration of 10,000 acres of seasonally inundated floodplain habitat and the increase in flooding in the Yolo Bypass are expected to increase the amount and value of accessible rearing habitat for juvenile salmon and splittail. For salmon, the intent is to route salmon away from the interior Delta and through habitat that is favorable for growth.*" (p. 5.E-v)

The Bypass may be favorable to juvenile fish growth in winter compared to rivers, but its flows attract and strand many adult anadromous fish. Springtime warming of the water also increases water temperatures to lethal levels for smelt and salmon. Pollution from adjacent agricultural and industrial dischargers is a serious problem, as is methylation of mercury. Numerous unscreened diversions (some simple tide gates) pose a threat to fish. These problems are ignored in the assessment.

"*Floodplain restoration also is expected to increase the export of production downstream, providing increased food supplies (phytoplankton, zooplankton, insects, and small fish) for pelagic fish species such as delta smelt and longfin smelt (Kneib et al. 2008)."* (p. 5.E-v*)*

While Bypass floods are one of the benefits of wet years, BDCP provides no added Bypass flooding in drier years, when such benefits are in short supply and critically needed.

CM4 Tidal Natural Communities Restoration

"*Under the hypothetical restoration footprint, BDCP restoration is expected to add about 55,800 acres of subtidal and intertidal habitat for covered fish in the Delta by the end of the permit term, representing a 54% increase in these communities relative to current levels. The greatest* *increase in tidal acreage would be in the South Delta, followed by Cache Slough, Suisun Marsh, West Delta, and East Delta subregions; there is no restoration under CM4 in the North Delta or Suisun Bay subregions.*" (P. 5.E-xi)

As we pointed out above, there is little value in developing subtidal and tidal habitats in the South Delta. There are huge problems associated with increasing such habitat in the Cache Slough area (e.g., warm isolated habitats, mercury methylation), especially in the areas proposed (e.g., Prospect Island and leveed lands south of Cache Slough). Suisun Marsh simply is not in play in drier years. Emphasis should be on West and Central Delta.

"Splittail are expected to benefit from the restoration of tidal marsh and floodplain habitats. Splittail exhibit a wide tolerance for conditions in the Delta. Their abundance is believed to relate more to the amount and duration of flooding of Yolo Bypass and other floodplain areas used for spawning. Splittail are expected to benefit from the expansion of food production in tidal wetlands due to the expanded flooding of Yolo Bypass (CM2) and, to a much lesser extent, other floodplain areas (CM5)." (P. 5.E-xii)

Splittail do relatively well in wet years with existing floodplains; it is in drier years when they would benefit from such actions, which are not provided in the BDCP floodplain prescriptions. Splittail may benefit from South Delta floodplain restoration, but in drier years most splittail production is lost to South Delta exports.

"The expectation is that restored shallow areas would promote production of tules and other native macrophytes that will increase the availability of aquatic insects, other invertebrates, and detritus to augment food for covered fish species. The change in the prod-acres index over the implementation period relative to the current level suggests that, by the end of the permit term (LLT), restoration benefits to food production would be greatest in Cache Slough followed by the South Delta… Transfer of this production to food for listed fish species could be complicated by potential consumption by clams, nutrient levels in the Delta and hydrodynamic factors. However, benefits can be maximized by restoration design and adaptive learning of restoration methods in the Delta." (P. 5.E-xii)

This is another example of the gross over-estimation of benefits from the proposed BDCP restorations. First, the Cache Slough area is already highly productive and shows no sign of food limitations. Second, there is little evidence that any of the productivity from the area is transferred to the Delta in drier years when benefits would be greatest. There is little chance that benefits can be "maximized" by design or adaptive learning. The three major areas proposed, leveed lands south of Cache Slough, Prospect Island, and Yolo Ranch, if converted to tidal habitats as discussed earlier, would have devastating negative effects on Cache Slough area habitats as well as habitats downstream in the Central and West Delta.

"BDCP restoration will modify flood conveyance levees and infrastructure to restore 10,000 acres of seasonally inundated floodplain along river channels in the South Delta." (P. 5.E-xii)

Again, the need for and potential benefit of South Delta floodplain restoration are greatly overestimated. Much of the benefit is estimated to accrue from the South Delta to salmon and splittail in wet years. Production of both species is already relatively good in wet years in the San Joaquin, but minimal in drier years when the proposed habitat benefits would not accrue.

CM6 Channel Margin Enhancement

"*There is some indication that channel margin could be extremely important rearing habitat in years with low precipitation when floodplains are not functioning. A study by McLain and Castillo (2009) found that densities of Chinook salmon fry in the Sacramento River and Steamboat Slough were higher compared with Miner Slough and Liberty Island Marsh during a low outflow year. Fry apparently bypassed marshy habitats at the downstream end of the Yolo Bypass because outflow during the winter was relatively low and flows into the Yolo Bypass were negligible (McLain and Castillo 2009*)." (P. 5.E-vi)

The majority of BDCP channel margin habitat restoration is located above Rio Vista on the Sacramento. The crucial channel margin habitats of the Delta migration corridors of the lower Sacramento and San Joaquin rivers are ignored. In drier years, these habitats are critically important to many Delta fishes including young salmon, steelhead, splittail, and Delta smelt. The BDCP proposal for channel margin restoration is totally inadequate given the importance of such habitat. As mentioned above, channel margin restoration has been some of the most successful restoration efforts to date in the Delta.

"By targeting areas that have been shown to have poor habitat value and biological performance coupled with extensive occurrence of covered fish species, it is possible that channel margin enhancement, together with associated restoration activities such as CM7 Riparian Natural Community Restoration, can provide more than a proportional 4% increase in overall habitat value. Such locations include the greatly altered reach of the Sacramento River between Freeport and Georgiana Slough, for example." (P. 5.E-xiv)

The 20-mile prescription for channel margin restoration in the BDCP is inadequate. The spot treatments prescribed are totally inadequate for a restoration category that has been proven successful and needed. The greatly altered large leveed channel upstream of Rio Vista would be difficult to restore and is not the area of greatest need. The many miles of channel margins between Rio Vista and Collinsville, Antioch and Pittsburg, and around Sherman Lake are more important and largely un-leveed. These areas are also adjacent to important shoal and pelagic habitats, unlike the prescribed Freeport to Georgiana Slough reach upstream of Rio Vista that will be subject to the direct effects of the BDCP tunnel intakes.

Expected Benefits to Fish from BDCP Restoration

Appendix 5E is wildly optimistic as to the potential benefits to key fish species from BDCP-prescribed restoration.

Cache Slough ROA

Delta Smelt: *"The decrease in HSI for the egg-larvae stage is the result of increased water temperatures in the subregion by the LLT primarily due to climate change impacts. There was* *almost no change in the HSI value for temperature over the period due to covered activities alone reflecting the lack of impact of the BDCP on temperature in Cache Slough.*" (P. 5.E-95)

Our earlier discussion of the Cache Slough locations especially Liberty Island and Prospect Island clearly point out that these areas are too warm for Delta smelt from spring through summer, especially in dry years. The BDCP analysis of the effect on water temperature of adding 10,000 acres of open water on water temperatures is seriously flawed. The added tidal exchange alone will draw the LSZ further into Delta and expose fish to potentially lethal water temperatures. Water diversions from the area including the NBA will also have an impact. There may be little change in HSI values because the area is already too warm in spring and summer, especially in dry years.

Salmon: **"***Salmonids, those that enter the Yolo Bypass, make extensive use of the Cache Slough area. Fish can move down through the bypass and into Cache Slough where their survival is affected by local conditions. Tidal marsh restoration in Cache Slough is likely to benefit primarily juvenile foraging salmon by providing access to high-value areas for rearing. Increases in size at ocean entry have been shown to correlate with increased ocean survival (Claiborne et al. 2011). The aggregate effects of these improvements in habitat availability and environmental condition are likely to result in better outmigration success for juvenile Chinook salmon.*" (P. 5.E-100)

The prescribed actions for the Yolo Bypass only affect habitat in winters of wet years and do little for salmon in dry years when such benefits are critically needed. Adding slightly to the frequency of inundation in wet years will not provide the needed benefits for salmon.

Longfin Smelt: **"***The overall impact was toward appreciably greater habitat for longfin smelt in Cache Slough although it is not clear from this analysis whether the increase in habitat quantity compensates for the decrease in habitat value (HSI) related primarily to increasing temperatures*" (from climate change).

West Delta ROA

Delta Smelt: "*The West Delta subregion currently provides HUs largely for larval and juvenile delta smelt with relatively small amount of habitat for delta smelt spawning (Table 5.E.4-24). This is because most of the subregion is subtidal with a small amount of tidal freshwater (Figure 5.E.4-67).*" (P. 5.E-105)

This statement is simply not true. The entire West Delta ROA from Collinsville to Rio Vista is generally freshwater in winter and spring of most years and has ideal shoreline habitat for spawning smelt. Such statements reflect the lack of understanding in the BDCP of the actual habitat requirements of many of the species of interest.

"*Suitability was lowest in all time periods for juvenile delta smelt because of low turbidity in summer and fall months*." (P. 5.E-106)

One reason for the lower turbidity is that the South Delta water export facilities pump water from the LSZ, which is replaced by high inflows from Sacramento River reservoir releases. Despite such effects, Longfin and Delta smelt still concentrate in the LSZ in the West Delta in all but the wetter years. The increases in habitat values predicted are small because so little habitat restoration is proposed in the West Delta. What habitat is proposed, at Dutch Slough, North Sherman, and Decker Island, as outlined in my report above have overly optimistic benefits predicted for these sites given their location, restoration design, and potential function. It should be noted that the proposed North Delta water exports would further reduce turbidity by 7 to 8 percent.

Comments on Appendix 5EB – Review of Restoration in the Delta

"*This report summarizes the lessons learned from previous restoration activities in the Delta, to provide a starting point for planning and study of restoration concepts: what should we try to replicate or avoid?"* (P. 5.E.B-1)

These conclusions, as to benefits of past restoration efforts, are overly generous and lack scrutiny on many levels.

Liberty Island

Liberty Island is a case in point: *"In some cases, accidental changes have resulted in improved conditions for native fish species (e.g., Liberty Island)"* (P. 5E.B-1).

The many problems with Liberty Island (e.g., warm water, high inorganic turbidity, high methylation of mercury, etc.) make it a poor model for future restoration.

"*For example, the apparent success of the Liberty Island transformation appears to be due in part to the juxtaposition of flow from the Sacramento River (Yolo Bypass) and Cache Slough, tidal flux and wind that result in high turbidity, movement of sediment, and local prey production. Sediment comes primarily from Yolo Bypass and the inward movement of sediment from Suisun Bay during the summer, which, along with strong summer winds, keeps the area turbid during the portions of the year that Yolo Bypass is not flooded. The result appears to be that the island provides on-site habitat and food for delta smelt and other species (Whitley and Bollens 2013) while also exporting some of its production.* " (p5E.B-5) *"This site is perhaps the best example of the potential for restoration to provide habitat and food for native fish species. Liberty Island is part of a large complex of planned restoration areas and naturally restoring areas, including Cache Slough, Little Holland, and Prospect Island, and it is also hydrologically connected to the Sacramento River and is downstream of Yolo Bypass*." (P. 5E.B-13)

The wide, open, shallow embayments of Liberty Island and Little Holland Tract are very turbid from wind fetch across the islands. However, the shallow, muddy waters are not natural and certainly not tidal marsh as they were historically before reclamation. Waves and floods are continually eroding the inorganic soils of the two areas, which were previously under intensive agriculture and are now part of the Bypass. The shallow waters warm excessively in the intense sun and warm air of late spring through early fall. Water entering the area from the Bypass Tule

Canal can be best described as agricultural “return” water with high levels of organics, nutrients, agricultural chemicals, and other pollutants. Smelt are able to survive the summer only by seeking refuge in deeper nearby channels and holes scoured by historic floods. Their ability to survive the summer is highly questionable. The habitat may in fact have been better before the island breaching when narrow deep sloughs surrounded the original marshes or more recently the reclaimed agricultural islands (this would apply to both Liberty Island, Prospect Island and Little Holland Tract). Adding thousands of acres more of such habitat by breaching levees south of Cache Slough, north of Liberty Island, and on Prospect Island following the Liberty paradigm could be disastrous.

“*An important feature of the Liberty Island site it that it is hydrologically complex; these hydrodynamics shape environmental conditions and the resulting biological response. The site is at the downstream end of the Yolo Bypass and is heavily influenced by freshwater flow from the Sacramento River. It is also subject to significant tidal fluctuations that push water upstream and then pull water back downstream. The result is high turbidity and flow conditions that appear to have limited the growth of SAV.”…”Tidal flow rather than river discharge was 43 responsible for 90% or more of the material flux into and out of Liberty Island* (P. 5E.B-14).

The site is not heavily influenced by freshwater flow from the Sacramento River except during floods. Normally its minor inflows are from the Bypass Tule Canal. Tidal flows do enter the lower end of Cache Slough near Rio Vista, but only have a minor influence on lower Bypass water quality and habitat conditions.

“*The landward transport of sediment, surrounding backwater sloughs with high residence time, and complex morphology—along with large open areas where sediment is resuspended by wind and tidal currents—are all physical drivers that allow Liberty Island to have habitat suitability that favors native species like delta smelt.*” (P. 5E.B-15).

The Liberty Island habitat does not favor Delta smelt. By midsummer most smelt in the area are found in the Sacramento Deepwater Ship Channel to the east of the Bypass. Liberty Island is generally too warm for smelt by early summer.

Decker Island

“*Restoration at Decker Island, which involved restoration of a U.S. Army Corps of Engineers dredge spoils site, has been plagued by development of dense Egeria beds, especially in shallow channels that were created at the site (Rockriver 2008). Nonnative fish species were more abundant than native species in restored channels with dense vegetation. Rockriver (2008) recommended substrate changes to discourage centrarchid fish species (e.g., bass), and chemical applications to control SAV.*” (P. 5E.B-6).

The site is also plagued with water hyacinth (FAV), which requires chemical treatment by the Department of Boating and Waterways. Shallow channels primarily a problem when they “dead end.” Flow-through channels tend to stay open, although Egeria and other invasive SAV plants invade most Delta shallow water habitat.

Franks Tract

"*In contrast to the more complex hydrodynamics of Liberty Island, the lake is primarily influenced by tidal flow*." (p5E.B-15).

Franks Tract has very complex hydrodynamics beginning with tidal inflows from False River and Old River, along with negative flows down Old River from the Tract to the South Delta export pumps.

Mildred Island

"*Currently, the deep water at Mildred Island appears to prevent Egeria and clams while allowing phytoplankton production (Lucas et al. 2002)… Breaching of Mildred Island, on the other hand, resulted in relatively little Egeria and net production of phytoplankton to the Delta, though it also harbors large populations of nonnative predatory fish (Nobriga et al. 2005*)." (P. 5E.B-16)

Any plankton production would likely be exported at the South Delta export pumps, as net flows are almost always in that direction, which is why there are few native fish. Neither Franks nor Mildred should be left in their present state, as they offer refuge and breeding areas for nonnative fishes, as well as sinks for native fishes.

Big Break

"Big Break is presently a flooded island similar to Franks Tract. Pilot-scale restoration projects within it will: (1) restore tidal marsh, floodplain, and Antioch dune habitat on the Delta of Marsh Creek to restore target fish and dune species, (2) restore bio-filtration floodplains along urbanizing reaches of Marsh Creek to protect and improve water quality entering the Delta, (3) monitor aquatic species in Big Break and water quality along Marsh Creek, (4) develop a volunteer-driven native plant nursery to generate plants for restoration, and (5) continue a public outreach, education, and citizen planning program in the watershed to monitor the project over time." (P. 5E.B-17)

As discussed previously, the Big Break pilot projects offer little value for Delta native fishes, leaving another extremely poor habitat complex within the West Delta low salinity zone area that should be restored.

Donlan Island (P.5E.Bp-17)

The EIR/EIS fails to mention the dysfunctional nature of this restoration site. (See previous discussion of this site.)

Sherman Lake (P. 5E.Bp-18)

The EIR/EIS fails to mention the dysfunctional nature of much of this site (e.g., large areas of invasive FAV). (See previous discussion of this site.)

Prospect Island

"*Prospect Island has flooded seven times since 1981, and likely has little value for agriculture (Sanderstom et al. 2010). Therefore, the intentional breaching and re-flooding of Prospect Island could create beneficial habitat for Delta and migratory fish species (Sanderstom et al. 2010).*" (P. 5E.Bp-18)

Or it could just as easily create very poor habitat conditions as discussed previously.

Dutch Slough

"*The 1,200-acre pasture site has the potential for restoring over 6 miles of shoreline and a mosaic of tidal, riparian, and upland habitats, to provide enhanced fish and wildlife habitat in the western Delta. The unique, relatively unsubsided site topography would allow restoration of intertidal dendritic channels.*" (P. 5E.B-19)

As stated earlier, the Dutch Slough project would create poor habitat similar to Big Break and Franks Tract and its waters and aquatic production would drawn eastward toward the South Delta export pumps.

McCormack-Williamson Tract

"*The McCormack-Williamson Tract is a 1,654-acre island located immediately downstream of the confluence of the Cosumnes and Mokelumne Rivers, owned by The Nature Conservancy. The island offers opportunities for restoration of critical tidal freshwater marsh and floodplain habitat (Grosholz and Gallo 2006; Moyle et al. 2007) and may also moderate flood flows in the northern Delta, and is particularly suitable for expanding shallow water and tidal marsh habitat in the Delta.*" (P. 5E.B-20)

As discussed earlier, the island is "downstream" of the Delta Cross Channel, thus its flows are destined for the South Delta exports. The area is too warm in summer for Delta smelt. It does not lie in the spawning and rearing zone of Delta smelt.

Decker Island

"*Collectively, these efforts should lead to the long-term sustainability of a complex wetland ecosystem with considerable wildlife, water quality, and aesthetic benefits (California Department of Water Resources 2013).*" (P. 5E.B-21)

As discussed previously, the Decker Island DWR mitigation site is largely dysfunctional. There are no plans to adaptively rebuild the site to make it functional nor are there any specific plans to restore the remainder of the island that has a Corps dredge spoil easement.

What are the Major Flaws in BDCP's Proposed Native Delta Fish Habitat Restoration Program?

Given the described weaknesses in the BDCP habitat restoration prescriptions described above, what are the fundamental flaws in BDCP's approach to habitat restoration?

1. Above all, BDCP assumes that the quantity of habitat is more important than the quality of habitat. It ignores the fact that habitat restoration must replicate the quality of habitat under which species evolve over eons.
2. There is too much focus on tidal marshes that the fish will not use, which provide little indirect benefit to fishes through foodweb enhancement, and are located in areas of the Delta that are not beneficial.
3. There is a lack of focus on pelagic habitats particularly in the key Low Salinity Zone which typically occurs from lower Suisun Bay into the West Delta (most important is the Collinsville to Rio Vista reach of the lower Sacramento River and the Pittsburg to Prisoners Point reach of the lower San Joaquin River, as well as the confluence waters of the two rivers of Eastern Suisun Bay).
4. There is little emphasis on channel margin habitat particularly in the regions mentioned above in #2.
5. There is disregard for the many neglected areas that need restoration funding to fix poor habitat conditions despite decades of pleas from their government and NGO owners and managers (e.g., Sherman Lake, Big Break, Franks Tract, McCormick-Williamson Tract).
6. There is too much emphasis on areas that are too salty (Suisun Marsh), too warm (Cache Slough/Bypass and South Delta), and where waters are destined for South Delta exports (South and East Delta).
7. There is a lack of emphasis on salinity control and water temperature, and tidal flows and mixing, freshwater inputs, and Delta exports that control these key habitat features.
8. More emphasis is needed on the physical controls that are available or could be installed to enhance salinity and water temperatures of the important habitats (e.g., Montezuma Salinity Control Weir, Delta Cross Channel Gates, temporary installed weirs, Head of Old River Gates, and South Delta export facilities).
9. There is no mention of managing the open water (pelagic) habitats along the hundreds of miles of deepwater dredged shipping channels that have greatly affected the Delta, or mitigating for the ongoing effects of dredging on these habitats.
10. There is a disturbing disregard for water quality in the Delta, not just water temperature and salinity. Methylmercury is a serious problem in tidal marshes and seasonally flooded habitats emphasized by BDCP. Many of the solutions recommended (e.g., source control, etc.) for these problems are infeasible or unlikely to be successfully implemented.
11. Many important areas have simply been left out of the plan (e.g., Grizzly Bay, Montezuma Slough, Chipps Island, Collinsville, West Sherman, Big Break, Franks Tract, northern shoreline between Collinsville and Rio Vista, lower San Joaquin from Jersey Point to Prisoners Point, lower Old and Middle Rivers, lower San Joaquin downstream of Stockton to Prisoners Point, eastern Suisun Bay from Pittsburg to Antioch including New York slough and the southern shoreline).
12. There is a lack of emphasis on fixing hydrological connections such as Montezuma Slough, False River, Dutch Slough, Three Mile Slough, Delta Cross Channel, Sacramento

Deepwater Ship Channel, Georgianna Slough, Miners Slough, Sutter Slough, and Steamboat Slough to enhance the Low Salinity Zone of the Bay/Delta.

13. There is nothing in the Plan that will effectively address non-native invasive aquatic species that have undermined the native habitats and fish communities.
14. There is little in the Plan that addresses basic nutrients and the base of the food chain – phytoplankton production.

About the Authors

Tom Cannon has studied and surveyed many of these habitats over the past four decades in various roles as a fishery biologist involved in the Delta. His professional career has focused on estuarine fisheries ecology with experience on East Coast and West Coast estuaries and degrees in fisheries ecology, biology and biostatistics.

From 1977-1980, Tom was project director of Bay-Delta ecological studies for PG&E's Bay-Delta power plants effects studies that included habitat assessments of each of their Delta sites. From 1980-1982, he was a consultant to the State Water Contractors, the National Marine Fisheries Service and the State Water Resources Control Board (State Board) determining the effectiveness of the 1978 Bay-Delta water quality standards in protecting the Bay-Delta ecosystem and striped bass population. In 1986-1987, he consulted to the State Water Contractors and Bureau of Reclamation during State Board hearings on water quality standards.

From 1994-1995, he consulted to the State Water Contractors and the California Urban Water Agencies working on the 1995 Bay-Delta water quality standards and how the new standards would affect the Bay-Delta ecosystem and its fish populations. Between 1995-2003, he was a consultant to the CALFED Bay-Delta Program where he worked on various teams assessing the effects of alternative Delta operations, habitat improvements and water supply infrastructure. From 2002-2010, he was involved in activities related to the Striped Bass Stamp Program, Salmon Hatchery Program and Delta fish surveys funded by the U.S. Fish and Wildlife Service to assess the effects on Delta fish and habitats.

In the past decade, Tom worked closely with the Fishery Foundation of California, California Striped Bass Association and the California Sportfishing Protection Alliance on Delta science related to fisheries, water quality standards and the Bay Delta Conservation Plan. For Wildlands Inc. he supported efforts to develop wetland and fisheries habitat throughout the Delta region and co-authored a 2007 report on fish use of shallow water habitats of the Western Delta for Wildlands Inc. and Fishery Foundation. There he compared fish populations and habitat from surveys conducted between 2002-2007 in the Western Delta with earlier surveys conducted in 1978-1979.[52] He has personally surveyed many of the restoration sites in this report.

Bill Jennings is a life-long fisherman who has been with the California Sportfishing Protection Alliance for more than thirty years, serving as both its Chairman and Executive Director. Between 1995 and 2005, he also served as Deltakeeper, where he oversaw an extensive water quality monitoring program that was approved by the State of California and which worked closely with the Aquatic Toxicology Laboratory at U.C. Davis and state and federal agencies in collecting water samples throughout the Delta. Bill has spent thousands of days on Delta waters patrolling, monitoring and fishing and thousands of additional days participating in administrative and legal proceedings before state and federal agencies protecting water quality and fisheries. He is personally familiar with many of the restoration sites discussed in this report.

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[52] Cannon, T. and Kennedy T., Fish Use of Shallow Water Habitats of the Western Delta 1978-79 and 2002-07, May 2007.

AQUALLIANCE
DEFENDING NORTHERN CALIFORNIA WATERS

July 30, 2015

Glenn-Colusa Irrigation District
Thaddeus Bettner, General Manager
344 East Laurel Street
Willows, CA 95988

Re: Comments on the Draft Environmental Impact Report for the Glenn Colusa Irrigation District 10-Wells Project (Groundwater Supplemental Supply Project SCH# 2014092076)

Dear Mr. Bettner:

AquAlliance submits the following comments and questions on the Draft Environmental Impact Report ("DEIR") for the Glenn Colusa Irrigation District ("GCID") 10-Wells Project (Groundwater Supplemental Supply Project) ("Project"). These comments represent the comments of AquAlliance and its members. The Project proposes to install five new production wells and continue operating five additional production wells during dry and critically dry years for 8.5 months from approximately February 15-Marh 15 and April 1-November 15. The annual, maximum, cumulative total pumping is 28,500 acre-feet ("af") and is more water than the annual use of the Chico district of California Water Service Company that serves over 100,000 people.[1]

Unfortunately, the Project description fails to disclose details that are necessary for the public to review and comment. Moreover, there are no alternatives presented to the public beyond the No Project Alternative. The repeated use of conclusory statements leads to an absence of impacts in the EIR that are not supported by evidence. The DEIR as written fails to make a technically persuasive case for the 10 wells, and therefore the proposed Project should be rejected until the lead agency/Project proponent, GCID, can more effectively present scientific principles and analysis instead of mere assertions of negligible impact to third-parties and the environment. The recirculation of a new Draft EIR will be required because of the extreme deficiencies in the DEIR currently out for public review. The deficiencies in the DEIR cannot and will not be evaded by responses to comments in a Final EIR.

We include by reference all other letters submitted in response to this DEIR and submit comments and attachments created for AquAlliance by Kit Custis, AquAlliance's comments and attachments to the 10-Year Water Transfer Program, and an electronic copy of the report *Hydrostratigraphy and Pump-test Analysis of the Lower Tuscan/Tehama Aquifer, Northern Sacramento Valley, CA* that was hand delivered to the GCID office on July 28, 2015.

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[1] California Water Service Company *2010 Urban Water Management Plan Chico-Hamilton City District*, p. 32.

I. Legal Requirements Under CEQA

Under CEQA, the project must include “the whole of an action, which has a potential for resulting in either a direct physical change in the environment, or a reasonably foreseeable indirect physical change in the environment…”[2] To comply with CEQA’s standards for completeness, the project description must address “not only the immediate environmental consequences of going forward with the project, but also all ‘reasonably foreseeable consequence[s] of the initial project’.”[3] As courts have recognized for decades, “an accurate, stable and finite project description” is “the sine qua non of an informative and legally sufficient EIR.”[4] Reliance on a “curtailed, enigmatic or unstable definition of the project” stands as the paradigm of legal error under CEQA, because it “draws a red herring across the path of public input.”[5] An “EIR may not define a purpose for a project and then remove from consideration those matters necessary to the assessment whether the purpose can be achieved.”[6] CEQA requires “interactive process of assessment of environmental impacts and responsive project modification which must be genuine.”[7]

A lawful project description under CEQA helps the lead agency “develop a reasonable range of alternatives to evaluate in the EIR [that] will aid the decision-makers…”[8] However, “a lead agency may not give a project’s purpose an artificially narrow definition….” [9] A “curtailed or distorted project description may stultify the objectives of the reporting process.”[10] In Inyo III, the court rejected the Los Angeles Department of Water and Power’s attempt in its EIR to “narrow the city’s obligation—and the scope of this lawsuit—down to the relatively small flow of underground water destined for in-valley use.”[11] That narrow definition evaded the county’s warning that EIR simply assumed the “filling of the second aqueduct,” and the State Board’s warning that the narrow definition diverted attention “from the impacts of the major project which is the importation of additional water to Los Angeles.”[12] The “selection of a narrow project as the launching pad for a vastly wider proposal frustrated CEQA’s public information aims The department’s calculated selection of its truncated project concept was not an abstract violation of CEQA,” but rather, a failure to proceed “in a manner required by law.”[13] The “impermissibly truncated” and inconsistent project definition in the EIR also unlawfully skewed the lead agency’s assessment of the “no project” alternative and project alternatives.[14]

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[2] 14 Cal. Code Regs., § 15368; see also Nelson v. County of Kern (2010) 190 Cal.App.4th 252, 271.

[3] Communities for a Better Environment v. City of Richmond (2010) 184 Cal.App.4th 70, 82 (quoting Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova (2007) 40 Cal.4th 412, 428; Laurel Heights Improvement Assn. v. Regents of University of California (1988) 47 Cal.3d 376, 391, fn. 2 (Laurel Heights I).

[4] County of Inyo v. City of Los Angeles (Inyo III) (1977) 71 Cal.App.3d 185, 199.

[5] Id. at 199.

[6] County of Inyo v. City of Los Angeles (Inyo V) (1981) 124 Cal.App.3d 1, 9.

[7] County of Inyo v. City of Los Angeles (Inyo VI) (1984) 160 Cal.App.3d 1178, 1183; see Id. at 1186 (project cannot be defined to set up “a CEQA turkey shoot”).

[8] 14 Cal. Code Regs, §15124(b); see also In Re Bay-Delta Programmatic Environmental Impact Report Coordinated Proceedings (In Re Bay-Delta) (2008) 43 Cal.4th 1143, 1166 (lead agency “may structure its EIR alternatives analysis around a reasonable definition of underlying purpose and need”).

[9] Id.

[10] Inyo III, 71 Cal.App.3d 185, 192; see also Inyo VI, 160 Cal.App.3d at 1186 .

[11] Inyo III, 71 Cal.App.3d at 196.

[12] Id. at 198.

[13] Id. at 200 (quoting Pub. Res. Code, § 21168.5.

[14] Id. at 200-206.

In Communities for a Better Environment, the court held that the City of Richmond's EIR for a refinery project "fails as an informational document," in part because the EIR's project description "is inconsistent and obscure as to whether the Project enables the Refinery to process heavier crude."[15] The court noted that conflicting information in the EIR, and in 10-K statements filed with the Securities and Exchange Commission, contradicted the benign account provided in the EIR. The substantial evidence test was "not relevant" to assessment of violations of CEQA's information disclosure provisions. If the EIR does not "adequately apprise all interested parties of the true scope of the project for intelligent weighing of the environmental consequences, informed decision-making cannot occur under CEQA and the final EIR is inadequate as a matter of law.[16]

Project Definition in DEIR

Fundamental Purpose

The DEIR simply states that the Project "is proposing to install and operate five new groundwater production wells and operate five existing groundwater wells to augment District surface water supplies during dry and critically dry water years." (p. 2-1) The wells are proposed to operate "as needed during dry and critically dry years" until they reach a "maximum cumulative total annual pumping volume of 28,500 ac-ft." (Id.)

A complete and accurate description of the existing and affected environmental setting is critical for an adequate evaluation of impacts to it. *See e.g. San Joaquin Raptor/Wildlife Rescue Ctr. v. County of Stanislaus* (1994) 27 Cal.App.4th 713; *Galante Vineyards v. Monterey Peninsula Water Mgmt. Dist.* (1997) 60 Cal.App.4th 1109, 1122; *County of Amador v. El Dorado County Water Agency* (1999) 76 Cal.App.4th 931, 955; *Cadiz Land Co. v. Rail Cycle* (2000) 83 Cal.App.4th 74, 94.

As discussed, below, and in the expert reports created by Kit Custis on behalf of AquAlliance, the DEIR fails to comport with these standards.

Relationship to Past Projects and Plans

The Project is part of larger GCID projects, plans, grants, and agreements to transfer water (aka conjunctive use) and is also integrally related to other inter-connected actions by GCID, the California Department of Water Resources ("DWR"), the U.S. Bureau of Reclamation ("Bureau"), and others in the Sacramento Valley, and has the potential to have significant and far-reaching environmental impacts. However, the DEIR fails to make these connections that illustrate GCID's pursuit of conjunctive use projects.

For example, the broader history of the existing wells and GCID's delay in analyzing their planned long-term use for transfers and non-overlying water projects is not revealed. First, GCID was sued in 2007 over the claim that installing the wells (7 at the time) was exempt from CEQA because they were planned just for "research," despite the fact that GCID and local partners engaged in the Stony Creek Fan Project ("SCFP"). The SCFP's aquifer performance testing was hardly research, but preparation to enter the emerging water market as described in the 2005 Lower Tuscan grant proposal: "…this [conjunctive water use] program would provide

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[15] 184 Cal.App.4th at 89.

[16] Id. at 83 (citations omitted).

opportunities to benefit from water transfers through the state and federal water projects. Overall program recovery would occur through groundwater substitution from wells tapping the lower Tuscan Formation aquifer system. These wells could be operated in the Butte Basin in conjunction with the SWP [State Water Project – Oroville] or in eastern Glenn and Colusa County in conjunction with the CVP [Central Valley Project– Shasta]."[17] The district's attempt to now evaluate impacts from these wells in this DEIR cannot be limited to this project's artificially limited project description, but rather, must evaluate the whole of the impacts of operating these wells. Similarly, and as discussed further below, the DEIR should not simply assume that the construction of new wells will not foreseeably result in environmental impacts greater than those contemplated by this project's artificially narrow project description.

Also omitted from the DEIR is the assurance in the Bureau's 2009 Environmental Assessment for the *Glenn-Colusa Irrigation District Stony Creek Fan Aquifer Performance Testing Plan* that use of the wells in any way beyond "research" required additional analysis. The Findings of No Significant Impact document for that project states, that: "The data and information compiled during implementation of this aquifer testing plan would be used as input prior to longer term use of the wells and would require future environmental review." (U.S. Bureau of Reclamation, p. 10) In addition, the Glenn-Colusa Irrigation District Stony Creek Fan Aquifer Performance Testing Plan ("APT") response to comments claimed: "The APT is a two-year program and the test production wells would not be used after conclusion of the program unless there is a subsequent decision to do so that is supported by the appropriate level of environmental review. This commitment is confirmed in the SCF APT itself, the notice of exemption issued by GCID in the related CEQA review process (See Appendix A), the EA (page 15), as well as briefs filed in the Superior Court litigation and the Court's ruling in that case." (p.7)

Despite the promises and legal commitments, GCID waited until 2015 to produce this DEIR while using the wells for multiple purposes: "GCID first pumped these wells in 2007, at 547 ac-ft for that year. In 2008 and 2012, the wells were pumped at less than 500 ac-ft; and in 2009, a dry year, GCID pumped 1,405 ac-ft. In 2010, no groundwater was pumped. GCID entered into two water transfer agreements, in 2011 and 2013, and pumped 6,300 and 5,000 ac-ft, respectively, in those years to supply the water transfer programs (GCID, 2013)." (DEIR p. 3-15). What is not disclosed in the DEIR is that GCID planned to sell 85,000 af to San Luis Delta Mendota Water Authority ("SLDMWA") in 2008 by fallowing no more than 20 percent of the district's irrigated acreage, crop shifting, and "[2],500 acre-feet that could be transferred would be made available by groundwater substitution attributable to pumping from two GCID-owned electric wells."[18] The contribution the existing five and newly-proposed five wells would provide to these and similar projects cannot be circumscribed by an artificial label on the project description, but instead, must be considered in conjunction.

It is clearly a significant omission that the DEIR doesn't disclose what transpired in 2014 or what is planned for 2015. What is known by AquAlliance to date is:

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[17] Glenn Colusa Irrigation District and the Natural Heritage Institute, June, 2005. Proposition 50 planning grant proposal to create the Lower Tuscan IRWMP entitled: *Regional Integration of the Lower Tuscan Groundwater Formation into the Sacramento Valley Surface Water System Through Conjunctive Water Management.*

[18] GCID 2008. *Initial Study and Proposed Negative Declaration for Option Agreement Between Glenn-Colusa Irrigation District, San Luis & Delta-Mendota Water Authority and the United States Bureau of Reclamation for 2008 Operations, and Related Forbearance Program*, pp. 2-3.

- After GCID"s General Manager, Thad Better, assured the public at a 2014 Chico water forum that the GCID wells weren't being used, it turned out that GCID had the 5 wells running to help landowners flood their fields and pumped 459 af. [19]
- The 5 wells were also used to transfer 4,512 af to the Tehama Colusa Canal Authority in 2014.[20]
- In 2015 GCID is selling water again to Tehama Colusa Canal Authority by allowing their members to use personal wells - 15,269 acre-feet (af) of which 11,494 af will be made available by pumping groundwater.
- GCID also committed to sell 55,283 af of Sacramento River water to San Luis Delta Mendota Water Agency south of the Delta in 2015.
- On June 16, 2015 GCID turned on its existing five production wells while issuing a Notice of Exemption (NOE) based on an "emergency." To provide some history about these wells, they were installed eight years ago under a previous exemption that asserted that they were necessary for "research." The 2015 NOE claims that because of the 25% cut-back to their river water that was made clear in April, and new requirements to withhold additional water to attempt to save the 2015 winter-run salmon, they are facing emergency conditions. However, the most recent conditions could be foreseen by GCID, a water district that is in constant contact with the regulatory agencies and was fully aware of the serious hydrologic conditions and obliteration of the winter, fall, and spring salmon runs in 2014. There is no limit in time or volume in the NOE for the 5 wells.

GCID's failure to disclose its commitment to implement the SVWMA and its participation in repeated transfers, even when it claims in-district emergencies, proves that a shell game is operating. More of this will be discussed below.

Project Goals and Objectives

The fundamental purpose of the 10-Wells Project gives rise to more specific project objectives on page 1-5:

- Increase system reliability and flexibility
- Offset reductions in GCID Settlement Contract allotments during the irrigation season in drought years
- Periodically reduce Sacramento River diversions to benefit migrating fish
- Protect and maintain agricultural production in times of water shortage to minimize economic disruption

Below are specific comments and questions about the objectives presented.

1) "Increase system reliability and flexibility"
What "system" will receive "reliability and flexibility" from the 10-Wells Project? The vagueness of the objective leaves the reader unsure of the need for the Project. The Project is depicted as a "Supplemental Supply Project," however GCID is simultaneously selling river water to buyers north and south of the Delta in 2015.[21] The 10-Wells Project claims shortages yet in practice

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[19] Bettner, Thad e-mail to Barbara Vlamis June 2, 2014.
[20] Bettner, Thad letter to Jim Brobeck June 30, 2014.
[21] Bureau of Reclamation, 2015. *2015 Transfer Proposals as of May 19, 2015* obtained by AquAlliance through the Freedom of Information Act.

GCID has enough to sell water. It is in this way that groundwater is actually connected to water transfers, even if the Project's stated use is for district needs.

2) "Offset reductions in GCID Settlement Contract allotments during the irrigation season in drought years" The DEIR fails to address how GCID has specifically managed reductions in the past and that recent dam operations, or dam mismanagement is more likely, are part of the shell game to push CVP districts toward groundwater.[22] This objective directs the reader to the Alternatives that were considered and rejected, two of which make for shared sacrifice during extremely rare CVP reductions. The DEIR can't have it both ways – either reductions are rare or they are regularly expected and, therefore, the additional stress of the 10-Wells Project to the hydrologic system is against the best interests of even GCID and certainly its neighbors. If CVP reductions are planned to be much more regular, this must be disclosed and analyzed in the DEIR.

3) "Periodically reduce Sacramento River diversions to benefit migrating fish"
How will fish benefit from the extraction of 28,500 af of groundwater that has not been historically needed when it is well documented that groundwater loss comes at the expense of stream flow? "Groundwater pumping can alter how water moves between an aquifer and a stream, lake, or wetland by either intercepting groundwater flow that discharges into the surface-water body under natural conditions, or by increasing the rate of water movement from the surface-water body into an aquifer."[23]

4) "Protect and maintain agricultural production in times of water shortage to minimize economic disruption"
This is another laudatory goal that fails the sniff test. GCID's 2008 Negative Declaration for a project to transfer 85,000 af to San Luis Delta Mendota Water Authority by fallowing no more than 20 percent of the district's irrigated acreage determined that it would have "no impact" on "human beings, either directly or indirectly." The ability to absorb an 85,000 af loss of water during a Critical water year was GCID's legal position in the 2008 CEQA document, so why would the district possibly need 28,500 af from the existing and proposed wells to minimize economic disruption now and into the future? [24] In addition, the district regularly supports crop

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[22] Restore the Delta Protest Petition to the State Water Resources Control Board, July 22, 2015. "While we concede that DWR and the Bureau have in the near term diligently petitioned for temporary urgency changes reasonably promptly given natural conditions of drought in California and the Central Valley watershed of the Delta, the Board's authority to evaluate the temporary urgency change petition, and the petitioners' exercise of due diligence with respect to the substance of the petition, does not end with natural conditions. Instead, the California Constitution, Article X, Section 2, and the Public Trust Doctrine, as well as California Water Code sections 850546, 850217, and 850238 require the Board to consider whether the petitioners have also exercised due diligence in reasonably using and diverting water, as well as protecting public trust resources." (p. 5.)

[23] U.S. Geological Survey web site regarding groundwater depletion: http://ga.water.usgs.gov/edu/gwdepletion.html

[24] GCID 2008. *Initial Study and Proposed Negative Declaration for Option Agreement Between Glenn-Colusa Irrigation District, San Luis & Delta-Mendota Water Authority and the United States Bureau of Reclamation for 2008 Operations, and Related Forbearance Program*. "No Impact. The negative declaration assesses the potential impacts of the proposed Project. There would be no construction activities associated with the proposed Project. Typical farming practices with the idling of land in GCID would comply with applicable health and safety ·requirements. The potential increase in farmed acreage within the SLDMW A service area is within annual variability and could provide a minor beneficial effect on human economic activity. Therefore, the proposed Project would not cause substantial adverse effects on human beings, either directly or indirectly."

idling water transfers during dry and critical years, which the DEIR admits thwarts agricultural production. The district's on-again off-again support of this goal is arbitrary. Moreover, the project itself supports crop idling transfers by providing alternative water sources for the district in dry and critical years.

In 2010, a Below Normal water year, the *Glenn-Colusa Irrigation District 2010 Water Transfer to San Luis & Delta-Mendota Water Authority Draft Initial Study and Negative Declaration* had GCID planning to sell 20,000 af using groundwater substitution and didn't even *mention* impacts to the economy or humans. This pattern was repeated again in 2013, a Dry water year, when the water transfer CEQA document failed to mention, let alone consider, impacts to the economy or humans.[25] Clearly, GCID has through time demonstrated a lack of concern for impacts to the economy and humans, yet minimizing "economic disruption" has been elevated to an objective in the DEIR. The use of this goal obscures the district's historic behavior in feathering its own cap at the expense of the region's water and economy, which misleads the public.

In short, science and law should now converge to prevent GCID from framing the 10-Wells Project in a manner that forecloses meaningful alternatives and consigns the Sacramento Valley's future to fairy tales. As presented in the DEIR, the approach to project definition includes significant errors and omissions.

Key Problems with the GCID Project

GCID May Not Avoid Consideration of the Significant Environmental Impacts By Improperly Segmenting the Proposed Activities

The Project is part of GCID's multi-decade involvement in planning and implementing a much larger project, the Sacramento Valley Water Management Agreement ("SVWMA"), which still requires programmatic CEQA review. The SVWMA is not disclosed in the DEIR and has been gradually implemented by GCID and other parties absent the programmatic CEQA document (see Cumulative Impacts). The DEIR further fails to describe the numerous other programs of which this Project is a small component part. The review in the DEIR violates CEQA's prohibition against segmenting a project to evade proper environmental review (*Laurel Heights Improvement Association v. Regents of the University of California*, 1988, 47 Cal.3d 376).

The Project is a direct link to implementing the SVWMA and other subsequent plans and programs. Please consider the following:

- The SVWMA was signed in 2002 and the need for a programmatic EIS/EIR was clear and initiated, but never completed.[26] GCID is a signatory.

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[25] *Notice Of Preparation Initial Study And Proposed Negative Declaration Glenn-Colusa Irrigation District 2013 Water Transfer To San Luis & Delta-Mendota Water Authority.*

[26] Perhaps even more telling, the Bureau actually began its own Programmatic EIS to facilitate water transfers from the Sacramento Valley, and the interconnected actions that are integrally related to it, but never completed that EIS and now has impermissibly broken out this current segment of the overall Program for piecemeal review in the present draft EA. See 68 Federal Register 46218 (Aug 5, 2003) (promising a Programmatic EIS on these related activities, "includ[ing] groundwater substitution in lieu of surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater extraction wells, install groundwater monitoring stations, install new groundwater extraction wells…" Id. At 46219. See also

- Sacramento Valley Integrated Regional Water Management Plan (2006). GCID serves on the Joint Powers Authority and has been implementing the SVWMA through state grants and federal appropriations and agreements. (see more in Cumulative Impact section below).
- The Sacramento Valley Water Management Plan prepared by the Sacramento River Settlement Contractors in cooperation with the Bureau. (2006). GCID is a Settlement Contractor. "[t]o examine the potential for groundwater production and recharge within a gravely strata located in Glenn County, the Stony Creek Fan. GCID's Conjunctive Use Program is being developed in conjunction with the Stony Creek Fan Program and build upon data contain [sic] though this investigation and the Sacramento Valley Water Management Program." (p. 2-56).
- The Stony Creek Fan Partnership Orland Project Regulating Reservoir Feasibility Investigation. GCID is one of the partners. (Id.)
- GCID's Stony Creek Fan Aquifer Performance Testing Plan to install seven production wells in 2009 that will extract 26,530 AF of groundwater as an experiment.
- GCID's Lower Tuscan Conjunctive Water Management Program (Bureau provided funding). "GCID shall define three hypothetical water delivery systems from the State Water Project (Oroville), the Central Valley Project (Shasta) and the Orland Project reservoirs sufficient to provide full and reliable surface water delivery to parties now pumping from the Lower Tuscan Formation. The purpose of this activity is to describe and compare the performance of three alternative ways of furnishing a substitute surface water supply to the current Lower Tuscan Formation groundwater users to eliminate the risks to them of more aggressive pumping from the Formation and to optimize conjunctive management of the Sacramento Valley water resources."[27]
- GCID's water transfers in 2008 and in 2010.
- GCID's participation in the California Drought Water Bank for 2009. "In 2009, GCID transferred 6,585acre-feet to the California Department of Water Resources (DWR), as part of the 2009 Drought Water Bank. GCID made the transfer water available through crop idling."[28]
- The Bureaus of Reclamation's 2010/2011 Water Transfer Program of 395,910 af of CVP and non-CVP water with 154,237 AF of groundwater substitution (EA/FONSI p. 2-4 and 3-107). GCID was prepared to participate by selling 40,000 af of which 20,000 would have been available from groundwater substitution. (Final EA at p. 2-4)
- "One-year GCID transfer of surplus Base Water Supply and US Bureau of reclamation Project Water during calendar year 2011 to 8,200 acres of Colusa Drain Mutual Water Company, comprised of previously cultivated, agricultural land outside, but contiguous to

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http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788 (current Bureau website on "Short-term Sacramento Valley Water Management Program EIS/EIR").

[27] U.S. Bureau of Reclamation Assistance Agreement, 2006.

[28] Glenn-Colusa Irrigation District 2010 Water Transfer to San Luis & Delta-Mendota Water Authority Initial Study and Negative Declaration p. 1-2.

existing GCID boundaries, or otherwise, conveniently served with water from the Colusa Basin Drain when water is available within the Basin."[29] 6,300 af was transferred using groundwater substitution from GCID's wells for the first time.[30]

- In 2012 GCID's Critical Year Groundwater Well Program would pump 12,000 af. The Bureau planned water transfers of 76,000 af of CVP water all through ground water substitution.[31]
- In 2014 GCID planned to sell water north and south of the Delta.
  - Buyer Tehama Colusa Canal Authority sought 7,852 af with 4,154 af from groundwater substitution.
  - SLDMWA sought15,951 af.
- The 10-Year Water Transfers Program allows GCID to sell up to 91,000 af per year, including through groundwater substitution, from 2015-2024, to the San Luis Delta Mendota Water Agency.

The proposed project would facilitate additional water transfers that must be analyzed as part of the whole of the project. (See, *Citizens Association for Sensible Development of Bishop Area v. Com& of Invo* (1985) 171 Cal.App.3d 151, 165-166; *McQueen v. Board of Directors of the Midpeninsula Regional Open Space District* (1988) 202 Cal.App.3d 1136, 1144; *Laurel Heights Improvement Ass'n v. Regents of the University of California*, supra, 47 Cal.3d at pp.395-396.) The DEIR explains that GCID is a participant in the Long Term Water Transfer program ("LTWT") coordinated by and between the Bureau of Reclamation and the SLDMWA. (DEIR 3-76.) The DEIR notes that while the LTWT EIR originally evaluated GCID groundwater substitution transfers as part of the LTWT program, GCID now voluntarily seeks to convert all of its transfers under that program to cropland idling, while eliminating groundwater substitution, "originally shown at 25,000 ac-ft." (DEIR 3-76.) The DEIR explains that, "GCID elected to reduce the quantities from what was originally presented in the LTWT EIS/EIR in order to reduce potential conflicts between the proposed project and the LTWT." (DEIR 3-76.) In other words, to support and further the LTWT, GCID now proposes to pump a roughly equivalent amount of groundwater on its own, while still utilizing crop idling transfers as proposed under the LTWT. Moreover, nothing will prevent GCID from utilizing the existing or new wells to support groundwater substitutions under the LTWT. For each of these reasons, the direct, indirect, and cumulative impacts of GCID's participation in the LTWT should be considered here. See, AquAlliance, comments on the Long Term Water Transfer EIS/EIR, December 1, 2014.

Thus, while the DEIR provides no express explanation of why the proposed maximum groundwater pumping capacity of the project would be 28,500 ac-ft per year, the DEIR clearly explains that this project will be used to provide groundwater to the district in amounts almost identical to that which the district has voluntarily foregone in groundwater substitution under the LTWT. Nothing, however, under the LTWT nor under the proposed project affirmatively binds

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[29] http://www.ceqanet.ca.gov/DocDescription.asp?DocPK=651108

[30] Glenn Colusa Irrigation District Draft EIR Groundwater Supplemental Supply Project2015, p. 3-15.

[31] U.S. Bureau of Reclamation Memorandum to U.S. Fish and Wildlife Service January 24, 2012. *Section 7 Endangered Species Act Consultation with U.S. Fish and Wildlife Service (USFWS) for 2012 "North-to-South" Water Transfers.*

the district to these proposed amounts. Accordingly, and in order to avoid this shell game of simply taking the same groundwater under the pretense of a separate project under another name, these two projects must be evaluated together.

Indeed, GCID's participation in the LTWT itself belies the fundamental purposes of this proposed project, to provide additional water to the district in times of supposed shortages. In fact, the district proposes to sell off water rights under the LTWT during dry and critically dry years, and now proposes to pump an equivalent amount to offset the "shortage" it creates voluntarily by selling its water to south of delta users. As the DEIR states, these two projects are inextricably linked, and subject to the broad discretion of the GCID board to allocate water between the two on an annual basis.

<u>The DEIR must evaluate higher rates of groundwater extraction than proposed by the DEIR.</u>

The DEIR incompletely describes the project in the following, limited, terms:

> GCID is proposing to install and operate five new groundwater production wells and operate five existing groundwater wells to augment District surface water supplies during dry and critically dry water years (see Figure 2-1). The proposed project wells would be operated as needed during dry and critically dry water years to achieve a maximum cumulative total annual pumping volume of 28,500 ac-ft. Total capacity per well would be approximately 2,500 gallons per minute.

(DEIR 2-1.) The DEIR, however, provides no justification for limiting its analysis of the whole of the project to additional pumping of 28,500 ac-ft per year during dry and critically dry years. Nothing in the DEIR explains how or why groundwater extraction from these wells will be so limited.

What is the basis for the 28,500 ac-ft target? How, specifically, does this target amount of water satisfy each of the project objectives? What legal constraints, if any, are in place to ensure that no greater amounts could be withdrawn from these pumps? As the DEIR discloses in Table 3-4, the pumping capacities of the existing wells are far greater than the projected 2,500 gpm rate planned in the Project. (p. 3-15.)

Once constructed, additional operations of these pumps is entirely foreseeable. According to the DEIR at least, no further regulatory approvals would be needed to utilize the new and existing pumps in non-dry and critically dry years, and in amounts greater than 28,500 ac-ft per year (only construction approvals are referenced in the DEIR). The DEIR states that the pumps will be operated 24 hours a day and 7 days a week, but for only 8.5 months a year. Should the pumps be operated for the entire year, production increases to 40,300 ac-ft per year. Should the pumps be operated during any normal or wet year, the groundwater recovery anticipated by the DEIR would not be realized.

The DEIR states that "[a]ny future uses of groundwater facilities other than for supplementing GCID's water supply sources (for example, a water transfer) would require a separate evaluation and approval, at the time any such specific action is proposed, in compliance with NEPA and/or CEQA, as appropriate." (DEIR 2-3.) But this is simply not the case. As discussed above, five of the wells included in the present project were constructed, and have been operated on numerous occasions for numerous reasons, without CEQA review. Similarly, the DEIR itself notes that “GCID can augment its surface water supply with a maximum of 5,000 ac-ft of groundwater available annually from existing District-owned wells.” (DEIR 1-2.) Though the basis for the 28,500 af cap is not provided, it is evident that GCID intends to use its own wells to pump groundwater as needed and at any capacity.

The Supreme Court in *Laurel Heights I* held that an EIR must analyze future effects of a project where such effects are (1) reasonably foreseeable, and (2) significantly greater in scope or degree. 47 Cal.3d 376, 393-399. For example, in *Communities for a Better Environment v. City of Richmond*, 184 Cal.App.4th 70 (2010), the Court set aside an EIR for its failure to analyze Chevron’s ability to process lower grade crude oil as a result of equipment upgrades, even where the proposed air district permit for the project could have prevented the throughput of lower grade and more polluting crude oil. As here, the project purpose stated in the *CBE* EIR was “to allow more flexibility in refining future crude supplies.” But, as here, the “flexibility” Chevron achieved through its equipment upgrades allowed for more and different impacts than those put forth in the artificially limited project description. With no actual restrictions on the new infrastructure, the Court held the EIR to be inadequate, stating, “[f]ar from being an informative document, the EIR’s conclusions call for blind faith in vague subjective characterizations.” Such is the case with the project description at hand, which claims a maximum groundwater extraction of 28,500 ac-ft per year in dry and critically dry years only, while providing no binding requirements or even practical limitations that would so limit future groundwater extraction from these new wells, once constructed, to the proposed project amounts.

Nor may GCID simply rely on the DEIR’s proposed mitigation measures to truncate review of the project’s impacts. The Court in *Stanislaus Natural Heritage Project v. County of Stanislaus*, 48 Cal.App.4th 182 (1996), overturned an EIR where the lead agency failed to fully analyze future water supply impacts based on a mitigation measure designed to avoid such future impacts. The court rejected this as insufficient under CEQA, holding that the whole of the project must be evaluated, and only then may the efficacy of mitigation measures be considered. (205-206.)

In contrast, in *Kings County Farm Bureau v. City of Hanford*, 221 Cal. App. 3d 692, the Court of Appeal upheld an EIR that considered only a 20 year lifespan for a project, where the facility at issue obtained only a 20 year contract and permit to operate. Any future decision to extend the plant operation would require a new permit approval, and therefore, subsequent CEQA review. (739.) Here, in contrast, no future, binding, limitations, such as an expiring contract or regulatory permit, might limit GCID’s future uses of the newly constructed pumps to the stated project timing and amount.

In sum, the DEIR is premised on an improperly "curtailed" and "distorted" project description. (*County of Inyo* v. *City of Los Angeles* (1977) 71 Cal. App.3d 185, 192.) Since "[a]n accurate, stable and finite project description is the *sine qua non* of an informative and legally sufficient EIR" (*id.* at p. 193), even were the FEIR deemed to be adequate in all other respects, the selection and use of a "truncated project concept" violated CEQA and mandates the conclusion that the County did not proceed "in a manner required by law.'" (*Id.* at p. 200)

Any need for additional groundwater pumping can only be the result of either increased demand, decreased supplies, or a combination of the two. However, the DEIR fails to provide any quantitative information on these project drivers. Based on historic climatic variation, the DEIR simply projects forward that "it is anticipated that GCID could operate the proposed project approximately 16 times in a 40-year period." (DEIR 2-3.) But the DEIR fails to provide any substantial evidence to support this future baseline projection. Over the prior 40 year period used to project the scope of the project going forward, haven't demands increased while supplies have simultaneously diminished? Indeed, the DEIR itself cites to decreasing supplies as a project driver, effectively rendering the past 40 years of pumping rates totally inapplicable to the 40 future years of project operations that the DEIR analyzes. The DEIR fails to make any adjustments to its projections, which rely on historic data, to account for present and future changes in demand and supply. As just one example, demands within Glenn County alone have increased significantly from 2000-2013 as agriculture is expanded or converted to tree crops.[32] Meanwhile, supplies are decreasing statewide, regionally, and locally, as a result of increasing average temperatures, and decreasing precipitation. See, AquAlliance, Comments on Long Term Water Transfer EIS/EIR, December 1, 2014, pp. 41-44. The EIR must make some good faith attempt to evaluate these and similar factors when projecting the scope of operation of the proposed project.

II. The DEIR Does Not Establish that GCID has Any Legal Right to Pump this Additional Groundwater.

The DEIR fails to meaningfully address whether GCID has a legal right to increase groundwater pumping, whether in its existing wells, or within the newly proposed wells, for distribution of this pumped groundwater throughout the district. In contrast to GCID's appropriative surface water rights, which it may allocate to a non-overlying use, any overlying right to pump groundwater is limited to the beneficial use of said groundwater upon the property of the overlying landowner within the same basin or watershed. (*California Water Service Co. v. Edward Sidebotham & Son* (1964) 224 Cal. App.2d 715, 725; see also, *City of Barstow v. Mojave Water Agency* (2000) 23 Cal.4th 1224.) The DEIR does not demonstrate that GCID would, in fact, solely limit its use of extracted groundwater to lands it owns throughout the same basin or watershed. GCID was put on notice that construction of its five existing wells did not provide this right, and is reminded of that again here.

III. Hydrology

Groundwater Conditions

A complete and accurate description of the existing and affected environmental setting is critical for an adequate evaluation of impacts to it. *See e.g. San Joaquin Raptor/Wildlife Rescue Ctr. v. County of Stanislaus* (1994) 27 Cal.App.4th 713; *Galante Vineyards v. Monterey Peninsula Water Mgmt. Dist.* (1997) 60 Cal.App.4th 1109, 1122; *County of Amador v. El Dorado County Water Agency* (1999) 76 Cal.App.4th 931, 955; *Cadiz Land Co. v. Rail Cycle* (2000) 83 Cal.App.4th 74, 94.

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[32] AquAlliance 2015. Summary of Agriculture Reports 2000-2013. Based on actual reports found at: http://www.countyofglenn.net/govt/departments/ag/crop_reports.aspx

The 3.1.1 Environmental Setting section is deficient with its general description of the region's climate based on the work of Bertoldi in 1991. Even if the region experiences "typical years" in the future, it certainly has experienced shifting patterns since 2000. More current annual data and trends must be presented that reflects these changing conditions and specifically for Glenn County, where the wells are proposed for use and its surrounding counties.

The DEIR similarly provides limited groundwater elevation data of the Sacramento Valley groundwater basin in the subsection Groundwater Conditions. (pp. 3-7 to 3-10.) Table 3-2 provides groundwater level changes from the summer of 2004-2014. (DEIR p. 3-8.) DWR provides a number of additional groundwater level and depth to groundwater maps that the DEIR should use to help complete its description of the affected environment.[33]

AquAlliance's tables below illustrate maximum and average groundwater elevation decreases for Butte, Colusa, Glenn, and Tehama counties, all the counties believed to overly the Tuscan Aquifer, at three aquifer levels in the Sacramento Valley between the fall of 2004 and 2014.[34]

County Fall '04 - '14	**Deep Wells (Max decrease gwe)**	**Deep Wells (Avg. decrease gwe)**
Butte	-12.7 (-11.4)	-10.5 (-8.8)
Colusa	-59.5 (-31.2)	-59.5 (-20.4)
Glenn	-79.7 (-60.7)	-44.3 (-37.7)
Tehama	-34.6 (-19.5)	-10.9 (-6.6)

County Fall '04 - '14	**Intermediate Wells (Max decrease gwe)**	**Intermediate Wells (Avg. decrease gwe)**
Butte	-21.8	-6.5
Colusa	-39.1	-16.0
Glenn	-40.2	-14.5
Tehama	-20.1	-7.9

County Fall '04 - '14	**Shallow Wells (Max decrease gwe)**	**Shallow Wells (Avg. decrease gwe)**
Butte	-13.3	-3.2
Colusa	-20.9	-3.8
Glenn	-44.4	-8.1
Tehama	-15.7	-6.6

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[33] http://www.water.ca.gov/groundwater/data_and_monitoring/northern_region/GroundwaterLevel/gw_level_monitoring.cfm#Well%20Depth%20Summary%20Maps

[34] Id.

Below are the results from DWR's spring monitoring for Sacramento Valley groundwater basin from 2004 to 2014.

County Spring '04 - '14	Deep Wells (Max decrease gwe)	Deep Wells (Avg. decrease gwe)
Butte	-20.8	-14.6
Colusa	-26.9	-12.6
Glenn	-49.4	-29.2
Tehama	-6.1	-5.3

County Spring '04 - '14	Intermediate Wells (Max decrease gwe)	Intermediate Wells (Avg. decrease gwe)
Butte	-25.6	-12.8
Colusa	-49.9	-15.4
Glenn	-54.5	-21.7
Tehama	-16.2	-7.9

County Spring '04 - '14	Shallow Wells (Max decrease gwe)	Shallow Wells (Avg. decrease gwe)
Butte	-23.8	-7.6
Colusa	-25.3	-12.9
Glenn	-46.5	-12.6
Tehama	-38.6	-10.8

The additional DWR data in multiple counties that depend on the Tuscan Aquifer clearly present a more comprehensive picture of the conditions of the Sacramento Valley groundwater basin over time than what is provided in the DEIR. It also highlights significant data that is intentionally omitted from the DEIR. For Glenn County alone (all that is provided in the DEIR), the fall measurements indicate much more dramatic declines from summer measurements in the deep wells and all the spring levels punctuate the serious lack of groundwater recovery. Obfuscating basic and foundational material regarding existing conditions leaves the public and policy makers with a lack of confidence in the 10-Wells Project, the DEIR, and the lead agency, GCID. Therefore, the DEIR will need to be revised, once these data are obtained, and recirculated as a Draft EIR in order to ensure the public and relevant decision makers receive full disclosure of the existing conditions and trends that are used for analysis and the development of conclusions for the 10-Wells Project.

Groundwater Properties

The DEIR fails to discuss the pressurized condition of the down-gradient portion of the Tuscan formation, which underlies the Project area. Dudley finds significant importance in the pressurized state of the lower Tuscan aquifer located in the Butte Basin. "It is interesting to note that groundwater elevations up gradient of the Butte Basin, in the lower Tuscan aquifer system, are higher than the ground surface elevations in the south-central portion of Butte Basin. This creates an artesian flow condition when wells in the central Butte Basin are drilled into the lower Tuscan aquifer."[35] The artesian pressure indicates recharge is occurring in the up-gradient portions of the aquifer located along the eastern margin of the Sacramento Valley several miles east of the project.

The DEIR fails to provide recharge data for the aquifers although GCID was provided this information seven years ago. Professor Karin Hoover, Assistant Professor of hydrology, hydrogeology, and surficial processes from CSU Chico, found in 2008 that, "Although regional measured groundwater levels are purported to 'recover' during the winter months (Technical Memorandum 3), data from Spangler (2002) indicate that recovery levels are somewhat less than levels of drawdown, suggesting that, in general, water levels are declining."[36] According to Dudley, "Test results indicate that the 'age' of the groundwater samples ranges from less than 100 years to tens of thousands of years. In general, the more shallow wells in the Lower Tuscan Formation along the eastern margin of the valley have the 'youngest' water and the deeper wells in the western and southern portions of the valley have the 'oldest' water," adding that "the youngest groundwater in the Lower Tuscan Formation is probably nearest to recharge areas."[37] "This implies that there is currently no active recharge to the Lower Tuscan aquifer system (M.D. Sullivan, personal communication, 2004)," explains Dr. Hoover. "If this is the case, then water in the Lower Tuscan system may constitute fossil water with no known modern recharge mechanism, and, once it is extracted, it is gone as a resource."[38] The DEIR must account for this feature in its description of existing conditions, and its projections of recharge rates.

Groundwater Depletion

The DEIR illegally defers formulation and evaluation of mitigation measure WR-1. (*See, e.g.*, *POET, LLC v. State Air Resources Board* (2013) 218 Cal.App.4th 681; *Preserve Wild Santee v. City of Santee* (2012) 210 Cal.App.4th 260; *Sacramento Old City Association v. City Council* (1991) 229 Cal.App.3d 1011; CEQA Guidelines § 15126.4(a)(1)(B); *Defend the Bay v. City of Irvine* (2004) 119 Cal.App.4th 1261, 1275.) In relying on WR-1, the DEIR goes so far as to defer the environmental impact analysis that should be provided now, as part of the DEIR itself. Moreover, WR-1 fails to include clear performance standards, criteria, thresholds of significance, evaluation of feasibility, analysis of likelihood of success, and even facially permits significant impacts to occur. And importantly, WR-1 does not, in fact, reduce potentially significant impacts to less-than-significant levels, but rather, attempts to monitor for when significant effects occur.

WR-1 requires GCID "implement a groundwater monitoring program," but a monitoring program itself cannot prevent significant impacts from occurring. "The monitoring program will rely on DWR's CASGEM program and the District's monitoring network. The monitoring program will include semiannual measurements of groundwater levels at a network of wells throughout the Sacramento Valley. Many of the established observation wells (including multi-completion well clusters) are instrumented with data-logging pressure transducers to provide continuous

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[35] Dudley, Toccoy 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update*.

[36] Hoover, Karin A. 2008. *Concerns Regarding the Plan for Aquifer Performance Testing of Geologic Formations Underlying Glenn-Colusa Irrigation District, Orland Artois Water District, and Orland Unit Water Users Association Service Areas, Glenn County, California*. White Paper. California State University, Chico.

[37] Dudley, Toccoy 2005. Id.

[38] Hoover, Karin A. 2008. Id.

groundwater level data." (EIR 3-40.) Although monitoring does not disclose or analyze impacts for CEQA purposes, the DEIR still fails to provide any of the most foundational information about its proposed "groundwater monitoring program," such as how many wells will be monitored, what is a sufficient number of wells, how many will be monitored semiannually, how many will be monitored continuously, where are the monitoring wells located, what strata are the wells monitoring, who will manage and report on the data, and how will the public have access to the data and reports?

To elaborate on the timing of monitoring, it is absolutely crucial. Common sense suggests that significant groundwater pumping could occur in less than six months – one of the periods planned for monitoring. And monitoring after transfer-related pumping can only show whether significant impacts have occurred; it cannot prevent them. Yet this is exactly what the EIR proposes: "A subset of the well network will be selected for groundwater level monitoring prior to (monthly), during (weekly), and after (weekly for 1 month and monthly thereafter) groundwater pumping for the proposed project. The monitoring network will incorporate a sufficient number of monitoring wells and adequate spatial distribution to evaluate groundwater levels prior to, during, and after project operations." (EIR 3-40.) Hence, WR-1 only requires elements of the mitigation plan to kick in after monitoring shows significant impacts are occurring, which are extremely likely to occur given the fact that monitoring alone amounts to no mitigation or avoidance measures. Additionally, the DEIR fails to provide any guidance on what constitutes "a sufficient number of monitoring wells." (Id.)

Compounding WR-1's inadequacy as a mitigation measure, the DEIR asserts that, "As part of the monitoring program, GCID will use data from DWR's existing monitoring programs to establish longer-term antecedent trends in groundwater levels within the basin." (p. 3-40). But this is exactly the kind of information that must be provided to the public in the DEIR. When would GCID finally establish these trends, how would they be disclosed to the public, and what would they possibly alter with the Project?

Even still, the proposed mitigation measure WR-1 doesn't mitigate significant impacts. The mitigation proposal includes the following requirements: 1) "Reduce or relocate pumping until natural recharge corrects the issue." This, of course, could take years[39] and really amounts to no mitigation of the significant impact at all. (See also, AquAlliance, comments on the Long Term Water Transfer EIS/EIR, pp. 19-22, 36, 47, 59-61, 66.) 2) How GCID would feasibly and legally "relocate" pumping is not explained. 3) "Reimburse third parties for significant increases in pumping costs due to an increase in lift." In what amount, at what time, as decided by whom? Monetary compensation is not always sufficient to cover damages to business operations. (*See* CEQA Guidelines § 15370; *Gray v. County of Madera* (2008) 167 Cal.App.4th 1099, 1122.) 4) "Lower the pump in third-party wells affected by the proposed project," may help an injured third-

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[39] Custis, Kit 2015. "Although the DEIR doesn't provide an estimate of the stream depletion rate as a percentage of the stream flow, it appears from the maximum values listed in Table 3-6 that the depletion rates for the listed streams and rivers are less than 48% of the average stream flow. This would suggest that the time it takes until the aquifers pumped by the GCID well are 95% recharged by stream depletion may take decades. In fact, a report on the impacts from the 2009 groundwater substitution transfers simulating from 1976 to 2003 using the SACFEM groundwater model showed aquifer recovery following a single 1976 pumping event was only 60% after 30 years (Figure 4d in CH2MHill, 2010). This suggests that the impacts from a single year of GCID's groundwater extraction project and the impacts from reoccurring pumping events will continue for many years."

party, but like monetary damages may not sufficiently cover damages or be done in a timely manner with well companies months behind due to the existing dry conditions. Finally, "[o]ther actions as appropriate" is so vague as to be meaningless. (EIR 3-40.)

Mitigation measure WR-2 is similarly flawed with its reliance on monitoring and deferred analysis of impacts of the present project. WR-2 also assumes that subsidence impacts will take place quickly allowing GCID to determine exclusive culpability or deflect it to "regional conditions." (DEIR p. 3-41/42.) This simplistic view is not founded in science – more likely wishful thinking. The DEIR instead should disclose how long-term physical responses result from repeated lowering of groundwater. The following evidence demonstrates that the Project's subsidence impacts may be significant and it was first provided to GCID in 2008.[40]

Dr. Kyran Mish, former Presidential Professor, School of Civil Engineering and Environmental Science at the University of Oklahoma related: "It is important to understand that *all* pumping operations have the potential to produce such settlement, and when it occurs with a settlement magnitude sufficient enough for us to notice at the surface, we call it *subsidence*, and we recognize that it is a serious problem (since such settlements can wreak havoc on roads, rivers, canals, pipelines, and other critical infrastructure)."[41] Dr. Mish further explains that "[b]ecause the clay soils that tend to contribute the most to ground settlement are highly impermeable, their subsidence behavior can continue well into the future, as the rate at which they settle is governed by their low permeability." (Id.) "Thus simple real-time monitoring of ground settlement can be viewed as an *unconservative* measure of the potential for subsidence, as it will generally tend to underestimate the long-term settlement of the ground surface." (Id.) (emphasis added).

However, the DEIR asserts that, "If groundwater levels do not recover above historical lows within 6 months following cessation of project operation and project operations will not resume the next year, GCID will assume groundwater level drawdown is due to regional conditions and land subsidence monitoring may be stopped." (pp. 3-41 and 3-42.) This conclusory assertion falsely assumes that 1) Any water level above the *historic lows* avoids or offsets damage from non-reversible subsidence. 2) If groundwater recovers above historic lows, subsidence isn't occurring and therefore can't be attributed to the 10-Wells Project and 3) If groundwater levels don't recover above historical lows, when there is a planned one-year lapse in GCID's pumping, there are no impacts from GCID's pumping. However, the DEIR contains conclusions reached by the U.S. Geological Survey ("USGS") that affirm the long-term and gradual nature of subsidence that accrues from continuous groundwater depletion,: "These small changes accumulate over time and can lead to impacts such as changes in stream, canal, or levee elevations and slopes; damage to infrastructure such as roads, bridges, and utilities; damage to building foundations; and collapse of well casings (USGS, 2015b)." (p. 3-13.)

USGS also confirms that, "In many aquifers, ground water is pumped from pore spaces between grains of sand and gravel. If an aquifer has beds of clay or silt within or next to it (figure 2), the lowered water pressure in the sand and gravel causes slow drainage of water from the clay and silt beds. The reduced water pressure is a loss of support for the clay and silt beds. Because these beds

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[40] Mish, Kyran 2008. *Commentary on Ken Loy GCID Memorandum*. White Paper. University of Oklahoma.
[41] Id.

are compressible, they compact (become thinner), and the effects are seen as a lowering of the land surface. The lowering of land surface elevation from this process is permanent. For example, *if lowered ground-water levels caused land subsidence, recharging the aquifer until ground water returned to the original levels would not result in an appreciable recovery of the land-surface elevation*."[42] (emphasis added) It is quite clear that WR-2 is a completely inadequate mitigation measure for subsidence impacts.

The DEIR's evaluation of subsidence suffers from the same flaws as that of the Long Term Water Transfer Final EIS/EIR, and AquAlliance's April 8, 2015 comments on these deficiencies (pp. 2-5) are incorporated here.

Groundwater Quality

The DEIR fails to disclose the existence or extent of all the hazardous waste plumes in the Tuscan groundwater basin where GCID's wells are and will be located or in the Tehama formation that intermingles with the Tuscan in Glenn County. (*See e.g. San Joaquin Raptor/Wildlife Rescue Ctr. v. County of Stanislaus* (1994) 27 Cal.App.4th 713.) For example, the Orland dry cleaners plume is certainly within the incremental drawdown forecast in Figure 3-6. There is also no discussion of whether the increased groundwater extraction proposed by the Project may mobilize some of the PCE and TCE plumes under Chico since the pressurized condition of the down-gradient portion of the Tuscan formation, which underlies the 10-Wells Project area, benefits from recharge waters in the foothills and mountains to the east and north of Chico.[43] Toccoy Dudley et al support this finding of a pressurized lower Tuscan aquifer across the Sacramento River from GCID. "It is interesting to note that groundwater elevations up gradient of the Butte Basin, in the lower Tuscan aquifer system, are higher than the ground surface elevations in the south-central portion of Butte Basin. This creates an artesian flow condition when wells in the central Butte Basin are drilled into the lower Tuscan aquifer." [44] The artesian pressure indicates recharge is occurring in the up-gradient portions of the aquifer located along the eastern margin of the Sacramento Valley many miles into Butte County. This indicates that flow moves through the Chico plume areas toward the down-gradient portion of the Tuscan Aquifer where the existing GCID wells are located and new wells are proposed.

In addition, the DEIR fails to describe a significant saline portion of the aquifer stratigraphy of the project area. According to Toccoy Dudley, former Groundwater Geologist with the Department of Water Resources and former director of the Butte County Water and Resources Department, saline groundwater aquifer systems of marine origin underlie the various freshwater strata. The approximate contact between fresh and saline groundwater occurs at a depth ranging from 1,500 to 3,000 feet.[45]

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[42] U.S. Geological Survey (USGS). 2015a. "Land Subsidence from Ground-Water Pumping." Available at http://geochange.er.usgs.gov/sw/changes/anthropogenic/subside/. Retrieved July 24, 2015.

[43] DWR, 2009. Glenn-Colusa Irrigation District Test-Production Well Installation and Aquifer Testing, pp. 25-26.

[44] Dudley, Toccoy 2005. *Seeking an Understanding of the Groundwater Aquifer Systems in the Northern Sacramento Valley: An Update*.

[45] Id.

More recent research has documented threats of contamination. "The BFW [base of fresh water] boundary occurs primarily in late Tertiary to Quaternary unconsolidated sediments at depths near land surface to more than 3,500 feet below ground surface. The BFW is an uneven boundary that in some places reflects the major geologic structures underlying the Sacramento Valley, and in other areas, transgresses underlying geologic structures. In some areas, the BFW boundary is well above the base of post-Eocene marine strata. This is most likely caused by high artesian pressures and upward vertical gradients in deep aquifers in the Sacramento Valley, which have been documented in DWR monitoring wells. This suggests that migration of poor quality water into continental sediments that previously contained freshwater has occurred over geologic time. This finding has implications for brackish and saline water upconing beneath areas of prolonged groundwater pumping in the Sacramento Valley."[46]

Certainly the public has no idea of or ability to comment on the important water quality conditions not presented in the DEIR, which fails the full-disclosure mandate in CEQA. The 10-Wells Project must either be withdrawn or full disclosure must be presented in a recirculated DEIR. (See, e.g., *Laurel Heights Improvement Ass'n v Regents of Univ. of Cal.* (1993) 6 Cal.4th 1112; 14 Cal Code Regs., § 15088.5(a); 40 C.F.R. § 1502.9(c); *California v. Block* (9th Cir. 1982) 690 F.2d 753, 770.)

IV. Species Impacts

Aquatic Species

It is useful that the DEIR acknowledges the demise of four anadromous fish runs in Stony Creek (spring, fall, late-fall, and winter salmon). (pp. 3-43 - 3-44). The acknowledgement serves to illustrate the existing strains on the hydrologic system, both surface and ground, once supported these runs of salmon. We select one tributary mentioned as an example to elucidate many points. Stony Creek is simulated with the 10-Wells Project to have an average depletion of 1.8 cfs and a maximum of 11.6 cfs. The text that follows these figures in the 3.1 Water Resources section, states, "As shown in Table 3-6, the majority of the maximum streamflow depletions occur during or shortly following the drought of water years 1987–1992. During critically dry year types, it is expected that many of the surface streams within the drawdown area would naturally have minimal or no flow (for example, Stony Creek, Little Chico Creek, and Walker Creek). Furthermore, these streams do not substantially contribute supply to the CVP, SWP, or non-project water users." (p. 3-39).

The text is troubling for many reasons.

1) The conclusion that "many of the surface streams within the drawdown area would naturally have minimal or no flow," during critically dry years and therefore the impacts would be "less than significant" avoids serious consideration of the importance of underflow. "The DEIR's evaluation of impacts from stream depletion is also inadequate because it assumes that once a streambed becomes dry continued pumping of groundwater has no effect on surface flow. This

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[46] Springhorn, Steven T., el al, May 2013. *Base of Fresh Groundwater in the Sacramento Valley, California*, Geological Society of America Abstracts with Programs. Vol. 45, No. 6, p.51. https://gsa.confex.com/gsa/2013CD/webprogram/Paper219191.html

assumption ignores the role that stream underflow plays on maintaining pools and riparian habitats. The assumption also ignores the fact that the depth to saturated ground water beneath a streambed will impact the volume and duration of flow needed to re-wet the channel at the beginning of the next rainy season. The deeper the depth of ground water, the more aquifer voids there are that need to be re-filled in order for the stream to sustain constant flow. In other words, a greater volume of water for a longer period of time is needed at the beginning of the rainy season to sustain surface flows."[47] (p. 11.)

2) "Furthermore, these streams do not substantially contribute supply to the CVP, SWP, or non-project water users." On what basis is this conclusion made? The DEIR does not say. How much water in the streams is backfilling over used groundwater? How does contributing, substantially or otherwise, "to the CVP, SWP, or non-project water users" constitute the only value from a stream?

3) If the simulations are correct and the "majority of the maximum streamflow depletions occur during or shortly following the drought of water years 1987–1992," how is that not a significant impact when streams may already have minimal or no flows even according to the DEIR? Dewatering streams, be they ephemeral or annual, no matter how low the flow can be essential for fish species. For example, according to research conducted by Dr. Paul Maslin, Mud Creek provides advantageous rearing habitat for out-migrating Chinook salmon (1996). Salmon fry feeding in Mud Creek grew at over twice the rate by length as did fry feeding in the main stem of the Sacramento River. *Id. The Recovery Plan For The Evolutionarily Significant Units Of Sacramento River Winter-Run Chinook Salmon And Central Valley Spring-Run Chinook Salmon And The Distinct Population Segment Of California Central Valley Steelhead* confirms this importance of small areas of refugia for out-migrating salmon in tributaries to the Sacramento River: "Non-natal rearing tributaries to the Sacramento River include freshwater rearing habitat. Some non-natal rearing areas potentially have a high value because they provide critical and improved growing conditions, particularly during high winter flow events on the Sacramento River."[48]

4) The 10-Wells Project will further deplete the hydrology in Glenn County and may also affect the hydrology in surrounding counties, streams, and the Sacramento River. Dewatering of salmon bearing streams that interface with the targeted Lower Tuscan Formation Aquifer would result in physical changes to these streams that may result in significant adverse impacts to biological resources. This effect has been observed in the Cosumnes River, where "[d]eclining fall flows are limiting the ability of the Cosumnes River to support large fall runs of Chinook salmon." This is a river that historically supported a large fall run of Chinook Salmon.[49] Indeed, "[a]n early study by the California Department of Fish and Game . . . estimated that the river could support up to 17,000 returning salmon under suitable flow conditions." (Id.), citing CDFG 1957 & USFWS 1995. But "[o]ver the past 40 years fall runs ranged from 0 to 5,000 fish according to fish counts by the CDFG (USFWS 1995)," and "[i]n recent years, estimated fall runs have consistently been below 600 fish, according to Keith Whitener." (Fleckenstein, et al. 2004). Indeed, "[f]all flows in

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[47] Custis, Kit, 2015. *Comments and Recommendations on Draft Environmental Impact Report for Glenn Colusa Irrigation District's Groundwater Supplemental Supply Project, June 2015* for AquAlliance.
[48] National Marine Fishery Service, 2014.
[49] Fleckenstein, Jan; Anderson, Michael; Fogg, Graham; and Mount, Jeffrey 2004. *Managing Surface Water-Groundwater to Restore Fall Flows in the Cosumnes River*, Journal of Water Resources Planning and management.

the Cosumnes have been so low in recent years that the entire lower river has frequently been completely dry throughout most of the salmon migration period (October to December).” (Id.)

Research indicates that “groundwater overdraft in the basin has converted the [Cosumnes River] to a predominantly losing stream, practically eliminating base flows….” (Id.) And “investigations of stream-aquifer interactions along the lower Cosumnes River suggest that loss of base flow support as a result of groundwater overdraft is at least partly responsible for the decline in fall flows.” (Id.) Increased groundwater withdrawals in the Sacramento basin since the 1950s have substantially lowered groundwater levels throughout the county.” (Id.) The DEIR fails to consider such broader ecological and hydrological impacts stemming from increased groundwater extraction during already dry and critical years.

5) Lower Stony Creek is designated as critical habitat for spring-run salmon and Central Valley steelhead (p. 3-44), yet the DEIR concludes that because Stony Creek is already impaired, “[p]otential drawdown effects on surface waters of lower Stony Creek are anticipated to have less-than-significant impacts on anadromous salmonids.” (p. 3-53) The DEIR’s empty conclusion, without any supporting data or analysis, is taken by GCID as a release from even offering a mitigation measure for struggling Stony Creek that is suffering death by a thousand cuts. However, the federal register for critical habitat provides a different view of the needs and potential of Stony Creek.

> “The CHART [Critical Habitat Analytical Review Teams] has evaluated the available information, particularly with regard to Stony Creek (HSA 550410), and concluded that this stream is occupied by both spring run Chinook and steelhead. Juvenile spring run Chinook have been consistently documented using Stony Creek as rearing habitat since 2001 (Corwin and Grant, 2004), as well as in previous years (Maslin and McKinney, 1994). Similarly, juvenile steelhead have been periodically documented rearing in Stony Creek (Corwin and Grant, 2004; Maslin and McKinney, 1994). The CHART also concluded that Stony Creek has PCEs that support both species. Water temperature monitoring from 2001 through 2004 has shown that temperatures in Stony Creek under current operations are generally suitable for adult and juvenile salmonids (below 65 °F) from mid-October through late May. Water temperatures have been found to be suitable for salmonid spawning and incubation (below 56 °F) from mid-November through early May (Corwin and Grant, 2004). Though successful steelhead spawning has not been documented recently in Stony Creek, habitat conditions under current operations are considered marginally suitable to support steelhead reproduction. Because of ongoing restoration actions and ESA section 7 consultations, progress is being made toward improving these habitat conditions, and we expect conditions to continue to improve into the future.”[50]

We must be clear: any additional impairment by the 10-Wells Project is adverse modification of critical habitat, yet that is not addressed in the DEIR. Added to this significant lapse is the failure

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[50] National Marine Fisheries Service, 2005. *Federal Register /Vol. 70, No. 170 / Friday, September 2, 2005 /Rules and Regulations, Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California*.

of the DEIR to disclose many relevant recovery recommendations[51] for Stony Creek that the 10-Wells Project clearly undermines. Examples include, but are not limited to:

- Improve water temperature conditions in Stony Creek by identifying and implementing projects that would increase stream flows and increase shaded riverine habitat.
- Implement projects to increase floodplain habitat availability in Stony Creek to improve juvenile rearing habitat.
- Monitor and evaluate sportfishing impacts in Stony Creek to ensure that the fishery allows for the recovery of steelhead; modify regulations as necessary. (Id.)

The DEIR assumes an average depletion of 0.5 cfs in Little Chico Creek and a maximum of 3 cfs. (p. 3-53) The DEIR assumes an average depletion of 0.3 cfs in Big Chico Creek and a maximum of 11.6 cfs. (Id.)

Big Chico and Little Chico Creeks are also listed as critical habitat for Central Valley steelhead (Oncorhynchus mykiss) and Central Valley Spring Run Chinook Salmon (Oncorhynchus tshawytscha), although the DEIR fails to point out the salmon critical habitat designation for Little Chico Creek. (pp. 3-48 to 3-49). Again, any additional impairment by the 10-Wells Project is adverse modification of critical habitat, yet that is not addressed in the DEIR. Recovery actions for Big Chico Creek that are undermined by additional strains on streamflow include, but are not limited to:

- Implement projects to increase Big Chico Creek floodplain habitat availability to improve habitat conditions for juvenile rearing
- Increase monitoring and enforcement in Big Chico Creek to ensure that the water quality criteria established in the Central Valley Water Quality Control Plan (Basin Plan) are met for all potential pollutants (SWRCB 2007).

Giant Garter Snake

Section 2-4 presents permits and approvals that are required for the 10-Wells Project. Noticeably absent are requirements for a permit from the California Department of Fish and Wildlife and from the U.S. Fish and Wildlife Service for impacts to the giant garter snake ("GGS"). However, the DEIR acknowledges the potential for construction impacts: "Additionally, the proposed well sites are located within 200 feet of rice fields and canals, both of which provide suitable habitat for giant garter snake (GGS). Though the construction sites do not directly provide suitable habitat for GGS, nor do the sites contain suitable winter hibernacula for the species, it is possible that, due to their close proximity to suitable habitat at all well locations, GGS could be present within the project construction areas during construction. Though the likelihood of impacts on GGS are low, any impact on GGS would be significant. Implementation of avoidance measures listed in MM BIO-4 would eliminate impacts to GGS." (DEIR p. 3-52)

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[51] National Marine Fisheries Service, 2014. *Recovery Plan For The Evolutionarily Significant Units Of Sacramento River Winter-Run Chinook Salmon And Central Valley Spring-Run Chinook Salmon And The Distinct Population Segment Of California Central Valley Steelhead.*

It may be a good first step to prepare for "avoidance measures," but that does not eliminate the requirements under the California and federal Endangered Species Acts. The presence of wetlands in the Project area will require a permit from the U.S. Army Corps of Engineers (DEIR p. 3-50) that will lead to consultation with the U.S. Fish and Wildlife Service. GCID must also apply to the California Department of Fish and Wildlife for an incidental take permit.

Substantively regarding GGS, there is developing research that GGS may spend a great deal of time underground during the active season. "As for the probability of being in a terrestrial environment, much individual variation existed in the probability of being underground (logit-normal SD for individual-specific random intercept = 1.85 [1.63–2.12]). Predicting whether a given individual will be on the surface or underground is therefore fraught with uncertainty, despite high posterior precision of estimates of the behavior of an average Giant Gartersnake (Figs. 4 and 5)."[52]

This significant research must be considered if the 10-Wells Project moves forward. The DEIR also fails to acknowledge that there may be operational impacts to GGS. This must be developed and, if the Project goes forward, recirculated in a revised DEIR.

Additional Comments

The reader is referred to Figures 3.3 and 3.6 to view the potential drawdown effects on Stony Creek (DEIR p. 3-53) with Tehama-Colusa Canal mentioned as a reference point, however, it is not on either Figure.

As mentioned previously, the two-year and six-year scenarios leave out serious periods of drought or dry conditions, such as 2007-2010 and 2012-2015, a four-year drought that has been declared an emergency by Governor Brown multiple times. This is a serious omission undermining the description of baseline environmental conditions, analysis of supplies and demands associated with foreseeable project production, and exacerbated impacts of the project itself, that must be corrected in a recirculated DEIR.

Tables 3.1 and 3.6 are incapable of presenting data with which to simulate streamflow depletion because, as stated in the DEIR, there are "limitations of the available gaging data." (pp. 3-6 and 3-39). In an effort to locate existing data, AquAlliance checked the Big Chico Creek Near Chico (BIC) gage on July 24, 2015 and there is insufficient flow to even register a reading at this time.[53] In addition, the USGS no longer maintains a gage on Big Chico Creek.[54] Regarding Little Chico Creek estimated flows, Table 3-1 indicates that the period of record for DWR gage A04270 Taffee Road near Chico, CA was 1991-2002 and that gage A04280 Near Chico, CA was from 1975-1996 and that, "Data for this gage were downloaded in 2011; the data are no longer available from

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[52] Halstead, Brian J., Shannon M. Skalos, Glenn D. Wylie, and Michael L. Casazza. 2015. Terrestrial ecology of semi-aquatic giant gartersnakes (Thamnophis gigas). Herpetological Conservation and Biology. In Press, PP. 10-11.

[53] California Department of Water Resources , California Data Exchange Center. http://cdec.water.ca.gov/cgi-progs/queryF?BIC&d=24-Jul-2015+13:37. "BRT" signifies discharge at stage below available rating table.

[54] https://water.usgs.gov/nsip/

original data source: DWR, 2015a," (footnote "e" p. 3-6). Stony Creek's flows are also based on distant years and 1955 -1990 and 1941-1973 (p. 3-6). It is impossible for the public to have any confidence in modeling results that are using such antiquated input data. The DEIR relies on only modeling to consider impacts from the Project when it must compile and present results from actual monitoring and reporting prior to recirculating a revised DEIR.

Shallow Groundwater Monitoring Framework

A comprehensive monitoring program was proposed in the mid-2000s and is still absolutely necessary. The Sacramento Valley Integrated Water Management Plan lead to a draft Framework for Sacramento Valley regional water resource monitoring that would also benefit shallow domestic-well owners. Starting on page five, it reads: "Habitat Monitoring; The long-term health of riparian vegetation, wetland species, and a number of other native habitat are commonly associated with maintaining a minimum range of groundwater levels and an appropriate level of interaction between surface water and groundwater resources. The lowering of groundwater levels due to the interception of groundwater underflow to surface water systems due to the increased groundwater extraction associated with conjunctive water management programs, have the potential to impact the native habitat areas," and that, "In order to identify potential habitat impacts associated with implementation of conjunctive water management alternatives, a program-specific network of shallow monitor monitoring wells should be developed to detect changes in water levels over the shallowest portion of the aquifer. The groundwater monitoring network should contain shallow monitoring wells that will record changes to the water table elevation in the vicinity of these sensitive habitat areas."[55] The Framework has many other valuable suggestions that were protective of the region's residents and environment. Unfortunately, the Framework was shelved, and the shallow monitoring network never got off the ground.

This Framework could have been operation for over seven years and it should definitely be in place prior to the 10-Wells Project and continue in perpetuity. It should also be presented in a recirculated Draft EIR as a viable mitigation measure, or project alternative

V. Climate Change

Once SB 97 was approved in California in 2007, analysis of greenhouse gas emissions became a part of the CEQA process[56] and that is reflected in the DEIR from an air quality and air pollution perspective. Unfortunately, the DEIR fails to discuss Climate Change, the result of greenhouse gas emissions and its impacts on the hydrology of the region or the Sacramento River watershed upon which GCID's river and stream water claims depend. This obvious omission is at the heart of the 10-Wells Project that claims the need for more water in a district with an exorbitant claim to water - 825,000 af per year.

The gross omission of any climate change analysis in the DEIR fails to accurately describe the existing climatological conditions into which the project may be approved, fails to accurately describe the diminution of water and natural resources over recent and future years as a result of

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[55] McManus, Dan et al, 2007. *Sacramento Valley Water Resource Monitoring, Data Collection and Evaluation Framework*

[56] http://opr.ca.gov/docs/SB_97_bill_20070824_chaptered.pdf

climate change, fails to integrate these changing circumstances into any future baseline or cumulative conditions, and fails to completely analyze or support the DEIR conclusions regarding the project's potentially significant impacts. See, AquAlliance, comments on LTWT EIS/EIR, pp. 30, 40-45.

Both climate change and the 10-Wells Project have the potential to degrade the hydrology of the counties within GCID's district, surrounding counties, and flows in the Sacramento River.
This must be remedied in a recirculated DEIR

VI. The EIR fails to analyze a reasonable range of alternatives.

As discussed in Sections I and II above, the DEIR fails to explain what is driving the suggested demand for more water, which leads to a failure to produce viable alternatives. The 10-Wells Project is being sold as an essential need for GCID without providing the context of the Sacramento Valley Water Management Agreement, climate change, demand from outside the Sacramento Valley, and GCID's regular participation in the water market. Additionally, there is no discussion of the Water Fix's premise (formerly the Bay Delta Conservation Plan) that Delta exports through the Twin Tunnels will not only increase in the wetter years, but they will also rise in drier years from water transfers.

The "no project alternative" itself does not constitutes a reasonable range of alternatives.

CEQA requires public agencies to identify in an EIR feasible alternatives that could avoid or substantially lessen a project's significant environmental effects. (Pub. Res. Code §§ 21002, 21002.1(a), 21100(b)(4), 21150.) CEQA's procedures require that an EIR must present a "reasonable range" of alternatives to the project that "foster meaningful public participation and informed decisionmaking." (Guidelines, § 15126.6(f), Guidelines, § 15126.6(a) citing *Citizens of Goleta Valley v. Board of Supervisors* (1990) 52 Cal.3d 553 (*Goleta Valley II*), and *Laurel Heights I, supra,* 47 Cal.3d 376.)

However, this does not mean that the "rule of reason" allows the lead agency to concoct an arbitrary assemblage of "alternatives" selected to make the agency's preferred project a foregone conclusion. The "rule of reason" requires that the action alternatives selected for substantive discussion in an EIR must satisfy specific, objective criteria that would allow the decision makers a reasoned choice. For example, each alternative must be capable of "feasibly attain[ing] most of the basic objectives of the Project." (Guidelines, § 15126.6(a), (f).) The Guidelines provide that,

> The range of potential alternatives to the proposed project shall include those that could feasibly accomplish most of the basic objectives of the project and could avoid or substantially lessen one or more of the significant effects. The EIR should briefly describe the rationale for selecting the alternatives to be discussed. The EIR should also identify any alternatives that were considered by the lead agency but were rejected as infeasible during the scoping process and briefly explain the reasons underlying the lead agency's determination.

(Guidelines, § 15126.6(c) [emphasis added.) Hence, alternatives rejected as infeasible are not considered to be among the reasonable range of alternatives required to be considered. Nor can it be said that the no project alternative can be among the reasonable range of alternatives considered, as it is required to be evaluated regardless of whether it feasibly meets most of the project objectives, which it normally won't. Accordingly, an EIR that limits its substantive discussion to alternatives that the agency has already has determined are not feasible or will not attain the basic objectives of the project, fails to present a "reasonable range" of alternatives that fosters meaningful public participation or informed decisionmaking. (*Id.*)

Here, the DEIR has failed to satisfy CEQA's legal requirement to analyze a reasonable range of alternatives that would reduce or avoid the Project's significant impacts. Rather than evaluate the environmental benefits of any alternatives at all, the DEIR instead rejects out of hand a proper evaluation of any alternative mentioned in the EIR, discussing the environmental impacts of only the no project alternative and the proposed project alternative.

In addition, the DEIR eliminates from discussion alternatives that would not yield 28,500 ac-ft of water per year, but nothing in the project objectives indicates whether or why 28,500 ac-ft per year is a necessary project component. (DEIR 5-3.) Alternatives should only be eliminated if infeasible or do not meet most project objectives.

The DEIR fails to meaningfully evaluate the no project alternative.

The DEIR's discussion of the no project alternative is internally contradictory. On one hand, the DEIR states that, under the no project alternative, "[t]he five existing wells would be used as needed under GCID's discretion," such that "[a]s water shortages occur, GCID anticipates that groundwater pumping would increase both within the District's service area and in adjacent areas to meet future water demands." (DEIR 5-1.) On the other, the DEIR states that "[u]nder the No Project Alternative, GCID would not use its existing wells as part of a coordinated pumping program . . . to supplement water supplies to offset critical water year reductions." (DEIR 5-2.) In conjunction, this description renders the no project evaluation impossible to discern.

More troubling, the DEIR states that, under the no project alternative, the same project would still be built: "Under the No Project Alternative it is assumed that GCID would construct new wells on an as-needed basis for specific District use and that the existing wells included as part of the proposed project would be fully used as needed during years of shortages, once appropriate environmental analysis has been conducted." (DEIR 5-1.) Again, the DEIR's assessment that, under the no project alternative, the district's existing and proposed wells both would, and would not, be used, fails to support CEQA's fundamental purpose of informed environmental decision-making. The DEIR must evaluate the environmental consequences "as what would be reasonably expected to occur in the foreseeable future if the project were not approved." (Guidelines, § 15126.6(e)(2).) While the Guidelines do provide that, "If disapproval of the project under consideration would result in predictable actions by others, such as the proposal of some other project, this "no project" consequence should be discussed," here, the DEIR does not suggest that substantially the same project would be proposed "by others," as the Guidelines allow for, but rather, the DEIR simply suggests that GCID itself would go forward with the same project. This does not comply with CEQA.

In fact, through the no project alternative, the district could defend existing water rights in a way that would satisfy all of the project objectives. Recently past and current water management and allocation decisions by state and federal water project operators and managers have reverberated through the past four year's dire supply conditions.[57] These decisions are not just artifacts of current natural conditions. Not only could the CVP and SWP been managed better in the recent past, but the sellers, like GCID, who are also the holders of very senior water claims, could have fought for themselves, their regions, and the environment in which they live, do business, and recreate. How could they do this, one might ask, and how would it apply to the 10-Wells Project?

This could meet three of the Project's objectives. If the objective is to increase reliability and flexibility for GCID and not, as we wonder in Section I above, the system that facilitates the expansion of the water market, protecting the senior claims to water would meet this objective. It would also provide more flexibility to, "Periodically reduce Sacramento River diversions to benefit migrating fish," and "Protect and maintain agricultural production in times of water shortage to minimize economic disruption." By virtue of its senior water claims, in 2015 alone GCID has proposed to sell 55,283 af to SLDMWA south of the Delta and 15,269 af to TCCA north of the Delta.

While it wouldn't "Offset reductions in GCID Settlement Contract allotments during the irrigation season in drought years," the DEIR acknowledges that this has been extremely rare.

In addition, the DEIR's discussion of biological impacts under the no project alternative contains no explanation of how impacts would be reduced at all, simply stating, in its entirety: "Under the No Project Alternative, GCID would continue to implement its current water management program. Resulting effects on biological resources would be similar to what is presently occurring within GCID's service area." (DEIR 5-2.) This fails to provide any "compar[ison of] the environmental effects of the property remaining in its existing state against environmental effects which would occur if the project is approved," as CEQA requires. (Guidelines, § 15126.6(e)(3)(B).)

<u>The EIR should evaluate an alternative that reduces or eliminates water transfers.</u>

As discussed above, GCID admits it desires to forego groundwater substitution water transfers as part of the LTWT Program, instead selling water through crop idling under the LTWT, and pumping a roughly equivalent amount of groundwater through this project as it originally proposed to use for groundwater substitution under the LTWT. Further, this DEIR proposes that groundwater pumping for this project will only occur during dry and critical years to help offset diminished supplies during those times. And, the LTWT similarly asserts that transfers will only occur during dry and critical years, to help offset diminished supplies during those times; where GCID plans to act as a willing seller of water claims, via crop idling, under the LTWT.

Considering these inextricably interconnected programs in tandem, then, a reasonable alternative to the proposed project would be to not participate in cropland idling and water transfers during

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[57] California Sportfishing Protection Alliance, February 2014. Presentation to the State Water Resources Control Board. "In water year 2011, the Department of Interior used only 348.8 TAF of the 800 TAF of CVPI § 3406(b)(2) water. 'Interior decided to not bank the unused (b)(2) water from water year 2011.' In water year 2013, DWR exported more than 826,000 acre-feet of water beyond what it had informed its contractors it could deliver."

dry and critical years. Indeed, the DEIR itself provides strong reasoning for why this should be considered to be a potentially feasible alternative that would reduce or avoid significant environmental impacts. The DEIR, for example, rejects a potential alternative to *increase* crop idling as infeasible, stating that,

> Idling would counter the goals and objectives of the proposed project. Cropland idling would neither increase system reliability nor protect agriculture, and it has the potential to result in significant adverse impacts on land use, water quality, air quality, and wildlife.

(DEIR 5-4.) Because cropland idling is assuredly contrary to the proposed project's goals and objectives, and results in greater environmental impacts, an alternative to not voluntarily participate in the LTWT cropland idling program is, logically, wholly consistent with the proposed project's goals and objectives, and would lessen significant environmental impacts.

Accepting Shortages

When GCID experienced water cutbacks in the past, the entire State of California was also impacted by the multiple year dry conditions. This couldn't be more true in the current drought of 2012-2015. In the past, GCID and other districts in the Sacramento Valley lived within the means of less than 100% supply when times were hard. After all, fallowed fields can be replanted and shared sacrifice by hydrologic region benefits the whole.

VII. Growth Inducing Impacts

This Project has the potential to cause numerous growth-inducing impacts. Section 21100(b)(5) of CEQA requires that an EIR discuss the growth-inducing impacts of a proposed project. A project could have a growth inducing impact if it could:

- Foster economic or population growth, or construction of additional housing;
- Remove obstacles to population growth, for example, developing service areas in previously unserved areas, extending transportation routes into previously undeveloped areas, and establishing major new employment opportunities;
- Encourage and facilitate other activities that could significantly affect the environment, either individually or cumulatively.

The CEQA Guidelines, for example, provide an illustration of how a major expansion of a wastewater treatment plant that might remove wastewater treatment capacity as a constraint on growth in its service area. (CEQA Guidelines, § 15126.2(d).) The DEIR argues, contrary to the CEQA Guidelines, that "Except where supply limitations have been specifically identified as an impediment to development approvals, water supply reliability alone is not the determinative factor inducing growth in any region of California." (DEIR 4-1.) Nothing, however, in the Guidelines or statute suggest that a growth inducing impact is limited to "the determinative factor inducing growth," as if such a factor could ever even be objectively isolated. On the contrary, the removal of any growth limiting factor should be seen as inducing growth.

The DEIR concludes its analysis of growth inducing impacts by stating, "it is not expected that new agricultural opportunities would be of a significant magnitude to drive economic growth resulting in the demand for new housing above that anticipated by Glenn County's or Colusa County's general plans. Therefore, growth inducement is not expected as a result implementing the proposed project." (DEIR 4-1.) Not only does the DEIR not explain what "new agricultural opportunities" would occur, or what would actually constitute a "significant magnitude," but the DEIR also again relies on a false standard of significance by claiming that any such growth would not be meaningful if it was less than that contemplated by the Counties' general plans. (See, *Federation of Hillside & Canyon Ass'ns v. City of Los Angeles* (2000) 83 Cal.App.4th 1252, 1265 (growth inducement must be discussed even where consistent with general plan.) CEQA nonetheless requires this EIR to incorporate the discussion from any general plan and/or general plan EIR that describes the growth this project would induce. (*Friends of the Eel River v. Sonoma County Water Agency* (2003) 108 Cal.App4th 859, 877; *Sierra Club v. West Side Irrig. Dist.* (2005) 128 Cal.App4th 690. It is unlikely these wells or their water supply capacity were evaluated by the respective general plan EIRs. Moreover, and perhaps most importantly, the DEIR only seems to contemplate here the arbitrary pumping levels proposed in the project description, not the actual capacity of these pumps on an annual basis. It is precisely this development of additional capacity, not analyzed by this DEIR, that serves to induce growth.

The Bureau, DWR, the SWRCB, and the Settlement Contractors have all participated in the creation and implementation of the SVWMA that extracts water from areas of origin north of the Delta for export. This opening up of supply on a finite water supply, has only fueled additional demand, which again fuels pursuit of more supply. This is the essence of the dog chasing its tail. As demonstrated above and below, installing wells has been a pivotal piece of the SVWMA and the SVIRWM. This is the essence of growth inducement: creating more capacity. The 10-Wells Project is producing the amount of water needed by a city of over 100,000 people.

Added to this is what we discussed previously: Table 3-4 illustrates that the pumping capacities of the existing wells are far greater than the projected 2,500 gpm rate planned in the Project. (DEIR p. 3-15.) Additionally, the DEIR uses loose language to define the capacities of the new wells: "Each well would have a target pumping capacity of 2,500 gallons per minute and would require a 100- to 250-horsepower pump motor." (p. 2-3.) Having existing infrastructure with greater capacity than proposed in the Project, installing new infrastructure with higher capacity than the proposed Project, and retaining the ability to use that infrastructure for longer periods of time, from the proposed 8.5 months to 12 months, provides GCID with pre-approved and pre-installed infrastructure for future demand.

VIII. Cumulative Impacts

CEQA requires evaluation of a project's incremental effects "viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects." (CEQA Guidelines § 15065(a)(3).) "[A] cumulative impact consists of an impact which is created as a result of the combination of the project evaluated in the EIR together with other projects causing related impacts." (CEQA Guidelines § 15065(a)(3).)

An EIR must also discuss significant cumulative impacts. CEQA Guidelines §15130(a). Cumulative impacts are defined as two or more individual effects which, when considered together, are considerable or which compound or increase other environmental impacts. CEQA Guidelines § 15355(a). "[I]ndividual effects may be changes resulting from a single project or a number of separate projects. CEQA Guidelines § 15355(a). A legally adequate cumulative impacts analysis views a particular project over time and in conjunction with other related past, present, and reasonably foreseeable future projects whose impacts might compound or interrelate with those of the project at hand. Cumulative impacts can result from individually minor but collectively significant projects taking place over a period of time. CEQA Guidelines § 15355(b). The cumulative impacts concept recognizes that "[t]he full environmental impact of a proposed . . . action cannot be gauged in a vacuum." *Whitman v. Board of Supervisors* (1979) 88 Cal. App. 3d 397, 408 (internal quotation omitted).

Following these standards, the DEIR must evaluate the cumulative impacts to water resources caused by the project in conjunction with the closely-related projects, below.

The Sacramento Valley Water Management Agreement

The DEIR omits discussion of the SVWMA. The close connection of the 10-Wells Project to the SVWMA is laid bare through documents associated with the [Sacramento Valley] Integrated Regional Water Management Program ("SVIRWMP"), which is discussed briefly. (DEIR p. 3-76.) The DEIR's Section 3.8.2.3 highlights the following districts that benefitted from funds garnered through the SVIRWMP: Browns Valley Irrigation District, Anderson-Cottonwood Irrigation District, Feather Water District, GCID, Natomas Central Mutual Water Company, Sutter Mutual Water Company, Meridian Farms Mutual Water Company, Pelger Mutual Water Company, Reclamation District 108, River Garden Farms Company, and Butte Water District. Moreover, the DEIR discloses that public money through Proposition 50 has been used for 11 implementation projects in the Sacramento Valley. However, the details of the projects are not disclosed. Instead, the DEIR asserts that, "Although several of the projects funded by this grant are generally similar in nature, each project has independent utility, and is implemented by each grantee as needed to supplement their current surface water supplies in various water-year types." Nevertheless, the SVWMA and the Sacramento Valley Regional Water Management Plan's documents unveil a very different picture.

In 2003, the Bureau published an NOI/NOP for a "Short-term Sacramento Valley Water Management Program EIS/EIR." (68 Federal Register 46218 (Aug 5, 2003).) As summarized on the Bureau's current website:

> The Short-term phase of the SVWM Program resolves water quality and water rights issues arising from the need to meet the flow-related water quality objectives of the 1995 Bay-Delta Water Quality Control Plan and the State Water Resources Control Board's Phase 8 Water Rights Hearing process, and would promote better water management in the Sacramento Valley and develop additional water supplies through a cooperative water management partnership. Program participants include Reclamation, DWR, Northern California Water Association, San Luis & Delta-Mendota Water Authority, some Sacramento Valley water users, and Central Valley Project and State Water Project contractors. SVWM Program actions would be locally-proposed projects and actions that include the development of groundwater to substitute for surface water supplies, conjunctive use of groundwater and surface water, refurbish existing groundwater

> extraction wells, install groundwater monitoring stations, install new groundwater extraction wells, reservoir re-operation, system improvements such as canal lining, tailwater recovery, and improved operations, or surface and groundwater planning studies. These short-term projects and actions would be implemented for a period of 10 years in areas of Shasta, Butte, Sutter, Glenn, Tehama, Colusa, Sacramento, Placer, and Yolo counties.[58]

The resounding parallels between the SVWMA NOI/NOP and the presently proposed project are not merely coincidence: they are a piece of the same program, and are closely-related activities that will result in similar effects upon the same environmental resources.

Page 2 of the SVIRWMP's *Proposal for Implementation Grant, Step 2 Attachment 5, Work Plan*[59] presents the centerpiece project, the Conjunctive Water Management Project. "A successful Conjunctive Water Management Project within the Sacramento Valley requires three critical activities that must proceed in unison. These include (1) groundwater production, (2) groundwater recharge, and (3) monitoring and assessment." What follows are the participating districts with the number of productions wells they sought:

- Anderson Cottonwood Irrigation District Groundwater Production Element 4 wells
- Browns Valley Irrigation District Water Groundwater Production Element 1 well
- Feather Water District Water Management Groundwater Production Element 1 well
- Glenn-Colusa Irrigation District Groundwater Production Element 8 wells
- Lewis Ranch Groundwater Production Element 1 well
- River Garden Farms Groundwater Production Element 2 wells
- Meridian Farms Groundwater Production Element 1 well
- Pelger Mutual Water Company Groundwater Production Element 1 well
- RD 108 Groundwater Production Element 5 wells

How are these districts' projects, including the Lead Agency GCID's, viewed as "generally similar in nature," but with "independent utility" when they are pursuing the specific goals of the SVWMA and the SVIRWMP? And let us be clear, those goals are *not* just for "supplemental supply" within their districts as suggested. The SVIRWMP elucidates that, "These elements were strategically formulated under the adopted Sacramento Valley Water Management Agreement (SVWMA, Phase 8, included in Attachment 4), which was executed in December 2002 by more than 40 Sacramento Valley water users, the Department of Water Resources, the Department of Fish and Game, the Bureau of Reclamation, the Fish and Wildlife Service, and various water users throughout the state. **Fifty percent of the Conjunctive Water Management Project capacity will be dedicated to meeting water quality standards in the Bay-Delta while the remaining 50 percent will be used to improve local and regional water supply reliability or to help meet other water needs in the state**." [emphasis added] [60]

The DEIR also fails to disclose how many of the SVWMA districts and/or the SVIRWMP Participating Entities have installed wells that have been used in water transfers and how many are

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[58] http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=788
[59] Northern California Joint Exercises of Powers, June 2006.
[60] Id. p.2.

committed to participate in the 10-Year Water Transfer Program (aka Long-term Water Transfers)[61] or continuing transfers outside it.[62] In addition, where is the disclosure that the production wells above, added to others installed by SVWMA districts and SVIRWMP Participating Entities, have been used to facilitate the goals from the SVIRWMP quote immediately above?

The 10-Wells Project that is presented as a seemingly innocuous attempt to "augment District surface water supplies during dry and critically dry water years" (DEIR p. 2-1) is part of a much larger agreement and multiple planning efforts. GCID's past and current actions make it abundantly clear that the stated 10-Wells Project is just another attempt to obfuscate its involvement in implementing the SVWMA through massive public funds from SVIRWM grants and federal appropriations (see Section I).

The 10-Year Water Transfer Program (aka Long-Term Water Transfers)

The DEIR mentions the 10-Year Water Transfer Program ("10-Year Program") in section 3.8.2.1. It does *not* reveal that the 10-Year Program contains significant numeric figures that should be incorporated into the cumulative impact analysis, such as:

1. The EIS/EIR analyzed transferring up to 600,000 af per year from the selling districts. No matter what figure the Bureau transfers year-to-year, this program has the ability to transfer up to 600,000 af each year.
2. GCID may have provided internal direction to itself, subject to change, that counter numbers in the 10-Year Program's EIS/EIR (DEIR p. 3-76), but the 10-Year Program's Final EIS/EIR retained the original number and will allow the sale of up to 91,000 af per year from GCID in any given year. (p. ES-6 and p. 2-14.) A vote by the GCID Board of Directors is all it would take to reverse the internal commitment, a non-binding statement, and begin selling water at the 91,000 af per year threshold.

Annual Transfers

The DEIR fails to delineate the numerous transfers that have occurred in the recent past and those that are proposed outside the 10-Year Water Transfer Program. What should the public conclude from this glaring omission? GCID's failure to disclose their own repeated transfers and those from the region and Sacramento Valley is arbitrary and capricious.

The DEIR should disclose what level of monitoring has occurred during the past annual transfers. If monitoring transpired, was there comprehensive coordination of methods, data collection, and data analysis for both individual and all Sacramento Valley water transfers and are the products available to the public? This might shed light on the results of cumulative actions by numerous water sellers in the Sacramento Valley, including the lead agency, GCID. This material is not presented here nor is it in the public realm, to our knowledge.

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[61] U.S. Bureau of Reclamation and San Luis Delta Mendota Water Authority, 2015. Final EIS/EIR 10-Year Water Transfer Program (aka Long Term Water Transfers) p. ES-12. http://www.usbr.gov/mp/nepa/nepa_projdetails.cfm?Project_ID=18361

[62] Id. p. 4-5.

As discussed above, the cumulative installation of well infrastructure, the repeated annual water transfers, participation in the 10-Year Water Transfer Program, and the increasing escalation of groundwater use by Sacramento Valley water districts involved in water sales do not exist in a vacuum. Instead, they are actually integrated, important parts of a broader program to develop regional surface and ground water resources into a conjunctive use system. GCID has planned for multiple decades to exploit groundwater, to "… integrate the Lower Tuscan Formation into the Central Valley water supply system…" and bank "…SWP and CVP contractual entitlements in the Lower Tuscan Formation…"[63]

The Project is also only one of several proposed and existing projects that affect the regional aquifers and surface waters. The existence of these numerous related projects makes an adequate analysis of cumulative impacts especially important.

IX. Additional Comments and Questions

Modeling

SacFEM has serious flaws yet is relied on exclusively for projections and impact analysis. Material produced for AquAlliance's comments on the 10-Year Water Transfer Program's EIS/EIR are equally relevant for the 10-Wells Project and is presented here. "One example of incorrect modeling assertions in the EIR/EIS is the characterization[1] of SacFEM2013 and its parent code MicroFEM as 'three-dimensional' and 'high-resolution'. In fact, the SacFEM2013 model provides only a linked set of two-dimensional analyses[2], and would more charitably be described as "two-and-a-half dimensional" instead of possessing a fully-3D modeling capability. This limitation is not an unimportant detail, as a general-purpose 3D groundwater model could be used to predict many important physical responses, e.g., the location of the phreatic surface within an unconfined aquifer. For the SacFEM2013 model, this prediction is part of the data instead of part of the computed solution, and hence SacFEM2013 apparently has no predictive capability for this all-important aquifer response."[64]

The relevant content from the *SACFEM2013: Sacramento Valley Finite Element Groundwater Flow Model User's Manual*[65] on this topic illustrates that the model is indeed being touted as having the capacity "[t]o generate a 3D surface defining the elevation of the base of fresh groundwater." (p. 3-5.) In addition, the DEIR states that, "SACFEM2013 was developed using the MicroFEM modeling code (MicroFEM, 2015), which is capable of simulating three-dimensional, transient, single-density groundwater flow in layered systems." (p. A-1.) Sadly, it is clear that the DEIR is relying on the very limited predictive capability of SacFEM for many of the most crucial conclusions for disclosing the significance of impacts from the 10-Wells Project.

This thin veneer is no substitute for actual, on the ground data from GCID's groundwater substitution transfers using the five existing wells. For example, "GCID pumped groundwater from July to September 2013 to make water available for transfer to the San Luis & Delta

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[63] U.S. Bureau of Reclamation Assistance Agreement, 2006, p. 5.
[64] Mish, Kyran D., 2014. Comments for AquAlliance on Long-Term Water Transfers Draft EIR/EIS, p. 3.
[65] "A complete description of the construction and calibration of SACFEM2013 is provided in SACFEM2013: *Sacramento Valley Finite Element Groundwater Flow Model User's Manual* (CH2M HILL and MBK Engineers, Inc., 2015)." (DEIR p. A-1.)

Mendota Water Authority (SLDMWA). Groundwater was pumped in lieu of diverting surface water under its pre-1914 water right and its Settlement Contract No. 14-06-200-855A-R-1 with the United States Bureau of Reclamation (USBR)."[66] The results of the groundwater substitution transfer are poorly discussed in the report, regularly using vague numeric approximations such as "recovered to within a few feet" and "generally recovered." However the exhibits highlight the serious effects from pumping 5,000 af in 2013. When Figure D-7 is contrasted with Figure D-8, it is clear that impacts were occurring as far as 3-4 miles away across the Sacramento River in Butte County were still drawing water to the cone of depression six months later. The hydrograph figures illustrate some conditions that are not in the text and contradict some of the report, such as:

- Figure C- 2. Production well GCID 2 experienced a precipitous collapse of 240 feet at the end of the transfer period, but appears to have almost recovered in March 2014.
- Figure C-10 Monitoring well 21N02W04G002M dropped over 50 feet at the end of the transfer period and in March 2014 was still approximately 13 feet below the March 2013 starting measurement.
- Figure C-13. Monitoring well 22N02W01N001M dropped over 90 feet at the end of the transfer period and in March 2014 was still approximately 10 feet below the March 2013 starting measurement.
- Figure C-14. Monitoring well 22N02W15C002M dropped over 50 feet at the end of the transfer period and in March 2014 was still approximately15 feet below the March 2013 starting measurement.

Actual data with additional, unbiased professional analysis would have better informed the public than what is provided with the DIEIR's reliance on modeling. "MicroFEM is a poor choice for such large-scale modeling. It is an old code that apparently utilizes only the simplest (and least accurate) techniques for finite-element modeling of aquifer mechanics, and MicroFEM (and hence SacFEM2013) embed serious limitations into the model that compromise the accuracy of the computed results." [67]

<u>Maps must be provided to illustrate all wells in an expanded radius of the Project's wells</u>

There is a profound gap in understanding regarding the potential areas of impact from GCID's existing and proposed 10 wells. (See CEQA Guidelines § 15124(a).) There also are no maps in the DEIR that indicate the number of domestic and production wells even in the area of impact assumed by SacFEM. We argue that maps with this information must be provided in a recirculated Draft EIR and that the radius of potential impact must be expanded. Drawing from the scientific analysis completed by professors Todd Greene and Karin Hoover,[68] we find that, "The importance of this new information on the hydrostratigraphy around the GCID wells is that the generally symmetrical pattern of drawdown that resulted from the SACFEM2013 modeling effort may not reflect the predominance of coarser-grained, water-rich zones on the east side of the wells. The results of the SACFEM2013 model show that the total area of the pumping impacts and the outer distance to the no-impact boundary is greater to the west in Glenn County, than east in Butte

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[66] West Yost Associates, 2014. *2013 Final Water Transfer Report* for Glenn Colusa Irrigation District, p. 1.

[67] Mish, Kyran D., 2014. Comments for AquAlliance on Long-Term Water Transfers Draft EIR/EIS, p. 4.

[68] Greene, Todd J. and Karin Hoover, 2015. *Hydrostratigraphy and Pump-test Analysis of the Lower Tuscan/Tehama Aquifer, Northern Sacramento Valley, CA*.

County. In fact, no wells in Butte or Tehama counties are proposed for monitoring in mitigation measures WR-1 and WR-2, and obviously are not included in the Glenn County BMO monitoring program. This lack of monitoring in Butte County, when that area may be a major source of the water pumped by GCID's wells, may allow for impacts that are inadequately recognized and thus improperly mitigated."[69]

Seismicity

The DEIR fails to discuss in any way the possible seismic risks from the 10-Wells Project. Not only does the construction of five new wells suggest a potential for seismic impacts, but there is also potential for seismic shaking because of subsidence from Project operations that in turn may cause additional stress to existing structures. Lack of disclosure in the DEIR necessarily leads to an absence of analysis of the potential effects from the Projects' construction and excessive groundwater pumping on the numerous known earthquake faults running through and about Northern California. As recently detailed in a paper published by a well-respected British scientific journal, "[u]plift and seismicity driven by groundwater depletion in central California," excessive pumping of groundwater from the Central Valley might be affecting the frequency of earthquakes along the San Andreas Fault, and raising the elevation of local mountain belts. The research posits that removal of groundwater lessens the weight and pressure on the Earth's upper crust, which allows the crust to move upward, releasing pressure on faults, and rendering them closure to failure. The 10-Wells Project and the cumulative water transfer projects impact the volume of groundwater extracted as farmers are able to pump and then forego surface water in exchange for money. The drought has exacerbated the demands from the water transfer market that is the major goal of the SVWMA, which is being implemented through the SVIRWMP and the 10-Year Water Transfer Program and has also depleted the natural regeneration of groundwater supply due to the scarcity of precipitation.

Detailed analyses of this seismicity and focal mechanisms indicate that active geologic structures include blind thrust and reverse faults and associated folds (e.g., Dunnigan Hills) within the Coast Ranges-Sierran Block ("CRSB") boundary zone on the western margin of the Sacramento Valley, the Willows and Corning faults in the valley interior, and reactivated portions of the Foothill fault system. Other possibly seismogenic faults include the Chico monocline fault in the Sierran foothills and the Paskenta, Elder Creek and Cold Fork faults on the northwestern margin of the Sacramento Valley.[70]

This deficiency must be corrected and included in a recirculated Draft EIR.

X. Conclusion

GCID's examination of the proposed Project fails to comply with the most essential review and disclosure requirements of CEQA, thereby depriving decision makers and the public of the ability to consider the relevant environmental issues in any meaningful way (details above). Rather,

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[69] Custis, Kit, 2015. Comments and Recommendations on Draft Environmental Impact Report for Glenn Colusa Irrigation District's Groundwater Supplemental Supply Project, June 2015 for AquAlliance, p. 5.

[70] http://archives.datapages.com/data/pacific/data/088/088001/5_ps0880005.htm (Custis, Exhibit A 10-Year Water Transfer Program)

GCID has neglected to disclose significant information regarding the 10-Wells Project and cumulative impacts in violation of CEQA in what appears to be an ongoing effort to avoid disclosure of GCID's commitments to the SVWMA and implementation through the SVIRWM and the 10-Year Water Transfer Program. AquAlliance has demonstrated in 2010,[71] 2012,[72] 2013,[73] 2014,[74] and in 2015 that key questions have not been addressed, significant data gaps exist and the possible and very probable impacts are not disclosed, but summarily rejected without data and a scientific basis for the conclusions.

For the majority of the twentieth century, northern California supported family farming, healthy salmon runs, rich hydrologic watersheds, and a diverse environmental heritage. GCID members share in this heritage. We hope that GCID will not only recall the heritage of which it is a part, but actively participate in efforts to defend and restore the health of this region and its water legacy for future generations. That legacy continues to be in the crosshairs of water policies that have repeatedly failed in the San Fernando, Owens, and San Joaquin valleys of California. For all of the above-mentioned reasons, the 10-Wells Project should either be withdrawn or the DEIR should be withdrawn, revised, and recirculated after the release of the long-missing SVWMA programmatic EIR.

AquAlliance respectfully requests notification of any meetings that address this proposed GCID Project or any other GCID project that requires any consideration of CEQA. Please send AquAlliance any additional documents that pertain to this project, including a possible notice of determination through the U.S. Postal Service and e-mail.

Sincerely,

B. Vlamis

Barbara Vlamis, Executive Director
AquAlliance
P.O. Box 4024
Chico, CA 95927
(530) 895-9420
barbarav@aqualliance.net

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[71] AquAlliance comments on the 2010/2011 Water Transfer Program's EA/FONSI

[72] AquAlliance's comments on water transfers by Western Canal WD and Butte Water District, 2012.

[73] AquAlliance's scoping comments on the Bureau and SLDMWA's North-to-South Water Transfer Program, 2013.

[74] AquAlliance comments on the 2014 Bureau and SLDMWA's North-to-South Water Transfer Program and the SLDMWA's 10-Year Water Transfer Program EIS/EIR.

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY
REFER TO:
MP-410
ENV - 7.00

JAN 24 2012

FS	DFS	AFS-GRC	AFS-EA
AFS-ES-V		AFS-ES-C-S	ADM

Sect. 7

FILE

MEMORANDUM

To: Deputy Assistant Field Supervisor, Endangered Species Division,
Fish and Wildlife Office, Sacramento, California

From: Regional Resources Manager, Mid-Pacific Regional Office,
U.S. Bureau of Reclamation, Sacramento, California

Subject: Section 7 Endangered Species Act Consultation with U.S. Fish and Wildlife Service (USFWS) for 2012 "North-to-South" Water Transfers

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SACRAMENTO FISH & WILDLIFE OFFICE

The Bureau of Reclamation is beginning the environmental compliance process for Central Valley Project (CVP) related water transfers in 2012. Based on the limited nature of north-to-south water transfers that may be proposed in 2012, Reclamation requests concurrence from the USFWS that 2012 water transfers may affect, but are not likely to adversely affect Federally listed species in the Sacramento and San Joaquin River Valleys.

As described below, water transfers in 2012 would be different in nature, and much less than, those evaluated in the 2010-2011 Water Transfer Program Environmental Assessment (EA) and Biological Assessment (BA) and would therefore have fewer effects, and potentially no effects, on listed species. The most notable difference for 2012 transfers is that no crop idling transfers would occur. If capacity in the Delta becomes available to pump transfer water south, groundwater substitution transfers would be the only water transfers considered by the purchasing agencies south of the Delta.

In 2010, Reclamation completed the EA/Finding of No Significant Impact and Endangered Species Act consultation for the 2010-2011 Water Transfer Program. USFWS issued the Biological Opinion (BO) for 2010-2011 water transfers on March 2, 2010. The EA and BO considered effects of groundwater substitution and cropland idling transfers from CVP contractors in the Sacramento Valley to purchasing agencies south of the Delta. Because of wet hydrologic conditions and limited export capacity, CVP contractors did not request any crop idling or groundwater substitution transfers in 2010 or 2011, and no water transfers were made under the 2010-2011 Water Transfer Program.

Reclamation is currently working with the San Luis & Delta-Mendota Water Authority on the Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report (EIS/EIR) that will provide environmental coverage for water transfers for 10 years, from 2013 through 2022. The EIS/EIR is on schedule to be completed, with a signed Record of Decision, by April 2013. Because of the proposed completion date in 2013, Reclamation must complete environmental documentation for the 2012 water transfer season.

Potential Water Transfers in 2012

For 2012 water transfers, Reclamation anticipates a maximum of approximately 76,000 acre-feet of water could be transferred. The 76,000 acre-feet of transfer water would be made available through groundwater substitution. The same mitigation measures that applied to groundwater substitution transfers would be implemented in 2012 as were provided in the 2010-2011 EA and BO.

Potential Effects to Species of 2012 Water Transfers

As stated above, Reclamation and water agencies did not make any water transfers in 2010 or 2011, and thus the water transfer program did not have any effect on the species in these two years. Additionally, giant garter snake populations would likely have benefitted from the amount of water available during the past two years. The proposed 2012 water transfers, if implemented to their full extent, would not result in any rice lands being idled, as none of the water would be generated through crop idling, and the environmental commitments for groundwater substitution in the 2010-2011 Water Transfer BO would be met. This would eliminate effects on giant garter snake habitat and the potential effects on individuals cited in the BO of stress, reduced growth, reduced reproductive success or mortality. Given that the program was not implemented in 2010 and 2011, there would be no cumulative effects on any listed species from the program carrying forward into 2012. Therefore, it is highly unlikely that the implementation of the proposed transfer program in 2012 would have any effect on giant garter snake populations.

The EA and BA also evaluated effects of water transfers to the listed San Joaquin kit fox. The BO concurred with Reclamation's conclusion in its BA that the 2010-2011 Water Transfer Program was likely to affect, but unlikely to adversely affect Federally-listed threatened San Joaquin kit fox, as the transfers would not result in the conversion of natural lands to annual crops or annual crops to permanent (woody) crops. Given the smaller amount of the proposed 2012 transfers, these conclusions would also be valid for the proposed program, and no adverse effects on San Joaquin kit fox would be anticipated.

For 2010-2011 water transfers, Reclamation included an environmental commitment to implement transfers within the operational parameters specified in the 2008 Biological Opinion for the Coordinated Operations of the Central Valley Project and State Water Project. Therefore, the effects of the 2010-2011 Water Transfer Program on federally-listed threatened Delta Smelt and its critical habitat were covered in the 2008 Biological Opinion. USFWS agreed to this conclusion in the 2010-2011 Water Transfer Program BO. Reclamation would meet this environmental commitment when implementing 2012 water transfers. Therefore, the conclusions in the EA and BO for 2010-2011 water transfers would also be valid for 2012 transfers and no adverse effects on Delta Smelt would be anticipated.

Groundwater Overdraft in California's Central Valley:
Updated CALVIN Modeling Using Recent CVHM and C2VSIM Representations

By

HEIDI CHOU

B.S. (University of California, Berkeley) 2010

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE
in
Civil Engineering
in the
OFFICE OF GRADUATE STUDIES
of the
UNIVERSITY OF CALIFORNIA
DAVIS

Approved:

Jay Lund

Timothy Ginn

Thomas Harter

Committee in Charge

2012

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And finally, thanks to my family and close friends who have provided me with endless amounts of support and encouragement throughout this project.

Updates have been made to the CALVIN hydro-economic optimization model of California’s intertied water supply and delivery system. These updates better reflect water demands, groundwater availability, and local water management opportunities. This update project focused on improving groundwater representation in CALVIN, which included changing CALVIN groundwater parameters based on California Department of Water Resources’ (DWR) California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and the United States Geological Survey (USGS) Central Valley Hydrologic Model (CVHM) model inputs and results. Using these models, a CALVIN model with updated groundwater representation now exists.

In updating CALVIN, a detailed comparison between C2VSIM and CVHM was conducted and the results are discussed in this thesis. The updated CALVIN model was used to study the effects of different cases of overdraft on Central Valley groundwater basins. When compared to the updated CALVIN model’s case of overdraft, ending overdraft in the entire Central Valley results in less available groundwater and higher economic scarcities in all regions, driving the model to use more surface water to try to meet demands and also to use more artificial recharge to even out variability in surface water availability.

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CHAPTER 1

Introduction

This project included updating CALVIN's representation of Central Valley groundwater and revising some aspects of the CALVIN model framework to achieve more clarity in the terms representing groundwater conditions; this lays a streamlined framework for future CALVIN groundwater updates. With surface water reliability decreasing in California, groundwater continues to play a larger role in water supply. And because there is still much uncertainty in how much groundwater is actually available in California, this hydro-economic approach to modeling groundwater can be useful for water planners and managers. Using the updated model, several overdraft scenarios were examined to see how overdraft economically and physically affects Central Valley groundwater conditions and water users.

Groundwater in California

Groundwater provides about 30 percent of California's water demands in a normal year. In drought years and in the Central Valley, dependence on groundwater is even higher. An estimated 15 million acre-feet of water is pumped per year, which is more than what is being recharged, causing overdraft in some areas (Faunt et al. 2009; DWR 2003). Overdraft has negative effects on water quality, increases pumping costs, causes land subsidence, and eventually decreases groundwater availability. DWR estimates the overdraft in the state's groundwater basins to be one to two million acre-feet annually, mostly in the Tulare Basin. Even with substantial overdraft, there are no statewide regulations on groundwater pumping (DWR 2003). Groundwater availability in the Central Valley is particularly important for droughts, when the absence of surface water brings water users to pump more groundwater. The storage capacity in the Central Valley's aquifers is much larger than the water storage capacity of its surface water reservoirs, making groundwater pragmatic for long-term drought water storage.

CALVIN

CALVIN, the CALifornia Value Integrated Network model is an economic-engineering optimization model of California's water system. It covers 92% of California's population and 90% of the irrigated crop area (Howitt et al. 2012). The model uses a network flow optimization solver developed by the U.S. Army Corps of Engineers to provide results on surface and groundwater operations, and water use allocations based on maximizing statewide net economic benefit, or minimizing statewide water operations and scarcity costs. There are operating costs associated with infrastructure links in the system and scarcity costs are calculated from each area's water delivery demands. The current network consists of 41 urban demand areas, 25 agricultural demand areas, 44 reservoirs, 31 groundwater basins, and 1,767 links. Figure 1 shows the CALVIN coverage and network.

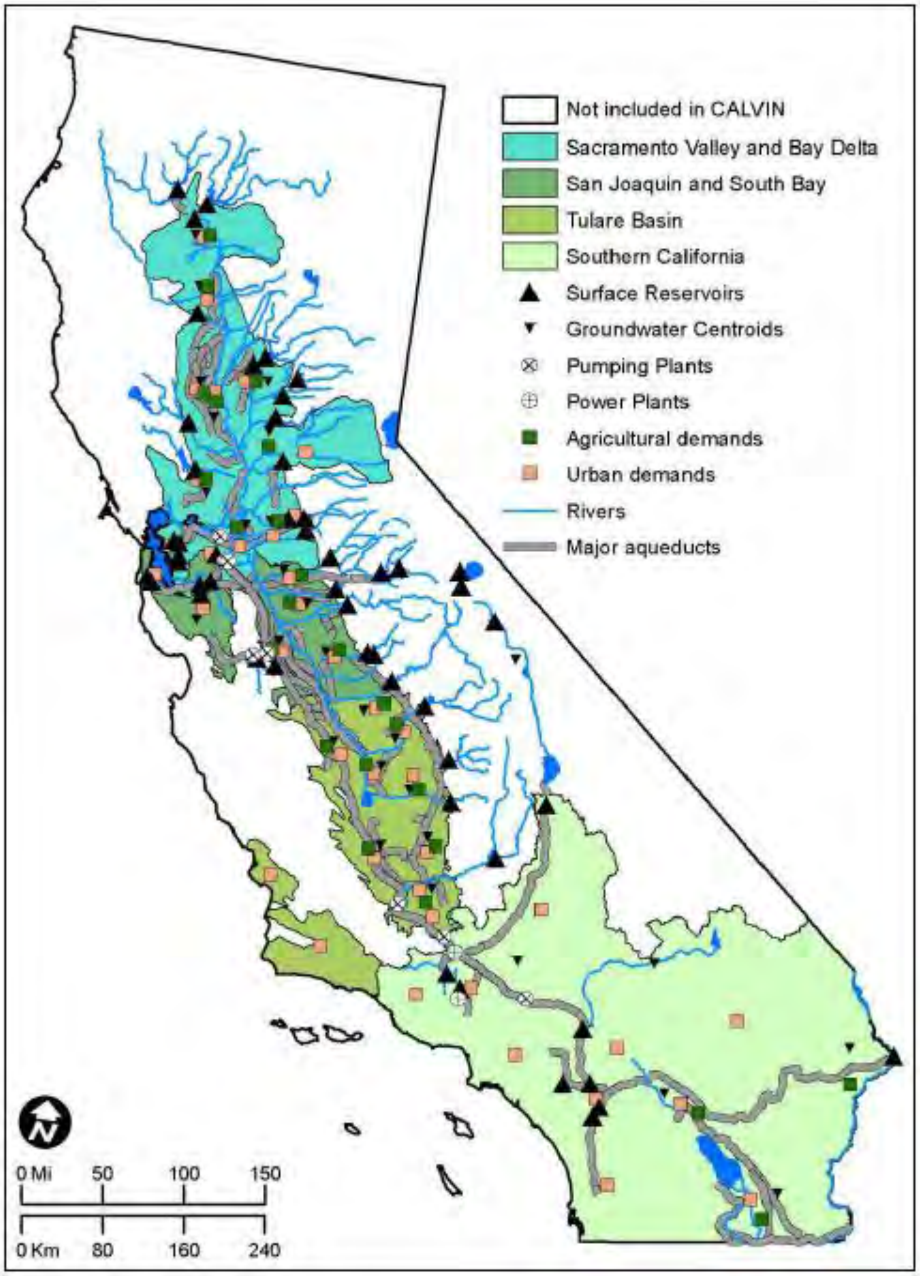


Figure 1.1: CALVIN Coverage Area and Network

Previous CALVIN Studies

CALVIN has been used to study a wide variety of different California water problems including infrastructure, water use, climate change, policy, and now–overdraft. These previous CALVIN studies are described in Table 1.1. This groundwater update project is the first major study of changes to CALVIN's Central Valley groundwater system since the model was developed in 2001.

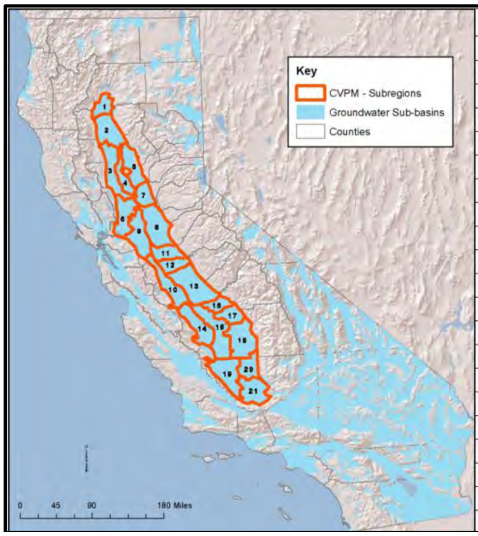
Table 1.1: Previous CALVIN Studies

Description	**Citation**
Integrated water management, water markets, capacity expansion, at regional and statewide scales	Draper et al. (2003); Jenkins et al. (2001; 2004); Newlin et al. (2002)
Conjunctive use and southern California	Pulido et al.(2004)
Hetch Hetchy restoration	Null (2004); Null and Lund (2006)
Perfect and limited foresight	Draper (2001)
Climate warming, wet and dry	Lund et al. (2003); Tanaka et al.(2006; 2008)
Climate warming, dry	Medellín-Azuara et al.(2008a; 2009)
Climate warming, dry and warm-only	Medellín-Azuara et al.(2008a; 2009); Connell (2009)
Severe sustained drought impacts and adaptation (paleodrought)	Harou et al. (2010)
Increasing Sacramento River outflows	Tanaka and Lund (2003)
Reducing Delta exports and increasing Delta outflows	Tanaka et al.(2006; 2008; 2011); Lund et al.(2007; 2008)
Colorado River delta and Baja California water management	Medellín-Azuara et al.(2006; 2007; 2008b)
Ending overdraft in the Tulare Basin	Harou and Lund (2008)
Cosumnes River restoration and Sacramento metropolitan area water management	Hersh-Burdick (2008)
Bay Area adaptation to severe climate changes	Sicke (2011)
Urban water conservation with climate change and reduced Delta pumping	Ragatz (2011)
Economic Responses to Water Scarcity in Southern California	Bartolomeo (2011)

(Adapted from Lund et al, 2010)

CALVIN Groundwater

Central Valley groundwater basins in CALVIN are represented by the Central Valley Production Model (CVPM) subregions as shown in Figure 1.2.



Subregion	Location
1	Redding Basin
2	Chico Landing to Red Bluff
3	Colusa Trough
4	Colusa Landing to Knight's Landing
5	Lower Feather R. and Yuba R.
6	Sacramento Valley Floor, Cache Cr., Putah Cr., Yolo BP
7	Lower Sacramento R. below Verona
8	Valley Floor east of Delta
9	Sacramento -San Joaquin Delta
10	Valley Floor west of San Joaquin River
11	Eastern San Joaquin Valley above Tuolumne R.
12	Eastern Valley floor between San Joaquin R. & Tuolumne R.
13	Eastern Valley floor between San Joaquin R. & Merced R.
14	Westland
15	Mid-Valley Area
16	Fresno Area
17	Kings R. Area
18	Kaweah R. and Tule R. Area
19	Western Kern County
20	Eastern Kern County
21	Kern R. Area

Figure 1.2: Groundwater Basins Modeled in CALVIN

Since CALVIN is an optimization-based system engineering model, groundwater heads are not represented as in a groundwater model; changes in groundwater volumes are modeled instead (Draper et al. 2003). For each subregion, flows, volumes, and fractions have been extracted, calculated, and/or estimated from physical simulation groundwater models and inputted as parameters into CALVIN to represent the interactions within the subregions and storage volumes of these basins. These parameters are summarized in Table 1.2. More detailed descriptions of these terms and their calculations are found in Chapter 2 and Appendices 1, 2, and 4. Figure 1.3 describes the terms and how groundwater interacts in CALVIN.

Table 1.2: Groundwater Data Required by CALVIN for each GWSB

Item	Data for CALVIN	Data type
1	Agricultural return flow split (GW & SW)	Fraction (1a+1b=1)
2	Internal reuse	Amplitude (≥1)
3	Return flow of total applied water	Amplitude (<1)
4	External flows	Monthly time series
4-1	Inter-basin flows	Monthly time series
4-2	Deep percolation from streams and lakes	Monthly time series
4-3	Deep percolation from precipitation	Monthly time series
4-4	Boundary inflow	Monthly time series
4-5	Subsidence	Monthly time series
4-6	Gains from diversions (conveyance seepage)	Monthly time series
4-7	Non-recoverable losses	Monthly time series
5	Groundwater pumping capacity (maximum & minimum)	Number value
6	Depth to groundwater (pumping lift) for pumping cost	Number value & cost ($)
7	Initial Storage	Number value
8	Ending Storage	Number value
9	Storage capacity (maximum & minimum)	Number value
10	Calibration Flows	Monthly time series
11	Urban return flow	Amplitude (<1)

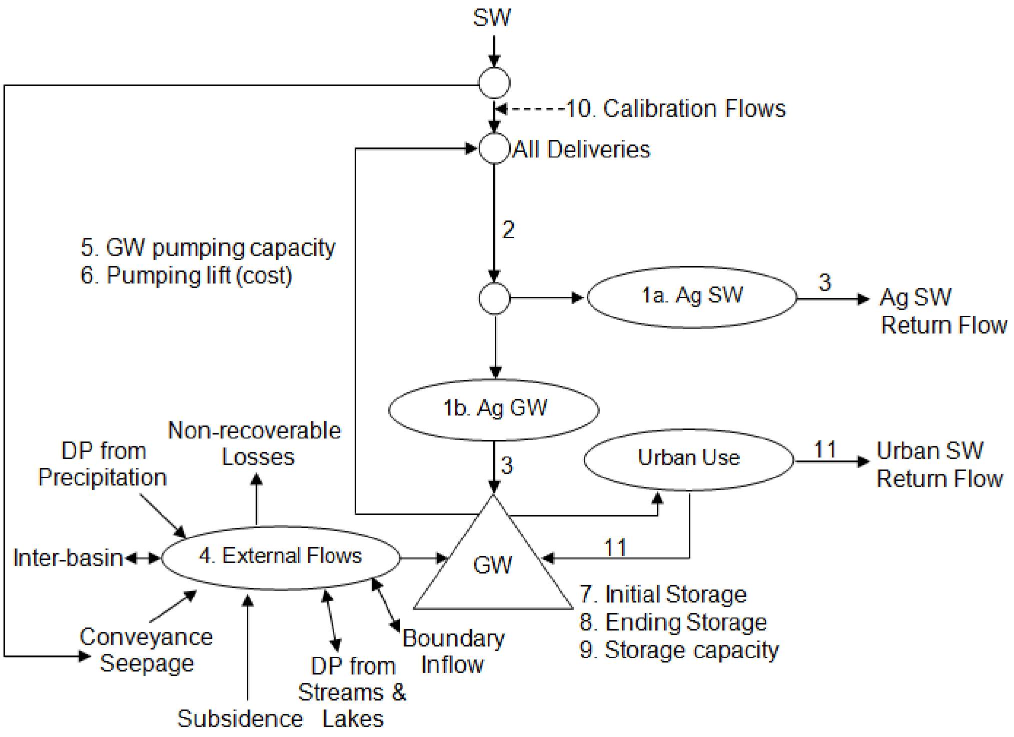


Figure 1.3: Flows and Interactions in CALVIN Groundwater Sub-basins

As seen in Figure 1.3, surface water and pumped groundwater come together at a node which represents all water deliveries to demand areas. These deliveries are then split between agricultural surface water and agricultural groundwater demands (term #1). A re-use amplitude (term #2) can be specified prior to this split. Following the water delivered to the surface water and groundwater demand areas, the return flow fraction (term #3) is the fraction of the water not used by the crops and is returned to groundwater or surface water. The external flows (term #4) include deep percolation from precipitation, inter-basin flows, boundary flows, stream leakage, subsidence, conveyance seepage, and non-recoverable losses (i.e. evapotranspiration and tile drain flows). Water pumped from the groundwater basin has capacity constraints (term #5) and also a pumping lift (term #6) to calculate pumping cost. The groundwater basin itself has initial, ending, minimum, and maximum storage constraints (terms #7-9). Any flows needed to maintain mass balance in the system or allow for feasible results are considered "Calibration flows" (term #10), which are added or removed prior to the delivery node to ensure that the appropriate amount of water can be delivered to the demand areas; calibration flows can be positive or negative. Such calibration flows also help reflect uncertainty in our understanding of California's hydrology. Urban return flow (term #11) is also represented as an amplitude, like term #3.

Previous CALVIN Groundwater Representation

Prior to this update project, CALVIN's groundwater representation was based on pre- and post-processing data and results from the Central Valley Ground Surface Water Model (CVGSM) 1997 No Action Alternative (NAA) run (USBR 1997). CVGSM is a special application of the Integrated Ground Surface Water Model (IGSM) to the Central Valley of California, used in the Central Valley Project Improvement Act (CVPIA) Programmatic Environmental Impact Statement (PEIS) of 1992. A description of CVGSM representation of CALVIN groundwater can be found in Jenkins et al. 2001 and Davis et al. 2001 (Appendix J).

Since CVGSM was used for CALVIN groundwater, new studies have shown that some of the old IGSM algorithms are very different from those used in MODFLOW, whose algorithms are widely tested and established, bringing some question in whether or not this version of IGSM's solutions are a good representation of the hydrologic system it is modeling (LaBolle et al. 2003). Considering that new and improved models like CVHM and C2VSIM (CVGSM's successor) have been developed, it was decided to update CALVIN groundwater based on one of the new, more detailed models. The groundwater terms calculated from the CVGSM model are compared with the new calculated terms from CVHM and C2VSIM in Chapter 3.

New California Groundwater Modeling Efforts

Several groundwater modeling efforts for California's Central Valley exist and are on-going. The Department of Water Resources (DWR) has developed and continues to update a groundwater model of California's Central Valley called the California Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) using the Integrated Water Flow Model (IWFM) (Brush et al. 2008). In addition, the United States Geological Survey (USGS) also developed a groundwater model for the Central Valley using MODFLOW and published its development in Professional Paper 1766 in 2009 (Faunt et al. 2009). This model also continues to be developed. These two models have been studied extensively to draw data and results for improving CALVIN's groundwater representation. C2VSIM, CVHM, and CVGSM (old CALVIN) use the same subregion definitions (CVPM regions) for groundwater basins, allowing for direct comparisons of data and results.

Using MODFLOW and the FMP, CVHM simulates key groundwater and surface water processes in the Central Valley for the 21 water-balance regions for water years 1962 to 2003. The model is based on year 2000 land use. A Geographic Information System (GIS) was used to develop a geospatial database to manage the data. The model is divided horizontally into a square grid of 20,000 square mile cells, and vertically into 10 layers, ranging in thickness from 50-750 feet. A geologic texture model was developed for CVHM to better characterize the Central Valley aquifer system. More information on CVHM is in Chapter 2 and Faunt et al. 2009.

Using the 3-D finite element code IWFM, C2VSIM simulates groundwater flow and groundwater-surface water interactions for the 21 subregions on a monthly basis from water years 1921 to 2003. The model is represented by three layers of 1392 elements. More information on C2VSIM can be found in Brush et al. 2008.

Although there are similarities in the two models' hydrologic inputs, the models operate differently and the outputs and results are significantly different in some areas. Some differences and the effects of those differences on this application to CALVIN are discussed here. A detailed comparison of the theory, approaches, and features of the two models can be found in Dogrul et al. 2011.

Project Description

This CALVIN groundwater update had several steps. First, CALVIN groundwater parameters were identified. Data for these parameters was then estimated based on C2VSIM and CVHM inputs and outputs for use and comparison with the previous CALVIN model (CVGSM) estimates. Following comparisons of these parameter estimates, separate simplified CALVIN model runs were conducted using these parameter values from each groundwater model. These results were compared and the decision was made to primarily use C2VSIM for the final CALVIN groundwater representation mostly due to C2VSIM's longer historical modeling period. Next, calibration of the 72-year CALVIN model based on C2VSIM was done and a new CALVIN model with updated groundwater representation based on C2VSIM emerged. Finally, additional studies were done by adjusting the overdraft scenarios based on CVHM and other simulated scenarios.

The major steps in this groundwater update project are summarized as follows:

1. Estimate, calculate, and/or extract terms from CVHM and C2VSIM to use as parameters (Table 1.2) for CALVIN update
2. Compare CVHM and C2VSIM terms and methods with CALVIN representation to determine which parameters from which model are to be used for the final CALVIN Groundwater update. Options included: CVHM, C2VSIM, or a combination of CVHM and C2VSIM.
3. Run the CALVIN model
4. Calibration of CALVIN model to ensure feasible and reasonable results
5. Additional overdraft studies to test updated model

Overview of Thesis

This thesis work updated CALVIN groundwater representation in the Central Valley and also improved many aspects of the CALVIN model. Chapter 2 describes CALVIN groundwater input terms and the groundwater representation based on CVHM. Chapter 3 discusses and compares the groundwater input terms from C2VSIM, CVHM, and CVGSM. Chapter 4 presents the updated CALVIN model with Central Valley groundwater representation primarily based on C2VSIM and the calibration process that resulted in the final updated model from this research project. This chapter also presents a comparison between the updated CALVIN model with the version of the model prior to the update. Chapter 5 applies the updated model to investigate the economic and physical effects of different cases of overdraft in the Central Valley. Finally, Chapter 6 summarizes the results from this research project, discusses the limitations, and presents some ideas for future work on the CALVIN model.

CHAPTER 2

CALVIN Groundwater Representation Based on CVHM

This chapter discusses the CVHM model and how it was used to calculate the groundwater input terms for CALVIN. This chapter also provides a description of the groundwater terms used for CALVIN and the CVHM calculated term results. Although CVHM was ultimately not used as the primary basis for Central Valley groundwater representation in CALVIN, studying the CVHM calculation of the groundwater terms was very useful for understanding CALVIN groundwater and the CVHM results were used for comparisons during model calibration (discussed in Chapter 4).

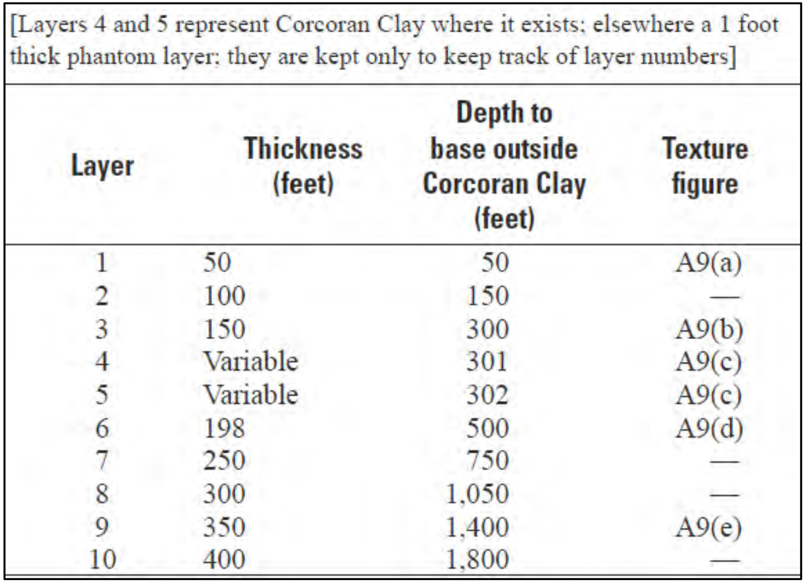
CVHM Description

CVHM was developed by the United States Geological Survey (USGS) to support a study assessing groundwater availability in California's Central Valley. This study, described in Faunt et al. 2009, had 3 major objectives:

1. To develop a better understanding of the freshwater-bearing deposits of the Central Valley; this objective was achieved by developing a new texture model.
2. To use improved water-budget analysis techniques to estimate water-budget components for the groundwater flow system in areas dominated by irrigated agriculture; this objective was achieved through the development of the Farm Process (FMP) to be used in conjunction with MODFLOW-2000 (MF2K).
3. To quantify the Central Valley's groundwater-flow system; this objective was accomplished by developing CVHM, which links the texture and landscape-process models with the groundwater-flow process model.

CVHM builds on many previous studies, but is primarily an update to the USGS Central Valley Regional Aquifer System and Analysis (CV-RASA), with the major update components being incorporating MODFLOW-2000 with the FMP into the model and spatial re-discretization of the model to finer spatial scales. Table 2.1 describes the model layer thicknesses and depths and Figure 2.1 shows a generalized vertical hydrogeologic cross section of the groundwater flow system. Figure 2.2 shows the farm process balance of the groundwater system. A detailed description of the CVHM development can be found in Faunt et al. 2009.

Table 2.1: CVHM layer thicknesses and depths (Table A3 from Faunt et al. 2009)



[Layers 4 and 5 represent Corcoran Clay where it exists; elsewhere a 1 foot thick phantom layer; they are kept only to keep track of layer numbers]

Layer	Thickness (feet)	Depth to base outside Corcoran Clay (feet)	Texture figure
1	50	50	A9(a)
2	100	150	—
3	150	300	A9(b)
4	Variable	301	A9(c)
5	Variable	302	A9(c)
6	198	500	A9(d)
7	250	750	—
8	300	1,050	—
9	350	1,400	A9(e)
10	400	1,800	—

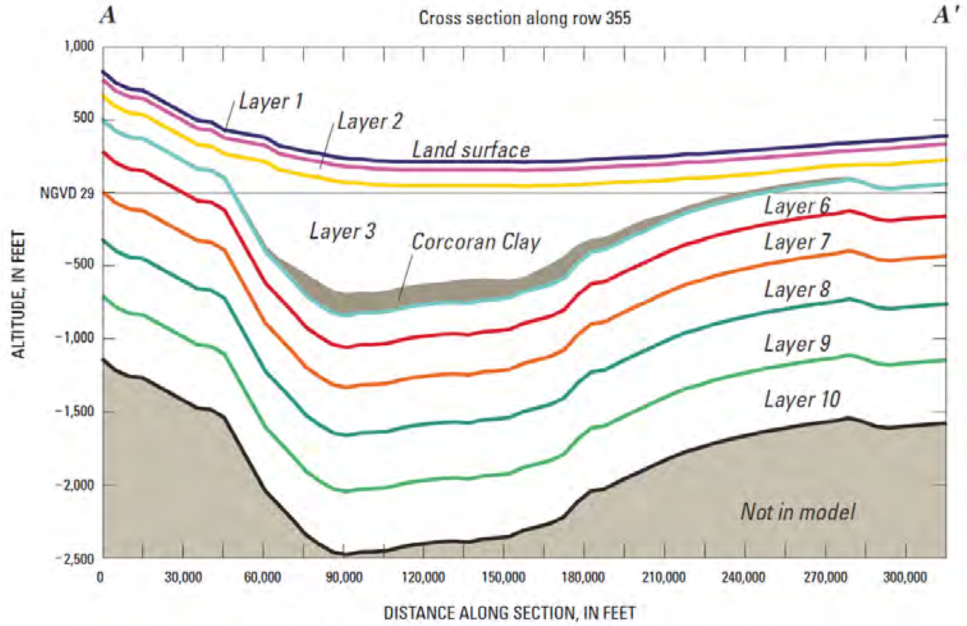


Figure 2.1: Generalized hydrogeologic section (A-A’) (Figure A11 from Faunt et al. 2009)

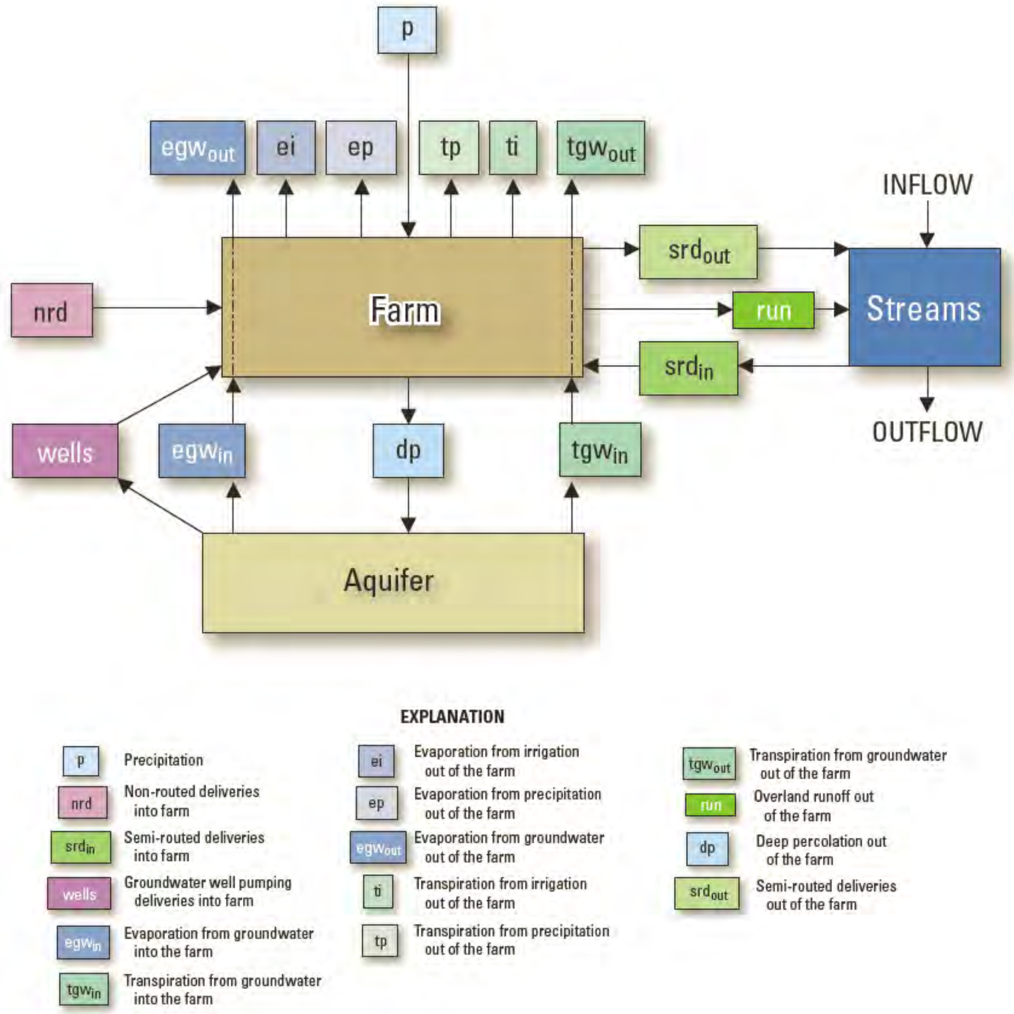


Figure 2.2: Inflows and outflows simulated by the FMP (Figure C5 from Faunt et al. 2009)

CVHM Datasets

Using pre- and post-processor results from CVHM, the parameters for CALVIN groundwater representation were calculated. The parameters were calculated for three different sets of data. The first set of data is based only on the data from 1980-2003 to focus on the time period after most major infrastructure changes in California (“CVHM Hist 1980-2003”). The second set of data is calculated from the entire historical time series (1961-2003) of the CVHM results (“CVHM Hist”). The third set of data is based on a CVHM run made with updated land use based on year 2000 (“CVHM 2000”). However, this run showed some obvious problems in Region 21 (in southern Tulare basin) and was ultimately not used, but its results were used for comparisons between the different CVHM datasets (Appendix 1).

Different approaches were taken when calculating the CALVIN groundwater parameters. The parameters summarized in this section will primarily be for calculations from results from the Zonebudget post-processor (“CVHM”), which estimates a mass balance for each region. Other versions of these calculations include results from FB_details.OUT and other input files, but these ultimately were not chosen to represent CVHM since it involved using terms from different post-processors that did not result in mass balance. However, these calculations still reflect reasonable methods to calculate these terms so some descriptions and results are summarized in Appendix 1. The calculations that were independent of these post-processors have the same results regardless of dataset. A summary of the different sets of CVHM data is shown in Table 2.2. This chapter presents and discusses the results used for CVHM to compare with C2VSIM and CVGSM.

Table 2.2: CVHM Datasets

Dataset name	Description
CVHM Historical (1980-2003) “CVHM Hist 1980-2003”	Based on historical CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1980-2003.
CVHM Historical (1961-2003) “CVHM Hist”	Based on historical CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1961-2003.
CVHM 2000 Land Use (1961-2003) “CVHM 2000”*	Based on an updated 2000 land use CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1961-2003.
CVHM Historical ZB (1980-1993) “CVHM”	Based on historical CVHM run using Zonebudget post-processor; averages based on 1980-1993. Used as final CVHM result for CALVIN comparisons with other groundwater models.

*Note that this run had obvious problems in some of the Tulare Basin regions so the results from this run were ultimately not used for any formal comparison.

CVHM Calculation of Terms

This section summarizes methods used to calculate the terms and the resulting values used for the final comparison between CVHM and the other models. For each term, there is a brief description followed by some tabulated results of calculated values. More details on these terms, alternative calculation methods, and a comparison of these terms’ results are in Appendix 1.

Agricultural Return Flow Split

The agricultural return flow split term represents the fate of applied water that is not consumed by crops or other consumptive uses. Return flow may return either to groundwater by deep percolation or to surface water. This term defines the fraction of agricultural use which returns to surface water (1a) and to groundwater (1b) as shown in Figure 1.3. Applied water is the amount of water used to meet demands.

Using the crop categories and properties in Table 2.3 and the corresponding subregion index data in the model input files, the splits to surface water and groundwater return flows were estimated. Based on the crop distribution file from the input files (a matrix of crop category numbers), the average of all the fractions of surface water runoff from irrigation for each subregion was taken. This results in the proportion of return flow to surface water. The proportion of return flow to groundwater is 1 minus this value. CALVIN takes only one fraction for surface water and one fraction for groundwater for each region over the model time period; these split fractions do not change over time in CALVIN. The results are shown in Table 2.4.

Table 2.3: Summary of Central Valley, California, crop categories and properties (from Table C4 from Faunt et al 2009)

Virtual crop category #	Land Use	Fraction of SW Runoff from Precipitation	Fraction of SW Runoff from Irrigation
1	Water	0.050	0.010
2	Urban	0.015	0.010
3	Native classes	0.207	0.010
4	Orchards, groves, and vineyards	0.102	0.010
5	Pasture/Hay	0.102	0.017
6	Row Crops	0.102	0.061
7	Small Grains	0.102	0.045
8	Idle/fallow	0.060	0.010
9	Truck, nursery, and berry crops	0.102	0.100
10	Citrus and subtropical	0.102	0.010
11	Field crops	0.102	0.077
12	Vineyards	0.013	0.012
13	Pasture	0.102	0.017
14	Grain and hay crops	0.102	0.045
15	Semiagricultural	0.323	0.350
16	Deciduous fruits and nuts	0.107	0.048
17	Rice	0.011	0.030
18	Cotton	0.102	0.102
19	Developed	0.102	0.078
20	Cropland and pasture	0.102	0.078
21	Cropland	0.102	0.078
22	Irrigated Row and Field Crops	0.102	0.068

Agricultural Reuse

CVHM does not explicitly "reuse" water locally for repeated irrigation. This might be included in future versions of the model, but is not in the version used here. As far as basic representation of this term using CVHM, 1 is used for all regions indicating no reuse, meaning water delivered to the region is the same as the applied (and re-applied) water in the region.

Return Flow of Total Applied Water

This term represents the return flow of total applied water, which applies to return flow to both surface water and groundwater. This term can be calculated by using given information on irrigation efficiencies (evapotranspiration of applied water, ETAW). In CVHM, the irrigation efficiencies are specified as a matrix of efficiencies for each subregion and each crop for each monthly stress period. The efficiencies vary from crop to crop for different subregions and they change through time. Table C6 from Faunt et al. 2009 gives the average area-weighted composite efficiency, by decade, for each subregion. Using the values from Table C6, the Return Flow of Total Applied Water is calculated as follows: Return Flow (%) = 1-ETAW (%). The composite efficiency and return flow of total applied water values for year 2000 are in columns 4 and 5 in Table 2.4.

Table 2.4: CVHM Agricultural Return Flow Splits, Composite Efficiencies, and Amplitudes of Return flow of Total Applied Water

Subregion	Agricultural Return Flow Split to GW	Agricultural Return Flow Split to SW	Composite Efficiency (fraction to ETAW)	Return Flow of Total AW
1	0.99	0.01	0.74	0.26
2	0.98	0.02	0.73	0.27
3	0.97	0.03	0.83	0.17
4	0.96	0.04	0.79	0.21
5	0.97	0.03	0.8	0.2
6	0.97	0.03	0.77	0.23
7	0.98	0.02	0.77	0.23
8	0.98	0.02	0.75	0.25
9	0.96	0.04	0.78	0.22
10	0.95	0.05	0.79	0.21
11	0.97	0.03	0.77	0.23
12	0.96	0.04	0.76	0.24
13	0.97	0.03	0.79	0.21
14	0.92	0.08	0.87	0.13
15	0.94	0.06	0.76	0.24
16	0.98	0.02	0.81	0.19
17	0.97	0.03	0.8	0.2
18	0.96	0.04	0.79	0.21
19	0.97	0.03	0.77	0.23
20	0.97	0.03	0.81	0.19
21	0.96	0.04	0.81	0.19

External Flows

The External Flows time series is the sum of several source flows into and out of the groundwater subregion, excluding pumping and recharge of agricultural applied water, which are represented separately in CALVIN. These flows include groundwater-surface water interactions (stream leakage), inter-basin groundwater flows, deep percolation from precipitation, boundary inflows, subsidence, and evapotranspiration/non-recoverable losses. The sum of these individual time series comprise the net external flows monthly time series that are used as input source flow in CALVIN.

Inter-basin flows represent the groundwater flow between subregions. For CVHM, these numbers were extracted from ZoneBudget output, “Inter-zone.” Positive values are flow into the groundwater subbasin and negative values are flows out of the basin to adjoining basins.

Stream leakage flows represent groundwater-surface water interaction within each region. These values are extracted from the ZoneBudget output, “Stream Leakage.” Positive values are flows into the groundwater subbasin and negative values are flows out of groundwater to surface water flow.

Deep percolation of precipitation is the volume of water percolating into groundwater from precipitation. This term was estimated using fractions calculated from the FB_details.OUT and applying those fractions to the Zonebudget “Farm Net Recharge” term. Using FB_details.OUT, the fraction ET_{precip} / (ET_{irrig} + ET_{precip}) was computed, where ET_{irrig} is the evapotranspiration from irrigation (applied water) and ET_{precip} is the evapotranspiration from precipitation (also called effective precipitation). This fraction was multiplied by the “Farm Net Recharge” term from Zonebudget to estimate the recharge from precipitation. The underlying assumption is that the relative contribution of precipitation to recharge is the same as that to evapotranspiration.

Boundary flow is the flow at each region’s boundary from either surface or basins from outside of the 21 subregions (not including inter-basin flow). For CVHM, only Region 9, the Delta, has boundary inflows. Positive values are flow into the groundwater subbasin and negative values are flows out of the subbasin.

Subsidence flows represent the effects of subsidence in each respective region on groundwater storage. For CVHM, subsidence flows are accounted for in the “Interbed Storage” term in ZoneBudget. Since this term had resulting values that were both positive and negative, it was evident that this term was not solely subsidence. However, the interbed storage flow would need to be accounted for in the CALVIN mass balance regardless of if it was solely subsidence or not, so this term was included in the External

Flows. Positive values are flow into the groundwater subbasin and negative values are flows out of the subbasin.

Evapotranspiration from groundwater is estimated by taking the negative irrigation recharge values from Zonebudget. This would be the fraction of Farm Net Recharge that is not recharge from precipitation and is negative, indicating a loss from the groundwater basin.

The average annual flows per region are summarized in Table 2.5. These flows are from the groundwater perspective; positive values are flows into the groundwater basin and negative values are flows out of the basin.

Table 2.5: Average Annual 1980-1993 CVHM-CALVIN External Flows (TAF/month)

Subregion	Inter-basin	Stream Leakage	Deep Perc. from Precipitation	Boundary flow	Subsidence	ET from GW	Net External Flow
1	-312.1	-131.5	440.2	0.0	18.3	-8.0	6.8
2	44.2	-293.1	631.4	0.0	23.6	-0.0	406.1
3	-225.8	-234.0	613.5	0.0	1.7	-124.5	30.9
4	558.6	-533.4	260.6	0.0	-0.4	-262.2	23.2
5	-184.9	-213.3	690.1	0.0	0.0	-227.8	64.2
6	-47.2	13.8	556.4	0.0	-0.3	-69.3	453.5
7	19.4	-42.9	278.0	0.0	7.6	-75.8	186.2
8	50.3	84.8	546.4	0.0	5.1	-0.7	685.8
9	237.7	551.8	263.2	-90.5	-0.6	-515.5	446.1
10	-79.9	38.2	158.0	0.0	15.1	-101.4	30.0
11	-54.9	-102.3	180.7	0.0	0.6	-4.3	19.8
12	-73.4	20.7	137.5	0.0	2.2	-29.2	57.9
13	-0.8	125.3	350.6	0.0	92.7	-3.6	564.2
14	85.2	5.6	100.5	0.0	69.1	0.0	260.4
15	621.8	177.6	177.4	0.0	140.2	0.0	1117.0
16	-196.1	35.0	106.4	0.0	45.9	0.0	-8.8
17	-176.8	174.8	159.7	0.0	40.3	0.0	197.9
18	-20.1	106.9	217.6	0.0	259.9	0.0	564.3
19	212.2	0.0	93.7	0.0	103.8	0.0	409.7
20	-164.4	19.3	62.2	0.0	104.0	0.0	20.9
21	-292.9	107.2	79.3	0.0	42.4	0.0	-63.9
Sac TOTAL	140.1	-797.8	4279.9	-90.5	54.9	-1283.7	2302.9
SJ TOTAL	-209.0	81.9	826.8	0.0	110.6	-138.5	671.8
TL TOTAL	68.8	626.4	996.7	0.0	805.6	0.0	2497.5
CV TOTAL	0.0	-89.6	6103.4	-90.5	971.1	-1422.2	5472.2

Pumping Capacity

This term is the upper-bound constraint for groundwater pumping in CALVIN. These are estimated as the maximum values of pumping extracted from the ZoneBudget output, "Farm Wells" from 1980 to 1993. These capacities are shown in Table 2.6.

Pumping Lift

Depth to groundwater ("pumping depth" or "pumping lift") is used in CALVIN to determine agricultural pumping costs. CALVIN assumes a fixed cost per foot of lift and these calculated costs are used as model inputs (CALVIN Appendix G, 2001). Depth to Groundwater is essentially the ground surface elevation minus the water elevation. Taking these values from the input and output files for the original CVHM run for year 2000, the average lift per region was calculated. The head values used were from MODFLOW so they represent the average head for a 1 square mile cell, and not the water level in a well, which will typically be lower. This indicates that this value, in addition to all other assumptions, is likely to be an overestimate since the average head is likely to be a smaller value than the effective water level. These average lift values are summarized in Table 2.6.

Since DWR measured groundwater level data for year 2000 exists, it was decided that using measured data of groundwater heads would best represent pumping lift for these regions. Details of how these averages were calculated can be found in Appendix 2. These average lift values are also summarized in Table 2.6.

Table 2.6: CVHM Pumping Terms and DWR Measured Well Depths

Subregion	Pumping Capacity (TAF/mo)	CVHM 2000 Pumping Depth (ft)	DWR 2000 Average Measured Well Data (ft)
1	2.3	153	71
2	354.7	43	40
3	4.4	63	27
4	2.4	N.A.	16
5	25.1	14	27
6	181.8	57	25
7	73.8	19	40
8	474.5	17	90
9	90.0	43	24
10	7.9	73	17
11	22.8	22	47
12	19.0	42	68
13	524.5	113	75
14	214.8	176	235
15	1066.5	36	93
16	32.1	123	57
17	275.5	80	34
18	570.8	186	80
19	471.2	165	139
20	162.2	366	298
21	113.3	250	191

Storage

The maximum storage is the upper-bound constraint for groundwater storage capacity in CALVIN. The "Storage" term from the Zonebudget post-processor is used here. The data in Zonebudget represents change in storage. Effective storage is used for this term to represent the absolute maximum available water. Calculation is as follows:

1. Arbitrarily set the initial storage to a very large number ($1x10^9$) such that the created storage time series is never negative.
2. Once storage values are converted from change in storage to storage, the effective storage can be calculated: Absolute Maximum storage – Absolute Minimum Storage (note that the original arbitrarily high number is now cancelled out).

The initial storage was calculated to be the effective initial storage, the maximum amount of water available in September 2003. This was calculated: Storage in 2003- Absolute Minimum storage. The results are shown in Table 2.7 below. A more detailed discussion of the method can be found in Appendix 1.

Change in storage is also estimated directly from the Zonebudget storage change values. The totals of changes in storage per month for 1980-1993 are summed up by year and averaged to get the average annual change in storage. Then this yearly change in storage value is multiplied by 72 years to get an estimated storage change for 72 years. These storage changes are shown in the last column of Table 2.7. Positive values indicate overdraft and negative values indicate an increase in groundwater storage. The ending storage values were calculated from the initial storage minus the change in storage over 72 years. Additional overdraft scenarios and calculation methods will be discussed in Chapter 5.

Table 2.7: CVHM Storage Capacity, Initial & Ending Storage, and 1921-1993 Change in Storage (TAF)

Subregion	Maximum Storage Capacity	Initial Storage	Ending Storage	Change in Storage*
1	19,543	16,346	13,302	3,045
2	33,133	19,031	15,954	3,077
3	22,782	10,350	11,124	-773
4	15,730	8,552	9,810	-1,257
5	23,850	16,587	16,897	-311
6	34,350	11,683	15,140	-3,457
7	12,190	10,180	9,148	1,032
8	31,153	12,230	10,634	1,595
9	81,528	18,419	29,742	-11,323
10	20,844	11,311	11,061	251
11	10,704	4,905	4,617	289
12	16,651	3,683	4,407	-723
13	48,168	33,636	22,880	10,756
14	32,789	32,789	23,293	9,495
15	38,000	22,341	9,786	12,555
16	27,274	27,274	17,839	9,435
17	31,370	24,960	15,818	9,142
18	58,956	58,956	38,607	20,349
19	28,006	28,006	20,750	7,256
20	20,229	20,229	13,575	6,654
21	58,804	58,699	53,088	5,611
Sac TOTAL	274,260	123,377	131,750	-8,372
SJ TOTAL	96,367	53,536	42,964	10,572
TL TOTAL	295,428	273,254	192,757	80,497
CV TOTAL	666,055	450,167	367,470	82,697

* Positive values indicate overdraft and negative values indicate an increase in groundwater storage.

Calibration Flow

For each groundwater basin, a mass balance could be achieved with a calibration flow to correct for the model error. To determine the mass balance, only the flows that directly flow in and out of the groundwater basin were considered: external flows, pumping, recharge from applied water, and changes in storage. Figure 2.3 shows these components and flow interactions. Recharge to groundwater, pumping, and storage changes ultimately will be modeled explicitly in final CALVIN, since these are actively managed as decision variables with associated management costs. But to check CVHM's representation of groundwater flows, the recharge flows and changes in storage are extracted and used here. As mentioned earlier, the change in storage is an output in the Zonebudget post-processor. The recharge flows are only the positive recharge flows from applied water (irrigation) because the recharge from precipitation and negative recharge terms are included in the external flows term. The mass balance results are summarized in Table 2.8. As seen in the results, the calibration flows to achieve the mass balance are rather small, which agrees with CVHM results presented in Faunt et al. 2009. In the overall CALVIN network, if the calibration flow was to be added or removed from the system, it would not be a direct interaction with the groundwater basin, as shown in Figure 1.3.

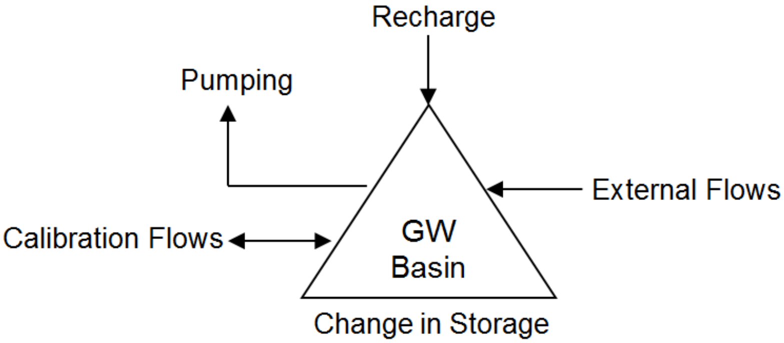


Figure 2.3: Groundwater Mass Balance Flows

Table 2.8: 13-year Average Annual Groundwater Mass Balance (TAF/yr)

Subregion	External Flows (+/-)	Pumping (-)	Total Recharge from Applied Water (+)	Change in Storage (+/-)	Calibration Flow (+/-)
1	7	49	0	-42	0
2	406	542	93	-43	0.02
3	31	32	12	11	0.04
4	23	6	1	17	0.08
5	64	62	2	4	0.02
6	453	414	8	48	0.18
7	186	201	1	-14	0.05
8	686	843	135	-22	0.03
9	446	284	2	157	3.44
10	30	45	13	-3	0.98
11	20	74	51	-4	0.12
12	58	59	13	10	0.88
13	564	816	104	-149	0.86
14	260	588	196	-132	0.01
15	1117	1837	547	-174	0.8
16	-9	184	62	-131	0.06
17	198	495	170	-127	0.18
18	564	1288	442	-283	0.09
19	410	725	215	-101	0.07
20	21	273	160	-92	-0.01
21	-64	183	170	-78	0.37
Sac Total	2303	2433	255	116	4
SJ Total	672	993	181	-147	3
TL Total	2498	5573	1961	-1118	2
CV Total	5472	8999	2396	-1149	8

Urban Return Flow

CVHM accounts for urban land use in its calculation of crop efficiencies; urban land use is considered a "virtual crop" as seen in Table 2.3 above. Specific fractions for just urban return flows were not separated for CVHM. Urban flows are generally small compared to agricultural flows so the return flows are also generally lower. CVGSM and C2VSIM do account for this term separately, and this is discussed in the next chapter, which compares the three models.

Discussion

This chapter focuses on how CVHM was summarized for the CALVIN update project. Although CVHM was ultimately not used as the groundwater basis for the updated CALVIN model, studying the model and calculating the terms provided useful insights during the calibration process and in the overdraft studies (Chapter 5). Future versions of CVHM will likely fit CALVIN purposes more closely and should be considered again when it is time for the next CALVIN groundwater update. The next chapter will present and compare the calculated terms for CALVIN from CVHM, C2VSIM, and CVGSM.

CHAPTER 3

Comparison of Models and Calculated Terms

This chapter discusses and compares the CALVIN calculated terms from C2VSIM, CVHM, and CVGSM. CVGSM was based on IGSM, a basin planning model that includes groundwater, surface water, groundwater quality and reservoir operation simulation routines (USBR 1997). C2VSIM is based on IWFM, whose precursor was the IGSM, but has been renamed to IWFM since many major changes and improvements were made. The calculated CALVIN terms show this similarity in the basis of the model's results in similar calculations and representations of some terms. CVHM is MODFLOW based with the Farm Process (FMP) package, which treats and represents many terms very differently than IWFM and IGSM, so some calculated terms differ greatly. However, some terms show strong agreement between CVHM and C2VSIM when compared with CVGSM, likely due to the more detailed discretization, calibration, and use of accepted and tested algorithms. IWFM and MODFLOW-FMP are newer models that address the physical and economic water balance in a watershed, allowing for simulations that account for both physical flow processes and water management practices. A detailed description and comparison of the theory, approaches, and features of the two models can be found in Dogrul et al. 2011. A comparison of IGSM and older versions of MODFLOW can be found in LaBolle et al. 2003.

Calculated Terms Comparison

The 21 groundwater subbasins (subregions) in all three models correspond with the CVPM regions used in CALVIN, allowing for direct comparisons. The same calculated terms for each model often account for additional flows or features that might be accounted for in a different term in the other model. Many different term calculation methods were used and the ultimate decision to use one method over others was based on trying to capture the term as best suited for representation in CALVIN, as a water management model, and looking at how the term compared with the other models and measured data. Different methods used in the calculations cause some differences in the calculated terms. Because C2VSIM output terms are similar to those of CVGSM, the calculations used for these two models were often more similar than the calculations used to calculate CALVIN terms from CVHM results. The effects of the differences in methods will be discussed in the sections below and the detailed descriptions of the terms can be found in Appendix J (Jenkins et al. 2001 and Davis et al. 2001), and Appendix 1 and 3 of this thesis. The various parameters representing groundwater in CALVIN are summarized in Table 1.2 and Figure 1.3. The comparison is structured by these sections below.

Agricultural Return Flow Splits

Table 3.1 shows some large differences for Agricultural Return Flow Splits between the models. The calculations for C2VSIM and CVGSM follow similar methods but result in very different splits. Detailed calculations and equations can be found in Appendix J and Appendix J-2 (II) (Zikalala et al. 2012). C2VSIM and CVGSM fractions are based on using model outputs and taking fractions of these to represent these splits. C2VSIM's fractions generally have higher return flows to groundwater, which agrees with CVHM, whose methods are based on taking the averages of fractions of surface water runoff from irrigation for each subregion from CVHM input files. Both newer groundwater models imply more irrigation return flow is to groundwater throughout the Central Valley.

Table 3.1: Agricultural Return Flow Splits to Groundwater

Subregion	C2VSIM	CVHM	CVGSM (1997)
	GW	GW	GW
1	0.28	0.99	0.45
2	1.00	0.98	0.69
3	0.60	0.97	0.60
4	0.99	0.96	0.12
5	0.72	0.97	0.59
6	0.98	0.97	0.37
7	1.00	0.98	0.42
8	0.93	0.98	0.14
9	1.00	0.96	0.74
10	0.94	0.95	0.21
11	0.94	0.97	0.65
12	0.94	0.96	0.22
13	0.97	0.97	0.25
14	1.00	0.92	1.00
15	1.00	0.94	0.30
16	0.84	0.98	0.13
17	1.00	0.97	0.42
18	1.00	0.96	0.99
19	1.00	0.97	1.00
20	0.82	0.97	0.59
21	1.00	0.96	0.94

Agricultural Reuse Amplitudes

As mentioned in Chapter 2, the non-reuse amplitude is 1 (no reuse) for all CVHM regions, neglecting local tailwater reuse. For CVGSM, the reuse fractions were a direct output in the model, but as seen in Table 3.2, amplitudes were quite high for reuse. When these amplitudes were used for the original CALVIN groundwater, they were some of the first to be adjusted (decreased significantly) during calibration, as discussed in the Chapter 4. In C2VSIM, the reuse amplitudes were calculated by summing the applied water and reused water and dividing that net sum by the applied water for the 1980 to 2003 time period. These values in Table 3.2 are significantly smaller than the earlier CVGSM values and seem fairly close to CVHM.

Table 3.2: Agricultural Reuse Amplitudes & Applied Water Return Flow Fractions

Subregion	Agricultural Reuse Amplitude			Agricultural Return Flow Fraction		
	C2VSIM	CVHM	CVGSM	C2VSIM	CVHM	CVGSM
1	1	1	1.32	0.47	0.26	0.39
2	1	1	1.26	0.14	0.27	0.29
3	1.086	1	1.28	0.20	0.17	0.35
4	1.001	1	1.21	0.14	0.21	0.35
5	1.049	1	1.283	0.21	0.2	0.37
6	1.001	1	1.08	0.06	0.23	0.28
7	1	1	1.3	0.25	0.23	0.45
8	1.003	1	1.23	0.12	0.25	0.33
9	1	1	1.21	0.09	0.22	0.21
10	1.003	1	1.33	0.20	0.21	0.4
11	1.005	1	1.272	0.22	0.23	0.43
12	1.004	1	1.18	0.16	0.24	0.34
13	1.002	1	1.18	0.12	0.21	0.27
14	1	1	1.22	0.18	0.13	0.26
15	1	1	1.21	0.12	0.24	0.27
16	1.015	1	1.18	0.28	0.19	0.45
17	1	1	1.17	0.13	0.2	0.27
18	1	1	1.25	0.18	0.21	0.31
19	1	1	1.21	0.03	0.23	0.29
20	1.014	1	1.17	0.10	0.19	0.3
21	1	1	1.25	0.10	0.19	0.32

Applied Water Return Flow Fractions

Table 3.2 shows that Agricultural Return Flow Fractions for CVHM and C2VSIM are generally lower than those of CVGSM. C2VSIM's fractions are calculated as the total applied water not consumptively used divided by the total applied water, where the terms used were determined following the calculations for Agricultural Return Flow Split. CVHM's values were determined by using the published composite efficiency values (evapotranspiration of applied water, ETAW) per region as discussed in Chapter 2 (Return Flow % = 1-ETAW %). CVGSM's return flow fractions are based on CVGSM NAA output data (Return Flow % = 1 – On-farm Efficiency %). DWR Bulletin 160-98 also had efficiencies published at the time, and they were generally higher than those from the CVGSM output, resulting in lower return flow fractions. So that was a primary basis for adjusting the CVGSM return flow fractions when calibrating the groundwater system in CALVIN in 2001. The calibration steps taken for the current update CALVIN are discussed in Chapter 4.

External Flows

External flows are entered into CALVIN for each subregion as a source time series. Some external flow terms were directly extracted from results files of the groundwater models, but a few required some calculations, as discussed below. Overall, the average annual external flows for C2VSIM and CVHM seem to follow a similar trend throughout the regions when comparing the 1980-1993 time period, which can be seen in Table 3.3 and Figure 3.1.

Table 3.3: Average Annual (1980-1993) Net External Flows (TAF/yr)

Subregion	C2VSIM[a]	CVHM[b]
1	16.5	6.8
2	342.8	406.1
3	0.5	30.9
4	75.9	23.2
5	199.6	64.2
6	250.4	453.5
7	224.8	186.2
8	613.9	685.8
9	116.8	446.1
10	146.1	30.0
11	49.9	19.8
12	119.9	57.9
13	529.6	564.2
14	391.1	260.4
15	815.1	1117.0
16	65.6	-8.8
17	226.2	197.9
18	257.5	564.3
19	493.3	409.7
20	180.8	20.9
21	389.5	-63.9
SAC TOTAL	1841.2	2302.9
SJ TOTAL	845.5	671.8
TL TOTAL	2819.1	2497.5
CV TOTAL	5505.8	5472.2

[a] C2VSIM averages are based on adjusted flows for 1980-1993
[b] CVHM averages based on 1980-1993, same as Table 2.5

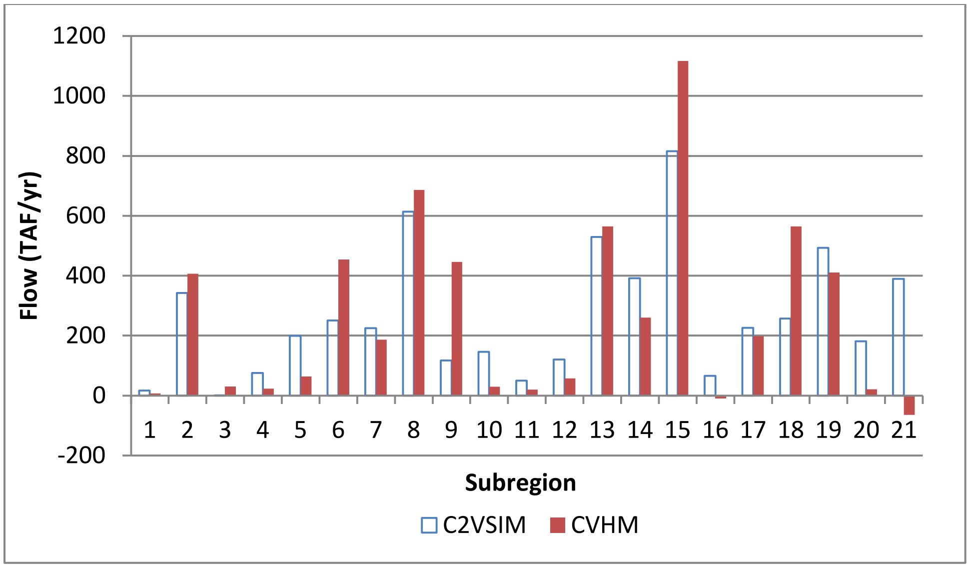


Figure 3.1: 1980-1993 Average Annual Net External Flows

The time period annual averages used to represent the models' external flows in CALVIN (1921-2009 for C2VSIM, 1980-1993 for CVHM, and 1921-1990 for CVGSM) are shown in Table 3.3a; these are the values that were input in CALVIN when comparing between models. These different time period-based external flows were used for each of the models because they were considered to be the best representation of updated land use and infrastructure. The CVGSM values are based on the entire time period of the CALVIN model run because that is what was used in the previous version of CALVIN. As seen in Table 3.3a, the average annual external flows for CVGSM are much larger than that of C2VSIM and CVHM. The newer models generally have more terms than CVGSM because the newer models break down the different terms more explicitly and it was decided to include all the time series terms to the external flow term so that a mass balance could be achieved. The breakdown yearly averages of each of the flows that comprise the net external flows averages are presented below in Tables 3.3b-d.

Table 3.3a: Average Annual Net External Flow Averages (TAF/yr)

Subregion	C2VSIM[a]	CVHM[b]	CVGSM[c]
1	28.2	6.8	1.6
2	176.8	406.1	402.5
3	-8.9	30.9	8.9
4	-95.5	23.2	260.6
5	66.9	64.2	144.2
6	180.4	453.5	367.1
7	168.2	186.2	277.5
8	401.5	685.8	747.4
9	84.8	446.1	13.7
10	72.2	30.0	296.1
11	-1.3	19.8	-158.8
12	48.7	57.9	155.1
13	344.1	564.2	863.1
14	278.2	260.4	308.6
15	594.2	1117.0	1160.8
16	51.2	-8.8	279.7
17	95.8	197.9	359.7
18	262.9	564.3	483.7
19	368.0	409.7	162.2
20	100.8	20.9	220.0
21	289.7	-63.9	387.2
SAC TOTAL	1002.4	2302.9	2223.5
SJ TOTAL	463.7	671.8	1155.5
TL TOTAL	2040.7	2497.5	3361.9
CV TOTAL	3506.8	5472.2	6740.9

[a] C2VSIM averages are based on adjusted flows for1921-2009
[b] CVHM averages based on 1980-1993
[c] CVGSM averages based on 1921-1993

Table 3.3b shows the Interbasin and Boundary Flows. Both terms are direct time series output results from the models or their post-processors. CVGSM shows a major problem with the interbasin flows because the net sum of the terms is not zero. Since interbasin flows are only the flows between basins, and not flows from outside the model boundary, the net sum of interbasin flows between regions should equal zero if a proper mass balance is to be represented. Although C2VSIM and CVHM have significant differences in their representation of interbasin flows, their overall totals are zero. This is a good example of the differences that arise between C2VSIM and CVHM due to their different methods and assumptions, but still achieve a mass balance. The Boundary Flows show significant differences between the three models.

Table 3.3b: Average Annual External Flows – Interbasin and Boundary Flows (TAF/yr)

Subregion	Interbasin Flows			Boundary Flows		
	C2VSIM[a]	CVHM[b]	CVGSM[c]	C2VSIM[a]	CVHM[b]	CVGSM[c]
1	25.7	-312.1	-28.2	84.0	0	0
2	-26.8	44.2	11.7	132.0	0	114.1
3	-18.5	-225.8	-72.8	45.6	0	14.4
4	49.4	558.6	115.1	0.0	0	0
5	-7.6	-184.9	-74.6	17.5	0	83.7
6	-24.3	-47.2	85.0	25.0	0	-9.2
7	-9.9	19.4	-3.2	75.3	0	62.5
8	91.7	50.3	278.9	111.7	0	22
9	-18.1	237.7	-127.4	13.8	-90.5	-16.1
10	-83.9	-79.9	-42.3	28.8	0	73.7
11	-60.4	-54.9	-118.0	0.0	0	0
12	-1.4	-73.4	-14.8	0.0	0	25.1
13	73.2	-0.8	184.8	0.0	0	70.2
14	72.6	85.2	-119.5	0.0	0	0
15	266.3	621.8	-1483.8	-53.4	0	15.1
16	-106.9	-196.1	160.2	7.8	0	54.2
17	-62.5	-176.8	48.1	3.9	0	6.8
18	-150.8	-20.1	72.8	23.5	0	67.7
19	56.1	212.2	-128.0	4.1	0	234.1
20	-110.7	-164.4	86.9	49.2	0	85.4
21	46.9	-292.9	-361.4	52.1	0	58.6
SAC TOTAL	61.6	140.1	184.5	504.9	-90.5	271.4
SJ TOTAL	-72.6	-209.0	9.7	28.8	0.0	169.0
TL TOTAL	11.0	68.8	-1724.7	87.2	0.0	521.9
CV TOTAL	0.0	0.0	-1530.5	620.9	-90.5	962.3

[a] C2VSIM averages are based on adjusted flows for1921-2009
[b] CVHM averages based on 1980-1993
[c] CVGSM averages based on 1921-1993

Table 3.3c shows groundwater-surface water (GW/SW) interaction from streams and lakes, and deep percolation of precipitation. GW/SW interaction from streams and lakes are direct outputs from the models or their post-processors. As can be seen in the table, CVHM does not represent GW/SW interaction from lakes (a small matter for the current Central Valley). Overall, the differences for GW/SW interaction from streams vary widely. And since this term is a direct output from the models, no adjustments were made here. This is another good example showing the differences between models and their representation of surface water and groundwater interaction.

The deep percolation from precipitation terms for C2VSIM and CVGSM are calculated in similar methods following the calculations for agricultural return flow splits. CVHM calculation of this term is based on the farm net recharge output and evapotranspiration splits. This term is significantly higher for CVHM than C2VSIM and CVGSM, likely largely due to the calculation method. The precipitation input data for C2VSIM and CVHM were compared and confirmed to be very similar. So this difference in deep percolation from precipitation between the two models is likely due to both the CALVIN term calculation methods and the methods in the groundwater models themselves. These differences are substantial, especially for the Sacramento Valley.

Table 3.3c: Average Annual External Flows - Deep Percolation from Streams, Lakes, & Precipitation (TAF/yr)

Subregion	GW/SW Interaction: streams			GW/SW Interaction: lakes			DP from Precipitation		
	C2VSIM[a]	CVHM[b]	CVGSM[c]	C2VSIM[a]	CVHM[b]	CVGSM[c]	C2VSIM[a]	CVHM[b]	CVGSM[c]
1	-235.3	-131.5	-77.6	0	0	0	137.3	440.2	107.4
2	-73.1	-293.1	46.6	0	0	0	134.4	631.4	223.7
3	-161.0	-234.0	-38.1	0	0	0	87.8	613.5	95.7
4	-323.1	-533.4	102.0	0	0	0	101.7	260.6	43.5
5	-190.7	-213.3	-18.4	0	0	0	144.8	690.1	148.3
6	45.2	13.8	201.5	0	0	0	109.0	556.4	74.7
7	9.1	-42.9	158.3	0	0	0	61.7	278.0	45.7
8	64.7	84.8	373.2	0	0	0	121.2	546.4	71.5
9	-3.1	551.8	15.3	0	0	0	84.0	263.2	141.9
10	-127.3	38.2	140.3	0	0	0	101.7	158.0	44.0
11	-180.0	-102.3	-324.8	0	0	0	78.8	180.7	153.8
12	-133.6	20.7	21.7	0	0	0	62.8	137.5	36.1
13	-34.9	125.3	388.9	0	0	0	163.9	350.6	92.5
14	0.0	5.6	0.0	0	0	352.7	45.6	100.5	51.3
15	-231.8	177.6	125.6	-53.4	0	2311.4	91.1	177.4	41.0
16	12.3	35.0	0.0	0	0	0	80.0	106.4	16.6
17	-23.0	174.8	144.2	0	0	0	112.3	159.7	61.0
18	-33.5	106.9	125.1	0	0	0	105.5	217.6	91.3
19	-160.5	0.0	0	0	0	0	46.1	93.7	51.3
20	26.5	19.3	0	0	0	0	61.7	62.2	36.3
21	80.5	107.2	205.4	-6.7	0	389.2	46.1	79.3	75.7
SAC TOTAL	-867.3	-797.8	762.8	0	0	0	981.9	4279.9	952.4
SJ TOTAL	-475.8	81.9	226.1	0	0	0.0	407.3	826.8	326.4
TL TOTAL	-329.4	626.4	600.3	-60.1	0	3053.3	588.5	996.7	424.5
CV TOTAL	-1672.6	-89.6	1589.2	-60.1	0	3053.3	1977.6	6103.4	1703.3

[a] C2VSIM averages are based on adjusted flows for1921-2009
[b] CVHM averages based on 1980-1993
[c] CVGSM averages based on 1921-1993

Table 3.3d shows the subsidence, diversion losses to groundwater (gains to groundwater), and losses from groundwater. For C2VSIM and CVHM, subsidence results are directly from model outputs or from post-processors. There seems to be some trends between the two models for subsidence, but CVHM generally has more subsidence gains to the basin than C2VSIM. No subsidence term was used from CVGSM.

Diversion losses to groundwater, or conveyance seepage flows, are a loss from the surface water irrigation or conveyance system, which is a gain to the groundwater basin. CVHM does not explicitly represent this term but it is accounted for when calculating the crop efficiencies, which is discussed in Chapter 2 and in Appendix 1. This term is an input to CVGSM and is reported in C2VSIM's result post-processor. Estimated canal losses have decreased over time, as seen from time series data for the individual regions. It is unlikely that an up-to-date model like C2VSIM would suggest higher diversion losses over time so the likely reason there are more diversion losses from canals represented in C2VSIM than CVGSM could be that CVGSM was somehow underestimating diversion water that was being lost to the groundwater basins.

Tile drain outflow represents the practice of removing excess water from upper layers of some groundwater basins. Of the 3 models, this is only represented in C2VSIM and only in regions 10 and 14.

Evapotranspiration losses from groundwater are a time series output from CVHM (from FB_Details.OUT). This term is not included in external flows for CALVIN since the non-recoverable (and recoverable) losses are accounted for by an amplitude on the surface water side. This was necessary for CVHM due to the methods used to calculate some of the other terms in CVHM. Evapotranspiration losses needed to be subtracted in the net external flows for CVHM because terms like the deep percolation from precipitation have significantly higher flows to the groundwater basins because the evapotranspiration losses are accounted for separately as its own term, which does not seem to be the case for C2VSIM or CVGSM. CALVIN and C2VSIM represent evapotranspiration losses and conveyance losses as a fraction on the surface water side, and these are discussed and tabulated in Appendix 5. This is another reason CVHM was not ultimately used for the update project because trying to account for this difference would have required more changes to CALVIN's basic framework (CALVIN's surface water loss fractions would all need to be changed to 1 to indicate no non-recoverable or recoverable losses on the surface water side for CVHM). Although the loss on the surface water side is accounted for by the loss fraction in C2VSIM and CVGSM, the recoverable loss from the surface water as a gain to the groundwater side needs to be added back to the system. Since the CALVIN network does not represent this directly, the external flows term includes that recoverable loss from surface water as a gaining flow to the groundwater system.

Table 3.3d: Average Annual External Flows – Subsidence, Diversion Gains, and Losses from Groundwater (TAF/yr)*

Subregion	Subsidence[1]			Diversion Losses to GW (Gains)			Tile Drain Outflow	Evapo-transpiration Loss
	C2VSIM[a]	CVHM[b]	CVGSM[c]	C2VSIM[a]	CVHM[b]	CVGSM[c]	C2VSIM[s]	CVHM[b]
1	-0.02	18.27	0	16.5	0	0	0	-8.0
2	0.01	23.61	0	10.4	0	6.4	0	0
3	0.78	1.69	0	36.5	0	9.7	0	-124.5
4	0.90	-0.37	0	75.6	0	0	0	-262.2
5	0.00	0.05	0	103.0	0	5.2	0	-227.8
6	5.13	-0.33	0	20.2	0	15.1	0	-69.3
7	0.01	7.56	0	32.0	0	14.2	0	-75.8
8	0.05	5.07	0	12.1	0	1.8	0	-0.7
9	0.11	-0.60	0	8.1	0	0	0	-515.5
10	42.35	15.11	0	141.4	0	80.4	-30.8	-101.4
11	0.01	0.57	0	160.2	0	130.2	0	-4.3
12	0.02	2.20	0	120.9	0	87	0	-29.2
13	9.21	92.70	0	132.6	0	126.7	0	-3.6
14	128.39	69.07	0	33.2	0	24.1	-1.5	0
15	78.99	140.19	0	496.5	0	151.5	0	0
16	0.14	45.87	0	57.8	0	48.7	0	0
17	0.25	40.29	0	64.8	0	99.6	0	0
18	70.69	259.94	0	247.5	0	126.8	0	0
19	43.97	103.84	0	378.2	0	4.8	0	0
20	46.59	103.96	0	27.5	0	11.4	0	0
21	48.77	42.43	0	22.0	0	19.7	0	0
SAC TOTAL	7.0	54.9	0	314.4	0	52.4	0	-1283.7
SJ TOTAL	51.6	110.6	0	555.2	0	424.3	-30.8	-138.5
TL TOTAL	417.8	805.6	0	1327.4	0	486.6	-1.5	0
CV TOTAL	476.4	971.1	0	2196.9	0	963.3	-32.3	-1422.2

*Positive values are flows into the groundwater basin and negative values are flows out of the basin.

[1] Subsidence for CVHM was actually the Interbed storage, which includes subsidence but is not entirely subsidence alone.

[a] C2VSIM averages are based on adjusted flows for1921-2009

[b] CVHM averages based on 1980-1993

[c] CVGSM averages based on 1921-1993

Although both C2VSIM and CVHM seem to represent Central Valley groundwater much better than the older CVGSM, there are still significant differences between the new, improved models, implying some level of uncertainty in the general understanding of Central Valley groundwater.

Pumping Terms

The pumping capacities and pumping depths are shown in Table 3.4. The pumping capacities for C2VSIM and CVHM are the maximum values of pumping for the period1980-1993. CVGSM capacities are the maximum monthly pumping for the period 1922-1990. If pumping volume is greater than 100 TAF, capacity is set to 110% of maximum value; otherwise, capacity is set to 105% of maximum value. The values shown in Table 3.4 do not include the correction factor.

The pumping depths for C2VSIM and CVHM were explicitly calculated using the heads from the input files. CVGSM depths to groundwater were not available for the previous CALVIN study so the depths to groundwater were pieced together from analyses for the Draft CVPIA PEIS (USBR 1997). Since there was some uncertainty in the C2VSIM and CVHM calculations and DWR measured groundwater level data exists, measured static water level was assumed to be the most appropriate and accurate set of data to be used for the CALVIN groundwater update (Appendix 2).

Table 3.4: Pumping Capacities and Depths

Subregion	Pumping Capacity (TAF/month)			Pumping Depth (ft)			
	C2VSIM	CVHM	CVGSM	C2VSIM	CVHM	Old CALVIN	DWR*
1	7.2	2.3	18.9	175	153	130	71
2	93.2	354.7	145.9	144	43	120	40
3	175.8	4.4	162.8	104	63	100	27
4	109.2	2.4	105.2	17	NA	60	16
5	240.1	25.1	214.9	35	14	75	27
6	85.7	181.8	141	64	57	70	25
7	120.5	73.8	87.3	95	19	95	40
8	185.6	474.5	198.5	148	17	110	90
9	43.9	90	67.1	30	43	80	24
10	185.2	7.9	188.5	80	73	60	17
11	64.9	22.8	47.5	54	22	75	47
12	86.9	19	73.2	48	42	90	68
13	225.8	524.5	277.1	108	113	125	75
14	221.1	214.8	317	373	176	350	235
15	335.3	1066.5	388.5	73	36	210	93
16	61.8	32.1	55.2	59	123	130	57
17	152.6	275.5	145.1	145	80	130	34
18	238.4	570.8	332.3	180	186	200	80
19	213.7	471.2	163	407	165	310	139
20	125.3	162.2	103	429	366	310	298
21	265.6	113.3	217.4	592	250	310	191

* Average Measured Groundwater Level Data

Constraining a minimum pumping rate would ideally help represent parts of the Central Valley that exclusively depend on groundwater. However, none of the models seemed to have sufficiently detailed calibrations to provide such insights.

Storage Terms

Table 3.5 shows the storage related terms. The storage values for C2VSIM are output by the results post-processor. The maximum storage capacity was set by taking the maximum storage at any time from 1980-2003. For C2VSIM, the initial storage was set to be the storage at the end of 2005. CVHM's storage terms are calculated by using the maximum effective storage for the maximum capacity (maximum value minus minimum value for 1980-1993) and the effective storage based on September 2003 (September 2003 storage minus minimum value for 1980-1993). CVGSM storage capacities were extracted directly from the model output, as with C2VSIM.

Actual groundwater storage capacity in California is unknown and is not accurately measureable at this time. The California DWR Groundwater Bulletin 118 estimates that the groundwater storage capacity for the whole state can be anywhere between 850 million acre-feet (MAF) to 1.3 billion acre-feet. The C2VSIM results for maximum storage are a much larger estimate of groundwater storage, since the sum total for just the Central Valley exceeds the Bulletin's estimates for the whole state. CVHM's storage seems comparable to the estimates presented in the Groundwater Bulletin. It is important to have a reasonable initial storage since CALVIN does not model water levels, but change in storage; the initial storage is essentially a reference starting point. But ultimately, when considering CALVIN results, the change in storage results could be applied to any initial storage so long as there is still water available in the basin.

Overdraft is estimated directly from the change in storage values for CVHM and C2VSIM. The storage change per month is summed over a long time period and divided by the number of years in that time period to get the average annual storage change for that time period. C2VSIM's average was based on 1980-2009 (29 years) and CVHM's average was based on 1980-1993 (13 years). Then this yearly storage change value is multiplied by 72 years to estimate total change in storage for 72 years. Positive values indicate overdraft and negative values indicate recharge to groundwater. CVGSM storage change was estimated for Table 3.5 by subtracting the initial storage from the ending storage from the model output.

As seen in the change in storage region totals at the bottom of Table 3.5, the differences are large in the Sacramento region, with CVHM showing overall gain to the groundwater storage and C2VSIM showing 12 MAF of overdraft. The estimated overdraft for the San Joaquin region also differs widely between the three models, with CVGSM being 8 MAF less than CVHM, and CVHM 4 MAF less than C2VSIM. The total Central Valley modeled overdraft from 1921-1993 are close for C2VSIM and CVHM, at 80 MAF, which is significantly less in CVGSM, at about 28 MAF. The largest difference in magnitude of overdraft between the three models is the Tulare region. If only the San Joaquin and Tulare regions were totaled, CVHM would have 20 MAF more overdraft than C2VSIM, but with the addition of 8 MAF of groundwater inflow modeled in CVHM’s Sacramento region, C2VSIM and CVHM have very close total Central Valley estimated overdraft values. Given the variability in groundwater use and recharge, estimates of overdraft are also quite variable with different method used for long term averaging. Additional overdraft scenarios and calculation methods will be discussed in Chapter 5.

Table 3.5: Maximum Storage Capacity, Initial Storage, and Change in Storage (TAF)

Subregion	Maximum Storage Capacity			Initial Storage			Change in Storage from 1921-1993*		
	C2VSIM	CVHM	CVGSM	C2VSIM	CVHM	CVGSM	C2VSIM	CVHM	CVGSM
1	38,510	19,543	5,448	38,447	16,346	1902	-990	3,045	128
2	136,757	33,133	24,162	136,494	19,031	24,905	-882	3,077	601
3	133,958	22,782	22,127	132,687	10,350	31,526	939	-773	-200
4	61,622	15,730	15,362	60,728	8,552	16,750	220	-1,257	-231
5	92,020	23,850	24,399	91,113	16,587	29,285	656	-311	991
6	175,719	34,350	22,864	174,968	11,683	34,169	-307	-3,457	1,871
7	58,484	12,190	12,270	56,539	10,180	14,448	5,330	1,032	-2,143
8	193,433	31,153	32,842	190,665	12,230	38,110	7,836	1,595	6,090
9	139,752	81,528	23,395	139,472	18,419	33,723	-362	-11,323	-2,730
10	91,920	20,844	29,250	90,210	11,311	72,159	3,155	251	-1,264
11	59,302	10,704	15,543	58,838	4,905	22,157	592	289	2,201
12	43,510	16,651	13,919	42,602	3,683	19,687	1,737	-723	966
13	142,508	48,168	47,484	138,216	33,636	53,506	9,656	10,756	-26
14	181,001	32,789	65,235	178,840	32,789	120,766	6,831	9,495	5,312
15	313,759	38,000	90,978	309,643	22,341	145,888	2,977	12,555	79
16	64,915	27,274	11,650	64,696	27,274	13,739	257	9,435	6,359
17	98,836	31,370	13,942	97,214	24,960	12,820	3,561	9,142	306
18	322,480	58,956	59,544	321,375	58,956	59,454	-11,063	20,349	6,828
19	147,060	28,006	68,266	141,750	28,006	77,268	13,526	7,256	-2
20	141,457	20,229	40,814	137,073	20,229	27,178	11,937	6,654	-773
21	351,327	58,804	81,622	341,142	58,699	88,838	27,903	5,611	4,007
SAC TOTAL	1,030,255	274,260	182,869	1,021,114	123,377	232,622	12,441	-8,372	4,377
SJ TOTAL	337,241	96,367	106,196	329,867	53,536	167,509	15,140	10,572	1,876
TL TOTAL	1,620,834	295,428	432,051	1,591,732	273,254	545,951	55,930	80,497	22,116
CV TOTAL	2,988,329	666,055	721,116	2,942,713	450,167	946,082	83,511	82,697	28,369

*Positive values represent overdraft and negative values represent gains to groundwater.

Urban Return Flow

As mentioned above, CVHM includes urban land use in the calculation of the farm efficiencies. C2VSIM and CVGSM include urban return flows separately so a return flow fraction can be calculated. C2VSIM simulates land use processes within the urban areas including groundwater pumping and surface water supply to meet urban demand, urban water supply shortage or surplus, and flow in excess of demand is returned to surface water bodies or to groundwater. In urban areas, a *Rootzone budget output* file tabulates monthly volumes of precipitation, runoff, applied water to urban regions, net return flow of applied water to surface water, and water that goes to the unsaturated zone as deep percolation. The algorithms for separating infiltration of applied water from the total monthly volume infiltrated and calculation of total return flows to SW and GW are similar to that described above. Calculated fractions show that for the Sacramento region, all water returned from urban regions returns to SW, whereas for the San Joaquin and Tulare regions all of the return flow infiltrates to GW. As seen in Table 3.6, C2VSIM representation of urban return flow fraction varies widely across all regions.

Table 3.6: Urban Return Flow Fractions

Subregion	**Urban Return Flow to GW**		**Urban Return Flow to SW**		**Total Urban Return Flow**	
	C2VSIM	CVGSM	C2VSIM	CVGSM	C2VSIM	CVGSM
1	0	0.501	0.496	0	0.496	0.501
2	0.001	0.522	0.521	0	0.522	0.522
3	0.001	0.503	0.495	0	0.496	0.503
4	0.001	0.504	0.497	0	0.498	0.504
5	0.001	0.515	0.508	0	0.509	0.515
6	0.004	0.533	0.524	0	0.528	0.533
7	0.002	0.006	0.519	0.53	0.521	0.536
8	0.002	0.005	0.532	0.522	0.534	0.527
9	0.001	0.524	0.524	0	0.525	0.524
10	0.455	0.528	0	0	0.455	0.528
11	0.477	0.537	0	0	0.477	0.537
12	0.474	0.528	0	0	0.474	0.528
13	0.464	0.526	0	0	0.464	0.526
14	0.452	0.512	0	0	0.452	0.512
15	0.449	0.51	0	0	0.449	0.51
16	0.476	0.005	0	0.516	0.476	0.521
17	0.471	0.522	0	0	0.471	0.522
18	0.468	0.528	0	0	0.468	0.528
19	0.448	0.512	0	0	0.448	0.512
20	0.5	0.518	0	0	0.5	0.518
21	0.465	0.005	0	0.514	0.465	0.519

Conclusions

CVHM and C2VSIM are up-to-date groundwater models whose methods and results have been reviewed and confirmed to be significant improvements from previous Central Valley groundwater models (i.e., CVGSM). Both new groundwater models have been designed and built with added detail to represent Central Valley groundwater hydrology and management practices. Both models are also undergoing improvements and updates. Although there are many differences between the models' methods and results, both can be useful for water managers and planners. The benefits and drawbacks of each model are subjective to the users of the model and what the models are being used for. Dogrul et al. 2011 discusses the differences of the theory, approaches, and features of the two models. Schmid et al. 2011 compares the models using a common hypothetical example.

For this CALVIN groundwater representation update, C2VSIM was used primarily because the model period for C2VSIM (1921-2009) matches the model period for CALVIN (1921-1993). It would have been possible to use CVHM (1961-2003), but a thoroughly estimated hydrology match would have been needed to extend CVHM's data back to 1921 in order for CVHM results to be used for the CALVIN external flows term. Another benefit was that since C2VSIM is essentially an updated and improved version of CVGSM, many of the calculation methods used in the past remained relevant. C2VSIM also had all the terms previously represented in CALVIN plus some updates, whereas CVHM sometimes combined some representation of CALVIN required terms in other areas and there was some doubt associated with the methods used to split these back out to CALVIN terms. However, throughout this project, there was much valuable correspondence with USGS regarding the uses of CVHM for CALVIN and many of the components that were difficult to calculate or not present in this version of CVHM will be present in future versions. Future updates to CALVIN groundwater should re-visit the idea of using CVHM for groundwater representation. CVHM is based on the widely used MODFLOW and many of the results in the current version are comparable with other studies (i.e. storage results) and physical measurements. The CVHM calculated terms and results were largely considered when calibrating the C2VSIM inputs to updated CALVIN; Chapter 4 discusses some of these considerations and presents the results of the updated CALVIN model.

CHAPTER 4

CALVIN with Updated Groundwater Representation

As discussed in the last chapter, the updated CALVIN groundwater representation is based primarily on C2VSIM. Another update that affects groundwater management is Delta pumping constraints, which are updated based on CALSIM II 2009 results (DWR 2011). This chapter presents the final terms used in CALVIN, discusses the calibration process, shows CALVIN network improvements, and compares the updated CALVIN with the previous version.

Updated CALVIN

The previous chapter compared the input terms between the groundwater models. However, C2VSIM had additional components that were not directly accounted for in CVHM and/or CVGSM. Table 4.1 shows the C2VSIM terms required to achieve a mass balance and used for the updated CALVIN model. Figure 4.1 is a schematic of the flows and interactions of these terms in the groundwater system in the updated CALVIN network. This schematic is similar to the flow interaction diagram in Chapter 1, but has some differences and also includes the nodes and links as in the updated CALVIN network. The schematic shows the hidden nodes, which are used in the model to separate the shadow value of the diversion from the shadow value of the delivery. This schematic does not show the calibration flow term since calibration flows were small and ultimately were not included. This schematic also includes artificial recharge, which was not previously explicit in the CALVIN groundwater system. Along with artificial recharge, some network improvements and simplifications were made by adding a few hidden nodes, and these changes are shown in red in the schematic.

Table 4.1: Groundwater Data Required by Updated CALVIN

Item	Data for CALVIN	Data type
1	Agricultural return flow split (GW & SW)	Fraction (1a+1b=1)
2	Internal reuse	Amplitude (≥1)
3	Return flow of total applied water	Amplitude (<1)
4	External flows	Monthly time series
4-1	Inter-basin flows	Monthly time series
4-2	Deep percolation from streams & lakes	Monthly time series
4-3	Deep percolation from precipitation	Monthly time series
4-4	Boundary inflow	Monthly time series
4-5	Subsidence	Monthly time series
4-6	Gains from diversions (conveyance seepage)	Monthly time series
4-7	Non-recoverable losses	Monthly time series
5	Groundwater pumping capacity (maximum & minimum)	Number value
6	Pumping lift (for pumping cost)	Number value & Cost ($)
7	Initial Storage	Number value
8	Ending Storage	Number value
9	Storage capacity (maximum & minimum)	Number value
10	Artificial Recharge Operation Cost	Cost ($)
11	Artificial Recharge Rate	Amplitude (<1)
12	Urban return flow	Amplitude (<1)

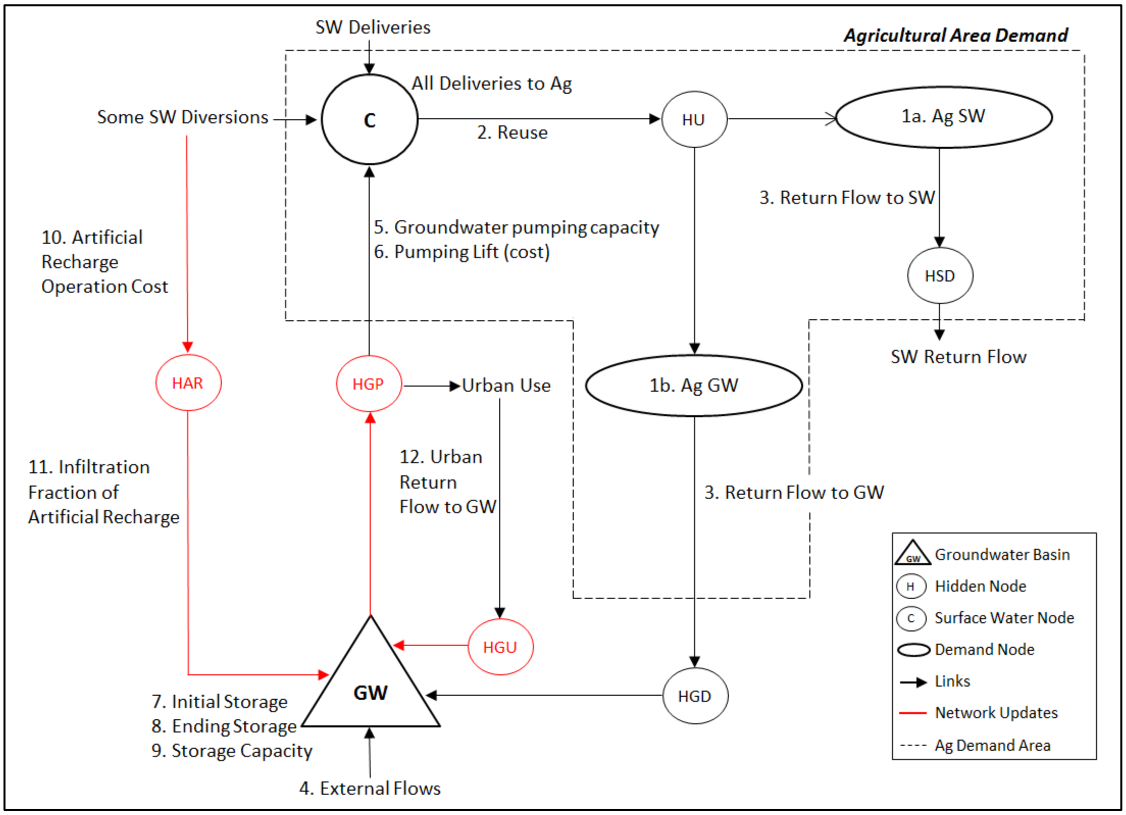


Figure 4.1 Updated CALVIN Groundwater Schematic

Network & Schematic Improvements

The schematic included the addition of the hidden nodes to simplify the direct groundwater interaction. The previous version of CALVIN had multiple pumping links and urban return flow links connected with the groundwater basins. Adding node "HGP" provides a link from groundwater which represents total pumping from the groundwater basin. From HGP, pumping is split between agricultural pumping and urban pumping. Similarly, the previous CALVIN had multiple urban return flows returning to the groundwater basin, and now combines return flows at "HGU" before returning to the aquifer. The link between HGU and the groundwater basin is the total urban return flow. Since C2VSIM represents artificial recharge for basins 13, 15-21, nodes and links for artificial recharge were added for those basins. A detailed description of the schematic updates is provided in Appendix 3.

Updated CALVIN & Old CALVIN Input Comparisons

The tables in this section compare the updated, calibrated CALVIN model and the CALVIN model prior to this groundwater update project. Table 4.2 shows the run numbers and a description of each run. Updated CALVIN will be referred to as "UPDATED CALVIN" and the previous version will be called "OLD CALVIN." These comparison tables will show and discuss the final values used for UPDATED CALVIN. A summary of the calibration process and reasons for some adjustments from the original C2VSIM inputs is discussed below.

Table 4.2: UPDATED CALVIN and OLD CALVIN

Run Name	Run Number	Description
"OLD CALVIN"	R17I03	The results from this run are discussed in Bartolomeo 2011. This is the "base" model for the groundwater update project.
"UPDATED CALVIN"	S07I14	This is the final calibrated run based primarily on C2VSIM groundwater terms and a hybrid CALSIM II-OLD CALVIN-based delta pumping & exports constraints.

Agricultural Return Flow, Reuse, and Total Applied Water Return Flow

Table 4.3 shows the Agricultural Return Flow to Groundwater fractions, the Reuse amplitudes, and the Total Applied Water Return Flow amplitudes. There are significant differences between old and UPDATED CALVIN for all three of these terms. UPDATED CALVIN has generally higher return flows to groundwater and lower reuse amplitudes. Many of the OLD CALVIN terms here were adjusted from the CVGSM based values in the groundwater calibration project from 2001. Details of why those earlier adjustments were made can be found in Appendix J and O (Jenkins 2001).

For the UPDATED CALVIN columns, the values adjusted during calibration are shown in bold italics and red. These particular values were adjusted based on comparisons with CVHM results and consideration of how reasonable the C2VSIM calculated value was. A summary of the calibration changes is in the calibration section below.

Table 4.3: UPDATED CALVIN Return Flow to Groundwater, Reuse, and Applied Water Return Flow

Subregion	Split Ag Return Flow to GW Fraction		Reuse Amplitude		Applied Water Return Flow Amplitude	
	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN*	OLD CALVIN
1	0.28	0.44	1	1	0.47	0.32
2	1	0.77	1	1	***0.26***	0.26
3	0.6	0.78	1.086	1.05	0.2	0.28
4	0.99	0.18	1.001	1.13	0.14	0.21
5	0.72	0.74	1.049	1.06	0.21	0.283
6	0.98	1	1.001	1.32	***0.12***	0.08
7	1	0.55	1	1.08	0.25	0.3
8	0.93	0.21	1.003	1.1	0.12	0.23
9	1	0.7	1	1.1	***0.1***	0.21
10	0.94	0.26	1.003	1.05	0.2	0.33
11	0.94	1	1.005	1.04	0.22	0.272
12	0.94	0.38	1.004	1.1	***0.18***	0.18
13	0.97	0.34	1.002	1.1	***0.13***	0.18
14	1	1	1	1	0.18	0.22
15	1	0.4	1	1.05	0.12	0.21
16	0.84	0.31	1.015	1.1	0.28	0.18
17	1	0.61	1	1.1	0.13	0.17
18	1	1	1	1	0.18	0.25
19	1	1	1	1	0.03	0.21
20	0.82	0.99	1.014	1.07	0.1	0.17
21	1	1	1	1	0.1	0.25

* Red Bold Italics indicate values adjusted during calibration

External Flows

Table 4.4 shows the average annual net external flows for UPDATED CALVIN and OLD CALVIN, along with the original C2VSIM flow averages since this term was adjusted significantly for many basins. Specifically, the external flow time series term that was adjusted was groundwater-surface water interaction from streams. Differences in stream exchanges before and after 1951 are due to the change in aquifer levels and therefore changes in surface-groundwater interactions. Stream-aquifer connections have changed over time so streams that may have gained water from aquifers before 1951 have reversed to losing water to aquifers. If the historical time series of stream-aquifer flows was used, there would likely have been a million acre-feet per year of water that was not accounted for correctly in the Central Valley. As a result, streamflow exchanges before 1951 were adjusted based on if the annual average difference for subregions was above 50 TAF/yr. Adjusted subregions are 2, 4, 5, 6, 9, 11, 13, 15, 18, 19 and 21 (shown in bold italics and red in Table 4.4). To maintain mass balance of water available within the subregion, the difference between historical and adjusted stream inflows was accounted for in the depletion areas of respective subregions or as depletions or accretions to major streams in these subregions. A more detailed description of this adjustment is in Appendix 4.

Effectively, the C2VSIM external flow values are used; some of the water was just moved from the external flows term to the depletions and accretions to account for the changes in aquifer levels after 1951. Overall, UPDATED CALVIN has much less external flows entering the groundwater system than OLD CALVIN’s external flows entering the groundwater system. The individual flows that summed to be net external flows are discussed in Chapter 3.

As mentioned in the previous chapter, C2VSIM represents evapotranspiration losses as a surface water loss fraction so it is not accounted for in the external flows time series. More details on the C2VSIM surface loss fractions can be found in Appendix 5.

Table 4.4: Net External Flow Averages Compared (TAF/yr)

Subregion	UPDATED CALVIN*	C2VSIM	OLD CALVIN (CVGSM)
1	28	28	2
2	***235***	177	403
3	-9	-9	9
4	***-68***	-96	261
5	***91***	67	144
6	***225***	180	367
7	168	168	278
8	402	402	747
9	***134***	85	14
10	72	72	296
11	***29***	-1.3	-159
12	49	49	155
13	***365***	344	863
14	278	278	309
15	***688***	594	1161
16	51	51	280
17	96	96	360
18	***241***	263	484
19	***424***	368	162
20	101	101	220
21	***322***	290	387
SAC TOTAL	***1206***	1002	2224
SJ TOTAL	***515***	464	1156
TL TOTAL	***2201***	2041	3362
TOTAL	***3922***	3507	6741

* Red Bold Italics indicate values adjusted during calibration

Pumping Terms

Table 4.5 shows the pumping related terms (capacity, depth, and unit costs) for CALVIN (UPDATED and OLD). The maximum pumping values from C2VSIM were used as pumping constraints except for a few regions (shown in bold italics and red). These exceptions were increased during calibration because it was found that the maximum pumping constraints were being hit often, and when comparing the C2VSIM maximum pumping capacities with CVHM, C2VSIM's maximum pumping values were significantly lower, indicating that the actual maximum could be larger.

Pumping depths and costs were not adjusted in the calibration phase. Since the data is based on average measured DWR groundwater level data, those pumping depths were used to calculate the pumping cost. Adjustments were made to the pumping costs to reflect year 2008 economic dollars. Details of the how pumping costs were calculated can be found in Appendix 2.

Table 4.5: UPDATED CALVIN Pumping Terms Comparison

Subregion	**Maximum Pumping (TAF/month)**		**Pumping Depth (feet)**		**Pumping Cost[1] ($)**	
	UPDATED CALVIN*	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN
1	7.2	20.76	71	130	$ 23.59	$ 30.00
2	93.2	153.23	40	120	$ 15.82	$ 28.20
3	175.8	170.98	27	100	$ 11.93	$ 23.80
4	109.2	110.47	16	60	$ 9.33	$ 16.00
5	240.1	225.65	27	75	$ 11.93	$ 18.80
6	85.7	148.06	25	70	$ 11.93	$ 18.20
7	120.5	96.02	40	95	$ 23.07	$ 28.80
8	185.6	208.38	90	110	$ 31.89	$ 28.60
9	***50***	73.77	24	80	$ 11.93	$ 20.40
10	185.2	197.88	17	60	$ 9.07	$ 15.60
11	64.9	52.21	47	75	$ 19.45	$ 20.60
12	86.9	80.56	68	90	$ 24.89	$ 23.60
13	225.8	290.96	75	125	$ 25.93	$ 30.00
14	221.1	332.85	235	350	$ 69.22	$ 76.40
15	335.3	407.88	93	210	$ 30.08	$ 46.60
16	61.8	60.76	57	130	$ 19.70	$ 29.80
17	152.6	152.39	34	130	$ 16.07	$ 31.60
18	***300***	348.95	80	200	$ 27.48	$ 45.20
19	213.7	171.1	139	310	$ 44.85	$ 68.40
20	125.3	108.1	298	310	$ 84.00	$ 67.20
21	265.6	228.31	191	310	$ 59.37	$ 69.60

* Red Bold Italics indicate values adjusted during calibration

[1] Note that UPDATED CALVIN pumping costs are based on year 2008$ dollars and OLD CALVIN costs are based on year 2000$ dollars

Storage Terms

The storage terms are shown in Table 4.6. The values in the table reflect the maximum, initial, ending, and average annual change in storage for the 72 year time period for water years 1921-1993.

For UPDATED CALVIN, the maximum storage constraint was not actually used in the final run since the initial and ending storages were set to simulate overdraft. The initial storage values were set based on C2VSIM initial storage values. The ending storages were set based on the calculated overdraft/change in storage discussed in Chapter 3, with some calibration adjustments. The change in storage calculated for the OLD CALVIN run was based on the initial storage minus the ending storage. The initial and ending storages for OLD CALVIN differ from the original groundwater calibration based on CVGSM, due to other CALVIN calibrations in the past 10 years.

As can be seen in the storage change numbers, there is some agreement that much more overdraft occurs in the Tulare basin than the other two Central Valley basins. The ending storages for UPDATED CALVIN that were adjusted from C2VSIM's calculated overdraft for the regions are shown in bold italics. Reasons behind this adjustment will be discussed in the next section.

In general, estimates of long-term overdraft vary widely, as such calculations are quite sensitive to the selection of periods, durations, and flows over wet and dry periods.

Table 4.6: UPDATED CALVIN Storage Terms and Overdraft

Subregion	**Maximum Storage Capacity (TAF/mo)**		**Initial Storage (TAF/mo)**		**Ending Storage* (TAF/mo)**		**Average Annual Storage Change for 1921-1993 (TAF/yr)[1]**	
	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN*	OLD CALVIN	UPDATED CALVIN	OLD CALVIN
1	38,510	5,448	38,447	1,902	39,437	1,774	-13.8	1.8
2	136,757	24,162	136,494	11,843	***136,494***	11,242	***0.0***	8.3
3	133,958	22,127	132,687	13,345	131,748	13,545	13.0	-2.8
4	61,622	15,362	60,728	10,350	60,508	10,581	3.1	-3.2
5	92,020	24,399	91,113	15,552	90,457	14,561	9.1	13.8
6	175,719	22,864	174,968	17,948	175,275	16,077	-4.3	26.0
7	58,484	12,270	56,539	10,025	51,209	12,168	74.0	-29.8
8	193,433	32,842	190,665	22,366	182,829	16,276	108.8	84.6
9	139,752	23,395	139,472	17,744	139,834	20,474	-5.0	-37.9
10	91,920	29,250	90,210	22,213	87,055	23,477	43.8	-17.6
11	59,302	15,543	58,838	10,948	58,246	8,747	8.2	30.6
12	43,510	13,919	42,602	10,380	40,865	9,414	24.1	13.4
13	142,508	47,484	138,216	31,143	128,560	31,169	134.1	-0.4
14	181,001	65,235	178,840	51,075	172,009	45,763	94.9	73.8
15	313,759	90,978	309,643	70,494	306,666	70,415	41.3	1.1
16	64,915	11,650	64,696	6,359	64,439	0	3.6	88.3
17	98,836	13,942	97,214	7,311	93,653	7,005	49.5	4.3
18	322,480	59,544	321,375	40,775	***321,375***	33,947	***0.0***	94.8
19	147,060	68,266	141,750	43,085	128,224	43,087	187.9	0.0
20	141,457	40,814	137,073	22,630	125,136	23,403	165.8	-10.7
21	351,327	81,622	341,142	51,595	***324,302***	47,588	***233.9***	55.7
SAC TOTAL	1,030,255	182,869	1,021,113	121,075	1,008,673	116,698	172.8	60.8
SJ TOTAL	337,240	106,196	329,866	74,684	314,726	72,807	210.3	26.1
TL TOTAL	1,620,835	432,051	1,591,733	293,324	1,535,804	271,208	776.8	307.2
TOTAL	2,988,330	721,116	2,942,712	1,902	2,859,203	909,908	1159.8	394.0

* Red Bold Italics indicate values adjusted during calibration

[1] Positive values represent overdraft and negative values represent gains to groundwater.

Artificial Recharge

In C2VSIM, subregions 13, and 15-21 manage their groundwater supplies with artificial recharge of imported or local surface water. Artificial recharge flows to groundwater are reported as C2VSIM diversions and are described in the simulation application's *CVdivspec.dat* file, which specifies diversions for spreading and destination subregions for infiltration facilities. In C2VSIM, spreading facilities have a recoverable fraction of 0.95 (an assumed infiltration rate). The groundwater budget output file has a "Recharge" term, which includes both diversion losses and water from spreading facilities. To separate artificial recharge volumes from the total recharge volume, an infiltration rate of 0.95 was applied to monthly diversion volumes for surface water diversions for spreading, where diversions for spreading are listed in Table 4.7. Monthly volumes of Diversion times 0.95 was taken as recharge from spreading facilities and was therefore separated from the total recharge term for subregions 13, and 15-21. Figure 4.1 shows the added nodes and links (in bold italics and red) that represent this artificial recharge addition to the CALVIN network. Artificial recharge was not explicitly represented in OLD CALVIN; historical artificial recharge was included in select inflows.

Table 4.7: Surface Water Diversion for Spreading

C2VSIM Source Node	Destination Subregion	Artificial Recharge Infiltration Rate	Non-recoverable Losses	Description
84	13	0.95	0.05	Chowchilla R riparian SR13 Spreading
74	13	0.95	0.05	Fresno R riparian SR13 Spreading
28	15	0.95	0.05	Kings R Main Stem to SR15 Spreading
43	15	0.95	0.05	Kings R North Fork to SR15 Spreading
37	15	0.95	0.05	Kings R South Fork to SR15 Spreading
52	15	0.95	0.05	Kings R Fresno Slough to SR15 Spreading
24	16	0.95	0.05	Kings R to Fresno ID SR16 Spreading
Import	16	0.95	0.05	Friant-Kern Canal to SR16 Spreading
25	17	0.95	0.05	Kings R to Consolidated ID SR17 Spreading
25	17	0.95	0.05	Kings R to Alta ID SR17 Spreading
Import	17	0.95	0.05	Friant-Kern Canal to SR17 Spreading
420	18	0.95	0.05	Kaweah R Partition A to SR18 Spreading
422	18	0.95	0.05	Kaweah R Partition B to SR18 Spreading
422	18	0.95	0.05	Kaweah R Partition C to SR18 Spreading
420	18	0.95	0.05	Kaweah R Partition D to SR18 Spreading
426	18	0.95	0.05	Kaweah R to Corcoran ID SR18 Spreading
18	18	0.95	0.05	Tule R riparian to SR18 Spreading
Import	18	0.95	0.05	Friant-Kern Canal to SR18 Spreading
7	19	0.95	0.05	Kern R to SR19 Spreading
Import	19	0.95	0.05	California Aqueduct to SR19 Spreading
Import	19	0.95	0.05	Friant-Kern Canal to SR19 Spreading
2	20	0.95	0.05	Kern R to SR20 Spreading
Import	20	0.95	0.05	Friant-Kern Canal to SR20 Spreading
Import	20	0.95	0.05	Cross-Valley Canal to SR20 Spreading
3	21	0.95	0.05	Kern River to Subregion 21B spreading
4	21	0.95	0.05	Kern River to Subregion 21C spreading
Import	21	0.95	0.05	California Aqueduct to SR21 Spreading
Import	21	0.95	0.05	Friant-Kern Canal to SR21 Spreading
Import	21	0.95	0.05	Cross-Valley Canal to SR21 Spreading

Table 4.8 shows the annual average historical artificial recharge per C2VSIM simulation and operation costs of artificial recharge facilities updated from OLD CALVIN artificial recharge costs. These are calculated to reflect operating costs for these agricultural groundwater recharge activities, which limit facility operations and the opportunity cost of land used for recharge basins.

Table 4.8: Artificial Recharge Operation Costs

Subregion	CALVIN Link	Diversions for Spreading	Average Annual Artificial Recharge (TAF/yr)	Operating Cost ($/AF)[1]
13	HAR13_GW-13	Chowchilla R riparian & Fresno R riparian	4	6.5
15	HAR15_GW15	Kings R	138	6.5
16	HAR15_GW16	Kings R & Friant-Kern Canal	24	6.5
17	HAR15_GW17	Kings R & Friant-Kern Canal	23	6.5
18	HAR15_GW18	Kaweah R, Tule R riparian & Friant-Kern Canal	178	6.5
19	HAR15_GW19	California Aqueduct, Kern R and Friant-Kern Canal	79	6.5
20	HAR15_GW20	Kern R, Friant-Kern Canal & Cross-Valley Canal	66	6.5
21	HAR15_GW21	Kern R, California Aqueduct, Friant-Kern Canal & Cross Valley Canal	208	6.5

[1] OLD CALVIN cost (5 $/AF) converted to 2008 dollars

Urban Return Flow

The urban return flow fractions used for UPDATED CALVIN are based on C2VSIM's representation of urban return flow, as discussed in Chapter 3 (Table 3.6). These can be compared with the urban return flow fractions for OLD CALVIN, which are from CVGSM (also shown in Table 3.6).

Agricultural Water Demands

Along with updating the input terms related to CALVIN groundwater, agricultural demands were also updated. Results from an improved and updated Statewide Agricultural Production Model – SWAP (Howitt et al. 2012) were used for UPDATED CALVIN's agricultural demands. Table 4.9 shows agricultural demands for OLD CALVIN and UPDATED CALVIN. The differences in the water delivery targets can be attributed to improvements made in SWAP crop production model in that some CVPM regions (3, 10, 14, 15, 19 and 21) were further discretized for better representation. A detailed description of SWAP is in Howitt et al. 2012.

Table 4.9 shows that overall net demand target for UPDATED CALVIN is slightly lower. Generally, this could imply that decreased shortages in deliveries can be expected in UPDATED CALVIN. The calibration steps were based primarily on determining if shortages reflected in the results of each run were "true" shortages or if a specific calculated input term caused the shortage, such as local capacity constraints, leading to scarcities even in very wet years. The calibration process to reduce these "untrue" shortages is discussed in the next section.

Table 4.9: Average Annual Agricultural Water Delivery Targets (TAF/yr)

Agricultural Demand Area	OLD CALVIN	UPDATED CALVIN
CVPM 1	126	139
CVPM 2	497	473
CVPM 3	2,196	1,315
CVPM 4	956	884
CVPM 5	1,313	1,485
CVPM 6	619	732
CVPM 7	429	413
CVPM 8	802	737
CVPM 9	926	1,208
CVPM 10	919	1,403
CVPM 11	855	777
CVPM 12	772	760
CVPM 13	1,506	1,679
CVPM 14	1,358	1,129
CVPM 15	1,701	1,828
CVPM 16	345	368
CVPM 17	797	739
CVPM 18	1,759	2,119
CVPM 19	887	842
CVPM 20	829	640
CVPM 21	1,195	999
SAC TOTAL	7,864	7,386
SJ TOTAL	4,052	4,620
TL TOTAL	8,871	8,664
TOTAL	20,787	20,670

During the calibration phase of OLD CALVIN in 2001, it was found that there was too much excess water in the system, so a calibration outflow was needed for CALVIN to have reasonable results. These calibration outflows were constrained time series that dumped water from the C delivery node (shown in Figure 4.1) before reaching the demand nodes, effectively increasing water use. Table 4.10 shows these averaged annual calibration flows from the 2001 calibration. These calibration flows were a primary reason CALVIN needed to be updated.

Table 4.10: Average Annual Old CALVIN Calibration Outflow (TAF/yr)

Subregion	Calibration Outflow
1	5
2	0
3	0
4	63
5	114
6	259
7	46
8	33
9	0
10	389
11	242
12	16
13	247
14	0
15	0
16	194
17	62
18	0
19	216
20	23
21	170
SAC TOTAL	520
SJ TOTAL	894
TL TOTAL	665
TOTAL	2,079

Calibration Summary

The results presented in the sections above for UPDATED CALVIN reflect the already calibrated values (shown in bold italics). This section discusses and summarizes calibration adjustments made to the original C2VSIM inputs.

Calibration Steps

The previous section compared UPDATED CALVIN and OLD CALVIN. This calibration section discusses the key differences between these two successfully calibrated runs. Table 4.11 presents those runs, their numbers, and a description of the runs. Starting with OLD CALVIN as a base, the newly calculated C2VSIM-based input terms were used for the “UPDATED CALVIN C2VSIM Base” run. The model solves, but the shortages were quite high in unusual ways, indicating some possibly “untrue” localized scarcity. Calibration adjustments were made for different terms in runs S07I05-S07I08 to try to minimize unrealistic scarcity. Run S07I08 is called “UPDATED CALVIN Old Delta” since it is the successfully calibrated CALVIN run with updated groundwater representation based primarily on C2VSIM, but does not include the updated Delta term constraints. Calibration adjustments were made for Delta terms in runs S07I08-S07I14. UPDATED CALVIN represents the final, calibrated run with all updates, including the updated Delta terms.

Table 4.11: CALVIN Calibration Runs

Run Name	Run Number	Description
"UPDATED CALVIN C2VSIM Base"	S07I05	The results from this run are based primarily on C2VSIM inputs as originally calculated prior to any calibration changes (external flows adjustment is included). Delta terms are based on OLD CALVIN.
"UPDATED CALVIN Old Delta"	S07I08	This is the final calibrated run based primarily on C2VSIM groundwater terms with Delta terms based on OLD CALVIN.
"UPDATED CALVIN"	S07I14	This is the final calibrated run based primarily on C2VSIM groundwater terms and a hybrid CALSIM II-OLD CALVIN-based delta pumping & exports constraints.

The calibration process was essentially split into two parts: 1) the calibration of CALVIN based on C2VSIM input terms (from UPDATED CALVIN C2VSIM Base to UPDATED CALVIN Old Delta), and 2) the calibration of the new Delta exports and pumping constraints (from UPDATED CALVIN Old Delta to UPDATED CALVIN). The section below summarizes the changes made in the entire calibration process, discussing the base calibration first, then the Delta terms calibration. A detailed description of the entire calibration process can be found in Appendix J(2) (Zikalala et al. 2012).

UPDATED CALVIN C2VSIM Base Calibration

Table 4.12 shows the resulting annual average shortages (scarcities) for the major runs. As can be seen between the UPDATED CALVIN C2VSIM Base run and the UPDATED CALVIN Old Delta run, there are significant decreases in scarcities in regions 2, 4, 6, and 18. Small decreases occur in regions 9, 12, 13, 20, and 21. These reductions in shortages are due to adjusting surface water diversion capacities, amplitudes for return flows, maximum pumping capacities, and calculated overdraft. These adjustments were made based on examining the results from each run and determining what term or factor might be causing that region to have unrealistic shortages, particularly shortages in very wet years caused by localized capacity constraints and amplitudes. Dual values for node conveyances to the subregions were considered to assess if the capacities or upper bounds were realistic for the physical system. Values that were not believed to represent "true" groundwater or capacity conditions were adjusted; these adjustments were based on comparisons with CVHM results or measured data. The shortages for each run (S07I05-S07I08) and the changes made between runs are described in more detail in Appendix J(2).

Table 4.12: Average Annual Agricultural Water Scarcity Comparison

Agricultural Demand Area	CALVIN Schematic Demand Node	CALVIN Delivery Link	Annual Average Water Shortages (TAF/yr)			
			OLD CALVIN*	UPDATED CALVIN C2VSIM Base	UPDATED CALVIN Old Delta	UPDATED CALVIN
CVPM 1	Ag-GW	HU1-CVPM 1G	0.0	0.7	0.8	1.0
	Ag-SW	HU1-CVPM 1S	0.0	0.4	0.7	1.1
CVPM 2	Ag-GW	HU2-CVPM 2G	0.0	189.0	0.0	0.0
	Ag-SW	HU2-CVPM 2S	0.0	0.0	0.0	0.0
CVPM 3	Ag-GW	HU3-CVPM 3G	0.0	0.0	0.0	0.0
	Ag-SW	HU3-CVPM 3S	15.0	0.0	0.0	0.0
CVPM 4	Ag-GW	HU4-CVPM 4G	0.0	70.7	0.0	0.0
	Ag-SW	HU4-CVPM 4S	0.0	1.7	0.0	0.0
CVPM 5	Ag-GW	HU5-CVPM 5G	0.0	0.0	0.0	0.0
	Ag-SW	HU5-CVPM 5S	0.0	0.0	0.0	0.0
CVPM 6	Ag-GW	HU6-CVPM 6G	0.0	45.5	7.3	28.5
	Ag-SW	HU6-CVPM 6S	0.0	1.2	0.5	0.5
CVPM 7	Ag-GW	HU7-CVPM 7G	0.0	0.0	0.0	0.0
	Ag-SW	HU7-CVPM 7S	0.0	0.0	0.0	0.0
CVPM 8	Ag-GW	HU8-CVPM 8G	0.0	0.0	0.0	0.0
	Ag-SW	HU8-CVPM 8S	0.0	0.0	0.0	0.0
CVPM 9	Ag-GW	HU9-CVPM 9G	0.0	8.3	0.1	12.7
	Ag-SW	HU9-CVPM 9S	0.0	0.0	0.0	0.0
CVPM 10	Ag-GW	HU10-CVPM 10G	0.0	48.4	48.7	51.4
	Ag-SW	HU10-CVPM 10S	0.0	3.3	3.4	3.5
CVPM 11	Ag-GW	HU11-CVPM 11G	0.0	0.3	0.3	0.7
	Ag-SW	HU11-CVPM 11S	0.0	0.0	0.0	0.0
CVPM 12	Ag-GW	HU12-CVPM 12G	0.0	25.4	22.6	23.4
	Ag-SW	HU12-CVPM 12S	22.0	1.6	1.1	1.5
CVPM 13	Ag-GW	HU13-CVPM 13G	0.0	75.9	74.5	74.9
	Ag-SW	HU13-CVPM 13S	0.0	2.4	2.3	2.4
CVPM 14	Ag-GW	HU14-CVPM14G	0.0	0.0	0.0	0.0
	Ag-SW	HU14-CVPM14S	0.0	0.0	0.0	0.0
CVPM 15	Ag-GW	HU15-CVPM15G	0.0	0.0	0.0	0.0
	Ag-SW	HU15-CVPM15S	0.0	0.0	0.0	0.0
CVPM 16	Ag-GW	HU16-CVPM16G	0.0	7.8	8.0	13.3
	Ag-SW	HU16-CVPM16S	0.0	2.6	2.6	2.7
CVPM 17	Ag-GW	HU17-CVPM17G	0.0	33.6	33.6	34.8
	Ag-SW	HU17-CVPM17S	0.0	0.0	0.0	0.0
CVPM 18	Ag-GW	HU18-CVPM18G	0.0	151.0	107.6	106.0
	Ag-SW	HU18-CVPM18S	0.0	0.0	0.0	0.0
CVPM 19	Ag-GW	HU19-CVPM19G	0.0	0.0	0.0	0.0
	Ag-SW	HU19-CVPM19S	0.0	0.0	0.0	0.0
CVPM 20	Ag-GW	HU20-CVPM20G	0.0	25.5	22.1	21.9
	Ag-SW	HU20-CVPM20S	0.0	5.3	4.8	4.9
CVPM 21	Ag-GW	HU21-CVPM21G	0.0	42.6	39.9	38.6
	Ag-SW	HU21-CVPM21S	0.0	0.0	0.0	0
Sacramento			**15.0**	**317.5**	**9.4**	**43.8**
San Joaquin			**22.0**	**157.3**	**152.9**	**157.8**
Tulare			**0.0**	**268.4**	**218.6**	**222.3**
Central Valley Total			**37.0**	**743.2**	**380.9**	**423.8**

*Note that OLD CALVIN had different SWAP targets

Since the surface water loss fractions were changed in this update, the surface water diversion capacities were examined more closely for the regions with significant shortages. Table 4.13 shows the changes made to the upper bound conveyance capacity for the surface water diversions and reasons for the adjustments. In most cases, the surface water loss amplitudes (discussed in Appendix 5) are lower for UPDATED CALVIN, indicating higher surface water losses so the upper bound capacities were increased to compensate for greater losses. The link that represents surface water diversion recoverable and non-recoverable losses comes after the link that the upper bound capacity is on in the CALVIN network. To better represent the "true" upper bound capacity, the upper bound capacities were increased so that when the flow reaches the link with the associated surface water loss, the original upper bound capacity could still be delivered.

Table 4.13: Surface Water Diversion Capacity Calibration Adjustments

Subregion	CALVIN SW Diversion Link	Upper Bound Capacity (TAF/month)		Source or Reason for Adjustment
		OLD CALVIN	UPDATED CALVIN	
2	D77-HSU2D77	12.7	29.7	USBR website
	C1-HSU2C1	1.8	1.98	Compensation for increased SW losses
	C11-HSU2C11	0.7	1.03	C2VSIM
	HSU2C9-C6	26.4	29.3	C2VSIM
4	D30-HSU4D30	194.1	236	Compensation for increased SW losses
6	C314_HSU6C314	32.1	34	Compensation for increased SW losses
	C16_HSUC16	36.3	38.5	Compensation for increased SW losses
	C21_HSUC21	40.5	42.9	Compensation for increased SW losses
12	D645-HSU12D645	5.4	5.94	Compensation for increased SW losses
	D649-HSU12D649	12.2	13.42	Compensation for increased SW losses
	D662-HSU12D662	107.1	117.81	Compensation for increased SW losses
	D664-HSU12D664	2	2.2	Compensation for increased SW losses
	D699-HSU12D699	4.5	4.95	Compensation for increased SW losses
13	D645-HSU13D645	111.4	122.54	Compensation for increased SW losses
	D649-HSU13D649	4.3	4.73	Compensation for increased SW losses
	D634-HSU13D634	42.9	47.19	Compensation for increased SW losses
	D624-HSU13D634	57.2	62.92	Compensation for increased SW losses
	D694-HSU13D694	0.5	0.55	Compensation for increased SW losses
18	C56-HSU18C56	179.6	197.56	Compensation for increased SW losses
	C58-HSU18C58	23.1	25.41	Compensation for increased SW losses

Calibration adjustments also were made to the C2VSIM calculated groundwater terms. Table 4.14 compares the final values used for UPDATED CALVIN and the original C2VSIM calculated values. These adjustments were not all made in just one run at one time; the changes were made throughout runs S07I05-S07I08 (discussed in detail in Appendix J(II) (Zikalala et al. 2012)).

The first column of Table 4.14 shows adjustments for total applied water return flow amplitudes. These amplitudes were increased to allow more water to return to the groundwater basins. The increases for this term were mostly justified based on comparisons with CVHM return flow amplitudes (Table 3.2).

The maximum pumping capacities were adjusted for regions 9 and 18. This was done because there were large shortages that seemed unreasonable for those regions. Additionally, maximum pumping was being reached even during normal water years and comparisons of the maximum pumping capacity for those regions with CVHM values indicated that they could be higher (Table 3.4).

Change in storage values were adjusted for regions 1, 18, and 21 because the C2VSIM-based calculations of storage change did not seem to reflect physically likely storage changes in those regions. Increased groundwater storage for regions 2 and 18 just did not seem realistic, so they were adjusted to have no storage change. Considering region 21's physical area, the C2VSIM calculated overdraft of 27,903 TAF seemed too high and unlikely to be true. So rather than eliminate region 18's recharge to groundwater, that addition of groundwater was accounted for in region 21 instead. Although this doesn't follow conventional calibration methods, regions 18 and 21 are both in the Tulare region, so making this adjustment seemed reasonable, from an overall Tulare basin perspective; the total overdraft for the Tulare region based on C2VSIM is not affected. Additionally, when compared with CVHM's region 21 calculated overdraft of 5,611 TAF, the UPDATED CALVIN value is much closer than the C2VSIM calculated value.

Table 4.14: Adjustments to Groundwater Terms

Subregion	Total Applied Water Return Flow Amplitude		Maximum Pumping Capacity (TAF/month)		Overdraft (TAF)	
	C2VSIM	UPDATED CALVIN	C2VSIM	UPDATED CALVIN	C2VSIM	UPDATED CALVIN
2	0.14	0.26	-	-	-990	0
6	0.06	0.12	-	-	-	-
9	0.09	0.10	43.9	50	-	-
12	0.16	0.18	-	-	-	-
13	0.12	0.13	-	-	-	-
18	-	-	238.4	300	-11063	0
21	-	-	-	-	27903	16840

Note that "-" just indicates that no changes were made for that term for that region.

The adjustments discussed above allowed for about an average annual 360 TAF of localized scarcities to be removed from the system, as seen in Table 4.12 when comparing shortages between UPDATED CALVIN C2VSIM Base and UPDATED CALVIN Old Delta. Adjustments were made until it was obvious that regardless of reasonable adjustments, the scarcities would remain, implying real scarcity in those regions not due to unrealistic local constraints. UPDATED CALVIN Old Delta was used as a base case for the next part of the update project – updates to Delta terms.

UPDATED CALVIN Delta Exports and Pumping Calibration

Table 4.15 compares the input constraints that affect the Delta. The major pumping plants for the Delta are Banks and Tracy Pumping Plants. For this update, the Tracy pumping upper-bound constraint was left as it was in OLD CALVIN; the CALSIM II Tracy pumping constraint had comparable maximums as the constraints used in OLD CALVIN. The Banks upper-bound pumping constraint used for UPDATED CALVIN is a hybrid of CALSIM II 2009 results (DWR 2011) and OLD CALVIN’s constraints. Although CALSIM’s complex Delta flow restrictions would be a better representation of real Delta exports than OLD CALVIN’s constraints, using CALSIM results alone as constraints would be too inflexible and would result in optimization infeasibilities. The hybrid version was used so that the final Banks pumping constraint is updated to be more comparable with CALSIM II 2009 results while still being able to achieve feasible results through CALVIN’s optimization methods.

A cumulative distribution was plotted for CALSIM II’s Banks pumping constraint and it was determined that the maximum of 465 TAF was a reasonable maximum to use for the new constraint. Then, in order to bring OLD CALVIN’s Banks upper-bound to a lower value, any value for pumping for OLD CALVIN that exceeded the 465 TAF maximum was set to 465 TAF. It appeared that every value was greater than 465 TAF so 465 TAF was used to be the Banks constraint, with adjustments for number of days per month.

The Required Delta Outflow is a constrained minimum flow in CALVIN. The constraint used for UPDATED CALVIN was based on both CALSIM II 2009 and OLD CALVIN. At every month, the maximum value for Delta Export Outflow between CALSIM II 2009 and OLD CALVIN was used as the constraint for UPDATED CALVIN. This results in UPDATED CALVIN having a larger annual average Delta Export Outflow constraint.

Table 4.15: Delta Pumping Constraints and Minimum Delta Outflow

Model	**Banks Pumping Upper-bound Constraint**		**Tracy Pumping Upper-bound Constraint**		**Total Delta Pumping Upper-bound Constraint**		**Minimum Delta Outflow**	
	Annual Average (TAF/yr)	Maximum (TAF/mo)	Annual Average (TAF/yr)	Maximum (TAF/mo)	Annual Average (TAF/yr)	Maximum (TAF/mo)	Annual Average (TAF/yr)	Maximum (TAF/mo)
UPDATED CALVIN	5475	465	2169	283	7644	748	6314	1713
CALSIM II 2009	2593	472	3331	283	5924	755	4944	1320
OLD CALVIN	6158	523	2169	283	8327	806	5593	1713

Table 4.12 shows that shortages for UPDATED CALVIN are higher than that of UPDATED CALVIN Old Delta. This is expected because in an attempt to have pumping capacity constraints and Delta exports be closer in comparison to CALSIM II 2009, there is less pumping and more required Delta outflow in UPDATED CALVIN than in OLD CALVIN (and UPDATED CALVIN Old Delta). As seen in the results, when the Delta terms were updated, there was more scarcity in the Sacramento region, which also agrees with the idea of more export outflow and lower pumping.

Table 4.16 shows the results from the CALVIN run for the Banks Pumping Plant and Tracy Pumping Plant. Although new constraints were used, the total annual average Delta pumping remained very close in comparison between the two models. This is interesting considering that UPDATED CALVIN has more Delta required outflow, and a tighter constraint for Banks pumping plant. This indicates that the upper bound constraint is reached more often in the Banks pumping plant in UPDATED CALVIN.

Table 4.16: Average Annual Delta Pumping Results (TAF/yr)

	UPDATED CALVIN	OLD CALVIN	CALSIM II 2009
Banks Pumping	4,383	4,906	2,984
Tracy Pumping	942	462	2,496
Total Delta Pumping	5,325	5,368	5,479

UPDATED CALVIN Results

This section presents and discusses the major run results for UPDATED CALVIN and compares them with OLD CALVIN's results.

Targets, Deliveries, and Scarcities

Table 4.17a shows the agricultural targets, deliveries and shortages for the model results. As mentioned before, the targets are different between the models because results from an updated version of SWAP were used to define water delivery targets for UPDATED CALVIN. One major problem with OLD CALVIN was that 2 million acre-feet of calibration flows out of the system were needed to have reasonable results, indicating that there was generally too much inflow in the system. With too much water in the system, scarcity is likely to be small, as seen in the last column of Table 4.17a. The scarcities for UPDATED CALVIN, though larger, are more reasonable and seem to better represent actual water scarcity, and omit the earlier 2 MAF/yr of calibration demands. The updated model has a much better physical basis.

Table 4.17a: UPDATED CALVIN and OLD CALVIN Agricultural Targets, Deliveries, and Scarcities (TAF/yr)

CALVIN Delivery Link	Target		Delivery		Scarcity	
	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN
HU1-CVPM1G	38.9	55.6	37.9	55.6	1.0	0.0
HU1-CVPM1S	100.0	70.7	98.8	70.7	1.1	0.0
HU2-CVPM2G	473.4	382.4	473.4	382.4	0.0	0.0
HU2-CVPM2S	0.0	114.2	0.0	114.2	0.0	0.0
HU3-CVPM3G	789.2	1713.1	789.2	1713.1	0.0	0.0
HU3-CVPM3S	526.2	483.2	526.2	468.2	0.0	15.0
HU4-CVPM4G	875.1	172.1	875.1	172.1	0.0	0.0
HU4-CVPM4S	8.9	784.0	8.9	784.0	0.0	0.0
HU5-CVPM5G	1069.5	971.3	1069.5	971.3	0.0	0.0
HU5-CVPM5S	415.9	341.2	415.9	341.2	0.0	0.0
HU6-CVPM6G	716.9	619.0	688.4	619.0	28.5	0.0
HU6-CVPM6S	14.7	0.0	14.2	0.0	0.5	0.0
HU7-CVPM7G	413.1	235.9	413.1	235.9	0.0	0.0
HU7-CVPM7S	0.0	193.0	0.0	193.0	0.0	0.0
HU8-CVPM8G	685.3	168.4	685.3	168.4	0.0	0.0
HU8-CVPM8S	51.6	633.4	51.6	633.4	0.0	0.0
HU9-CVPM9G	1207.5	648.4	1194.9	648.4	12.7	0.0
HU9-CVPM9S	0.0	277.9	0.0	277.9	0.0	0.0
HU10-CVPM10G	1318.8	238.9	1267.4	238.9	51.4	0.0
HU10-CVPM10S	84.2	680.1	80.6	680.1	3.5	0.0
HU11-CVPM11G	730.4	855.4	729.6	855.4	0.7	0.0
HU11-CVPM11S	46.6	0.0	46.6	0.0	0.0	0.0
HU12-CVPM12G	714.8	293.3	691.4	293.3	23.4	0.0
HU12-CVPM12S	45.6	478.5	44.1	456.5	1.5	22.0
HU13-CVPM13G	1629.0	512.1	1554.1	512.1	74.9	0.0
HU13-CVPM13S	50.4	994.0	48.0	994.0	2.4	0.0
HU14-CVPM14G	1129.0	1357.7	1129.0	1357.7	0.0	0.0
HU14-CVPM14S	0.0	0.0	0.0	0.0	0.0	0.0
HU15-CVPM15G	1828.0	680.5	1828.0	680.5	0.0	0.0
HU15-CVPM15S	0.0	1020.7	0.0	1020.7	0.0	0.0
HU16-CVPM16G	309.0	106.9	295.7	106.9	13.3	0.0
HU16-CVPM16S	58.9	237.9	56.1	237.9	2.7	0.0
HU17-CVPM17G	738.6	486.3	703.8	486.3	34.8	0.0
HU17-CVPM17S	0.0	310.9	0.0	310.9	0.0	0.0
HU18-CVPM18G	2119.4	1759.5	2013.4	1759.5	106.0	0.0
HU18-CVPM18S	0.0	0.0	0.0	0.0	0.0	0.0
HU19-CVPM19G	841.8	886.7	841.8	886.7	0.0	0.0
HU19-CVPM19S	0.0	0.0	0.0	0.0	0.0	0.0
HU20-CVPM20G	525.0	820.5	503.1	820.5	21.9	0.0
HU20-CVPM20S	115.2	8.3	110.4	8.3	4.9	0.0
HU21-CVPM21G	999.3	1195.4	960.7	1195.4	38.6	0.0
HU21-CVPM21S	0.0	0.0	0.0	0.0	0.0	0.0
Sacramento	7386	7864	7342	7849	44	15
San Joaquin	4620	4052	4462	4030	158	22
Tulare	8664	8871	8442	8871	222	0
Central Valley Total	20670	20787	20246	20750	424	37

Table 4.17b shows the urban targets, deliveries, and scarcities. As seen in the table, there are no differences between OLD CALVIN and UPDATED CALVIN in the Central Valley. Slight differences between the models in deliveries and scarcities can be seen in Southern California. Since the differences in urban deliveries are very small in comparison to the agricultural deliveries, the rest of this chapter will focus on the differences that apply to the agricultural side of the models.

Table 4.17b: UPDATED CALVIN and OLD CALVIN Urban Targets, Deliveries, and Scarcities (TAF/yr)

CALVIN Delivery Region	**Target**		**Delivery**		**Scarcity**	
	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN
Sacramento	1609	1609	1609	1609	0.3	0.3
San Joaquin	1571	1571	1571	1571	0.0	0.0
Tulare	1284	1284	1279	1279	5.1	5.1
Central Valley Total	4464	4464	4459	4459	5.4	5.4
Southern California	6840	6840	6648	6649	192.1	190.5

Water Deliveries and Recharge

Total water deliveries include water pumped from the ground and surface water deliveries. The first two columns of Table 4.18 show the groundwater pumping and surface water deliveries. The targets are different between the two runs (as shown in Table 4.17), but it is still useful to compare the total pumping and total surface water deliveries. As seen in groundwater pumping column, UPDATED CALVIN pumps over 2 MAF less groundwater than OLD CALVIN. Similarly on the surface water side, UPDATED CALVIN uses over 2.5 MAF more surface water than OLD CALVIN. This is due mostly to the successful removal of 2 MAF/yr of calibration demands present in OLD CALVIN.

With smaller total deliveries, it could be expected that the groundwater return flow is also smaller for UPDATED CALVIN. However, UPDATED CALVIN has additional representation of artificial recharge in the Tulare region. Interestingly, when considering total recharge to the groundwater basins for UPDATED CALVIN, it sums to be more recharge than in OLD CALVIN.

Table 4.18: Average Annual Groundwater Pumping, Surface Water Deliveries, Groundwater Return Flow, and Artificial Recharge Results (TAF/yr)

Subregion	GW Pumping		SW Deliveries		GW Return Flow		Artificial Recharge
	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN	OLD CALVIN	UPDATED CALVIN
1	39	41	98	86	18	18	-
2	145	410	328	86	123	99	-
3	109	463	1207	1719	158	480	-
4	12	274	872	682	123	36	-
5	227	391	1258	921	225	275	-
6	171	394	532	225	69	50	-
7	125	44	289	384	103	71	-
8	462	627	275	175	82	39	-
9	78	31	1117	896	119	136	-
10	305	299	1044	620	253	79	-
11	65	0	711	855	161	233	-
12	106	142	629	607	124	53	-
13	610	849	992	657	202	92	29
14	599	600	530	758	203	299	-
15	916	1,261	912	441	219	143	27
16	24	235	327	110	83	19	0
17	213	301	490	496	91	83	90
18	793	812	1221	947	362	440	302
19	601	298	241	589	25	186	0
20	215	211	399	618	50	139	0
21	177	602	783	593	96	299	1
Sacramento	1,368	2,675	5,974	5,174	1,020	1,203	-
San Joaquin	1,086	1,290	3,376	2,740	740	456	-
Tulare	3,539	4,319	4,903	4,552	1,131	1,608	449
Total CV	5,993	8,284	14,254	12,466	2,891	3,267	449

Change in Storage

CALVIN does not model actual storage capacities, but models the change in storage volume. The initial storage, as mentioned earlier, is an input term to CALVIN and is essentially just a reference starting point for the model. CALVIN outputs actual storage values, but they are relative to the set initial storage. For these models, change in storage has to be compared rather than the model output for storage since the initial storages differ between models. The changes in storage were calculated based on the model run output storage values for each region. Figures 4.2 - 4.4 show the change in storage by Central Valley region (Sacramento, San Joaquin, and Tulare) for UPDATED CALVIN and OLD CALVIN. Sacramento is the sum of Regions 1-9, San Joaquin is the sum of Regions 10-13, and Tulare is the sum of regions 14-21. Negative change in storage values indicate overdraft.

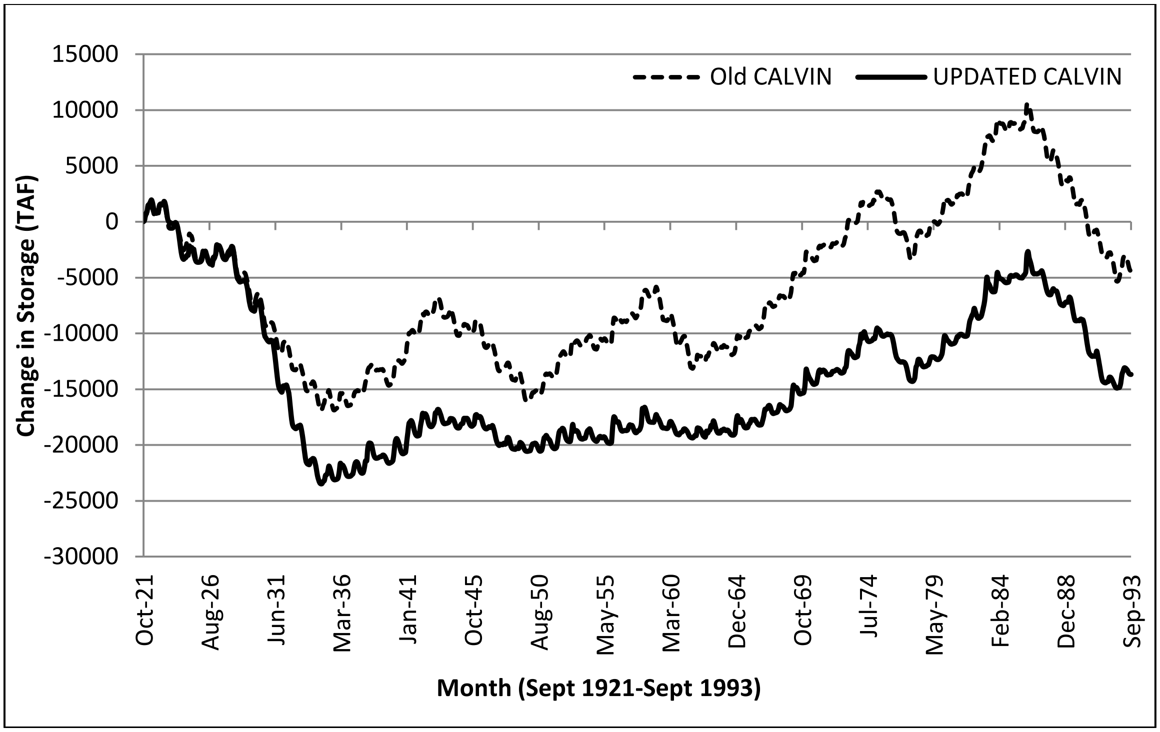


Figure 4.2: UPDATED CALVIN Sacramento Region (Basins 1-9) Change in Storage

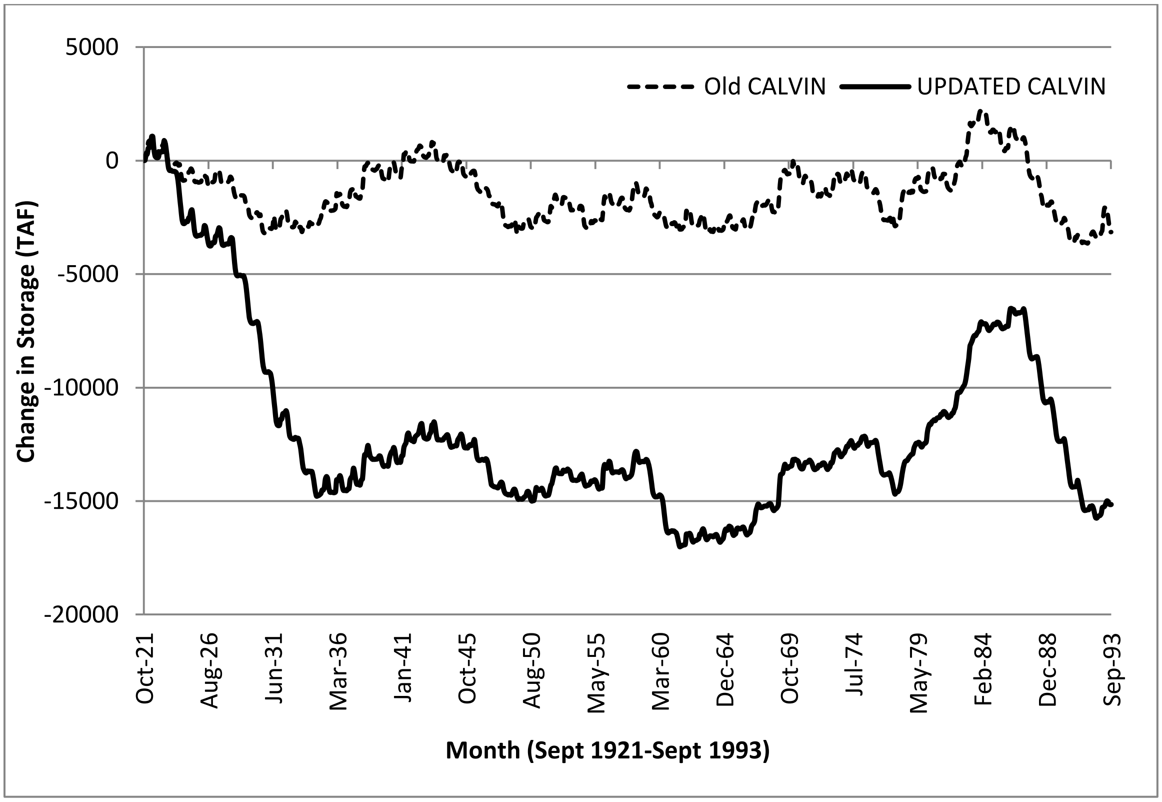


Figure 4.3: UPDATED CALVIN San Joaquin Region (Basins 10-13) Change in Storage

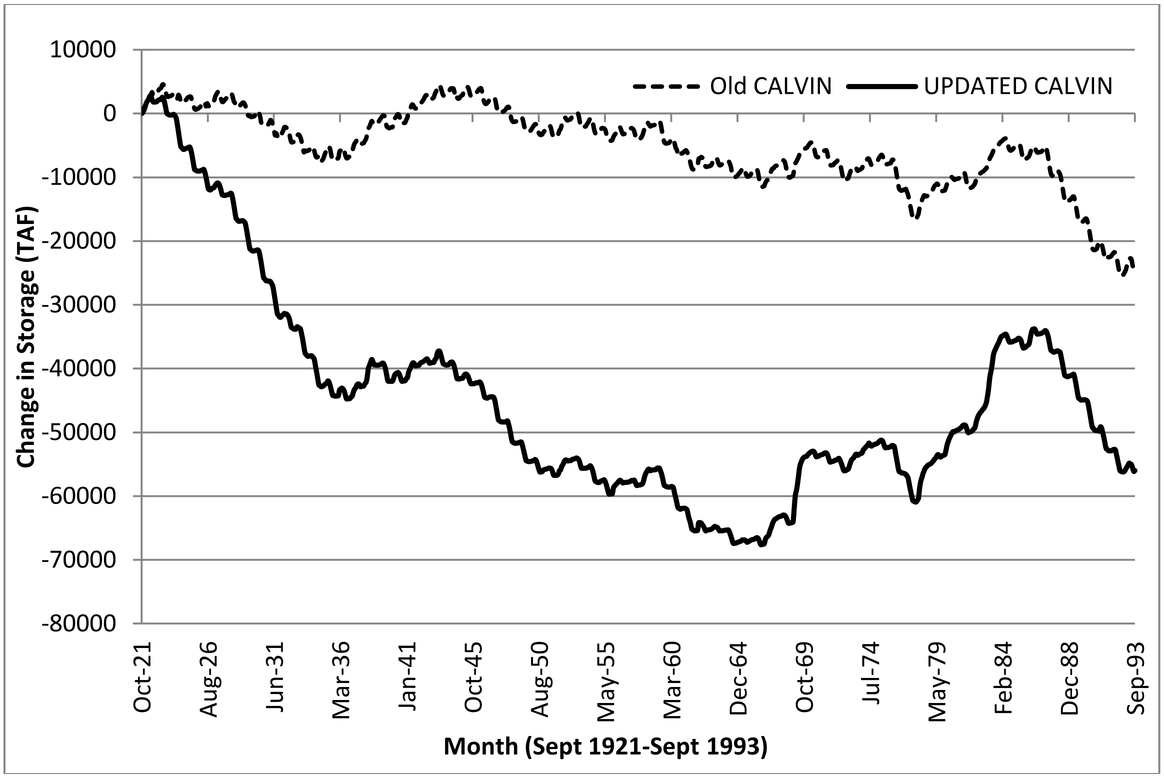


Figure 4.4: UPDATED CALVIN Tulare Region (Basins 14-21) Change in Storage

For all three Central Valley regions, UPDATED CALVIN has more overdraft overall than OLD CALVIN, agreeing more with both C2VSIM and CVHM. Change in Storage for both CALVIN models follow similar trends that agree with seasonal variations and year types, but UPDATED CALVIN's changes are greater and have more overdraft. These change in storage results help confirm the scarcity results in Table 4.16. Considering the Tulare region, scarcities were much higher for UPDATED CALVIN, and as can be seen in Figure 4.4, the overdraft difference is large. This also falls into line with the impression that OLD CALVIN had too much water in the system and its representation of groundwater was not always reasonable. The overdraft implied by UPDATED CALVIN agrees better with other studies on overdraft in the Central Valley, including CVHM's representation. Chapter 5 will discuss some different overdraft scenarios and their effects on the Central Valley.

System Costs

Many changes were made to UPDATED CALVIN, so the system's overall costs were affected. Table 4.19 shows the average annual system costs. The only changes to operating cost values for this update project were the groundwater pumping lift costs and the added artificial recharge costs; all other operating costs were not changed. These changes are reflected in the costs in the table. Scarcity costs are directly related to the scarcity estimates (Table 4.17), but follow seasonal patterns of demands and availability.

UPDATED CALVIN has overall lower pumping costs in the Central Valley, agreeing with Table 4.5, with lower pumping lifts and costs for UPDATED CALVIN. Surface water and other operating costs are not affected much. UPDATED CALVIN's artificial recharge adds an average annual $3 million/year in average costs. OLD CALVIN has much lower scarcity costs because there was much less scarcity in that version of CALVIN (Table 4.17). Overall, UPDATED CALVIN has about an annual average of $40 million (4%) less system costs than OLD CALVIN.

Table 4.19: Average Annual Central Valley System Costs ($millions/yr)

Costs	**UPDATED CALVIN**	**OLD CALVIN**
Groundwater Pumping	361	450
Surface Water Pumping	426	427
Artificial Recharge	3	0
Other[1]	294	264
Central Valley Operating Costs*	**$1,084**	**$1,141**
Scarcity Costs	21	4
Central Valley System Costs	**$1,105**	**$1,145**

[1] Other costs include: treatment, recycled water, and desalination.

*Total Operating Costs does not include hydropower benefits.

Results Summary

Table 4.20 summarizes the average annual results for the Central Valley (Regions 1-21) for UPDATED CALVIN. The percent differences from OLD CALVIN are also presented. Overall, UPDATED CALVIN has lower targets and lower deliveries; UPDATED CALVIN pumps 28 percent less groundwater and delivers14 percent more surface water than OLD CALVIN. This decreased pumping is a direct effect of the new input terms for UPDATED CALVIN. With the new groundwater representation, the scarcity for UDPATED CALVIN is 10 times that of OLD CALVIN, which better represents actual water scarcity in the Central Valley. Total Delta pumping is slightly lower in UPDATED CALVIN, but Tracy pumping for UPDATED CALVIN is more than two times that of OLD CALVIN; this increase in Tracy pumping is due to the lower Banks pumping constraint in UPDATED CALVIN. For total groundwater recharge, there is a 2 percent increase for UPDATED CALVIN, primarily due to the addition of artificial recharge representation. Total Central Valley overdraft for UPDATED CALVIN is nearly three times the amount of overdraft in OLD CALVIN; this new overdraft value is comparable with CVHM total overdraft ((Faunt et al. 2009) and DWR's Bulletin 118's estimated values (DWR 2003). Total system costs are 4% less for UPDATED CALVIN than OLD CALVIN.

Table 4.20: Updated CALVIN Summary – Average Annual Results

Results	OLD CALVIN	UPDATED CALVIN	
	Annual Average (TAF/yr)	Annual Average (TAF/yr)	% Difference
Total Central Valley Agricultural Target	20,787	20,670	-1%
Total Central Valley Agricultural Delivery	20,750	20,246	-2%
Agricultural GW Pumping	8,284	5,992	-28%
Agricultural SW Delivery	12,466	14,254	+14%
Total Central Valley Agricultural Scarcity	37	424	+1046%
Total Delta Pumping	5,368	5,325	-1%
Banks Pumping	4,906	4,383	-11%
Tracy Pumping	462	942	+104%
Total GW Recharge	3,267	3,338	+2%
Total Central Valley Return Flow	3,267	2,889	-12%
Total Central Valley Artificial Recharge	0	449	+100%
Total Central Valley Overdraft	394	1,160	+194%
Total Central Valley System Costs	$1,145	$1,105	-4%

Conclusions

This update project has greatly improved several aspects of CALVIN groundwater. First, schematic improvements were made to simplify the flows in and out of each CVPM groundwater basin. And overall, Central Valley groundwater representation in CALVIN has been greatly improved.

Many of the problems associated with OLD CALVIN's groundwater representation could be attributed to the problems with CVGSM (LaBolle 2003). Models like CALVIN can help inform water management decisions for a wide range of conditions. However, conditions are constantly changing so timely updates are needed to maintain the usefulness of the model. The inputs to CALVIN need to come from a trusted source or model that represents actual, or at least reasonable water and water use conditions. C2VSIM's groundwater representation is much more explicit and reasonable than the older CVGSM. However, C2VSIM results are not always close in comparison with other groundwater models (i.e. CVHM). With different representations and results, groundwater input terms to CALVIN can be very different and would overall represent groundwater very differently. It is important to remember this when considering UPDATED CALVIN results; errors and discrepancies in the C2VSIM groundwater model also carry over into CALVIN's groundwater representation. Nonetheless, this project provides a more accurate and up-to-date representation of Central Valley groundwater in CALVIN.

CHAPTER 5

Groundwater Overdraft in California's Central Valley

This chapter discusses an application of the updated CALVIN model to three groundwater overdraft cases in California's Central Valley. Overdraft is defined as a negative change in groundwater storage from the beginning to end of the model period. The comparison of study results shows potential effects of different levels of overdraft and confirms that the model is behaving well. All three model cases use the updated CALVIN model as a base and result in feasible solutions. Increasing Delta exports and surface water use are the primary adaptations to ending overdraft (aided by artificial recharge). Greater agricultural scarcity is the second adaptation.

Background

Groundwater overdraft occurs when groundwater extraction exceeds recharge over a long period. In California, few statewide regulations currently exist on groundwater extraction and water users commonly turn to groundwater use when demands cannot be met by surface water supplies. Continued overdraft of groundwater basins gradually depletes groundwater availability and can be environmentally detrimental (i.e. subsidence, increased nitrate leaching, and water quality degradation). Despite these negative consequences, some areas continue to pump groundwater at unsustainably high rates. Using a hydro-economic optimization model like CALVIN to study overdraft shows not only the basic, physical water system effects (i.e. effects on Delta pumping and recharge), but also some economic effects. CALVIN was previously used in a case study of the Tulare Basin that examined the economic effects of different management strategies to end overdraft in that basin (Harou and Lund 2007). Similar to the Tulare Basin case study, this overdraft study examines the economic effects of different overdraft scenarios. However, the 2007 Tulare Basin study had cases based on different management options for ending overdraft, whereas the study presented here uses different groundwater models' results to represent overdraft and compare those to a case without overdraft. This approach provides insight for managing overdraft in the Central Valley and also illustrates the consequences of remaining uncertainties in groundwater availability in the Central Valley.

Case Description

Of the three overdraft cases (Table 5.1), the first case is the "Base" updated CALVIN run with overdraft largely based on C2VSIM. In the "No Overdraft" case, no overdraft is allowed; all basin ending storage values were set to the basins' initial storage values. The "Higher Overdraft" case is a CVHM-C2VSIM-based overdraft scenario. Initially, there was a CVHM-based overdraft case, but since CVHM has major differences in groundwater representation of the Sacramento Valley (discussed in Chapter 3), there would not be a feasible CALVIN result based solely on CVHM overdraft results without new calibration. Instead, a semi-CVHM overdraft case was created using the updated CALVIN overdraft for subregions 1-9 (Sacramento region) and using the typically higher CVHM overdraft for subregions 10-21 (San Joaquin and Tulare regions).

Table 5.1: Overdraft Cases Description

Case Name	Run Number	Case Description
Base	S07I14	UPDATED CALVIN with overdraft based on C2VSIM with calibration adjustments. (1.2 MAF/yr Valley-wide).
No Overdraft	S07I14a	No overdraft (initial storage = ending storage).
Higher Overdraft	S07I14b	Overdraft for subregions 1-9 are the same as UPDATED CALVIN. Greater Overdraft for subregions 10-21 is based on CVHM. (1.45 MAF/yr Valley-wide).

Table 5.2 presents the total overdraft and average annual overdraft (1921-1993) per subregion for each case. Higher Overdraft is based on CVHM calculated overdraft for the San Joaquin and Tulare regions. CVHM has slightly less overdraft than the Base case in the San Joaquin region, but has significantly more overdraft in the Tulare region. Comparing the Central Valley totals with the Base run, the No Overdraft case has 84 MAF less groundwater available for use over the 72 years and the Higher Overdraft case allows 20 MAF more groundwater to be used over the 72 years. The results from these runs are presented and discussed below.

Table 5.2: 1921 – 1993 Overdraft Cases*

Subregion	Base		No Overdraft		Higher Overdraft	
	Total (72 years)	Annual Average (TAF/yr)	Total (72 years)	Annual Average (TAF/yr)	Total (72 years)	Annual Average (TAF/yr)
1	-990	-14	0	0	-990	-14
2	0	0	0	0	0	0
3	939	13	0	0	939	13
4	220	3	0	0	220	3
5	656	9	0	0	656	9
6	-307	-4	0	0	-307	-4
7	5,330	74	0	0	5,330	74
8	7,836	109	0	0	7,836	109
9	-362	-5	0	0	-362	-5
10	3,155	44	0	0	251	3
11	592	8	0	0	289	4
12	1,737	24	0	0	-723	-10
13	9,656	134	0	0	10,756	149
14	6,831	95	0	0	9,495	132
15	2,977	41	0	0	12,555	174
16	257	4	0	0	9,435	131
17	3,561	49	0	0	9,142	127
18	0	0	0	0	20,349	283
19	13,526	188	0	0	7,256	101
20	11,937	166	0	0	6,654	92
21	16,840	234	0	0	5,611	78
Sacramento	13,323	185	0	0	13,323	185
San Joaquin	15,140	210	0	0	10,572	147
Tulare	55,930	777	0	0	80,497	1,118
Central Valley Total	84,393	1,172	0	0	104,392	1,450

*Positive values represent a depletion of storage over time and negative values represent gains to groundwater over time.

CALVIN Study Results

This section discusses the results from this study. First, the average annual scarcities and water deliveries are presented, followed by a discussion of the recharge differences. Next, the time series for storages for each region are compared in plots, showing the differences in storage over time between the cases. Then the willingness-to-pay values, scarcity costs, and operating costs are tabulated and discussed. Finally, a summary table of the average annual results with the percent differences between the results for the different cases is presented.

Water Scarcity and Deliveries

Water scarcity is defined as the amount of target water delivery not supplied by the model to meet demands. These results are shown in Table 5.3. Ending overdraft increases water shortages statewide because there is not enough available surface water to meet all demands if groundwater is not overdrafted. As expected, the No Overdraft case has nearly double the water scarcity of the Base case and the Higher Overdraft case has less scarcity than the Base case.

Table 5.3: Overdraft Study Results – Average Annual Agricultural Water Scarcities (TAF/yr)

CALVIN Delivery Link	Base	No Overdraft	Higher Overdraft
HU1-CVPM1G	1.0	1.8	0.8
HU1-CVPM1S	1.1	2.2	0.6
HU2-CVPM2G	0.0	19.5	0.0
HU2-CVPM2S	0.0	0.0	0.0
HU3-CVPM3G	0.0	0.0	0.0
HU3-CVPM3S	0.0	0.0	0.0
HU4-CVPM4G	0.0	16.5	0.0
HU4-CVPM4S	0.0	0.2	0.0
HU5-CVPM5G	0.0	0.0	0.0
HU5-CVPM5S	0.0	0.0	0.0
HU6-CVPM6G	28.5	31.3	8.0
HU6-CVPM6S	0.5	0.7	0.5
HU7-CVPM7G	0.0	11.3	0.0
HU7-CVPM7S	0.0	0.0	0.0
HU8-CVPM8G	0.0	55.0	0.0
HU8-CVPM8S	0.0	4.4	0.0
HU9-CVPM9G	12.7	41.4	0.0
HU9-CVPM9S	0.0	0.0	0.0
HU10-CVPM10G	51.4	55.9	51.4
HU10-CVPM10S	3.5	3.9	3.4
HU11-CVPM11G	0.7	9.5	0.3
HU11-CVPM11S	0.0	0.6	0.0
HU12-CVPM12G	23.4	26.1	23.3
HU12-CVPM12S	1.5	1.8	1.5
HU13-CVPM13G	74.9	141.0	74.9
HU13-CVPM13S	2.4	4.5	2.3
HU14-CVPM14G	0.0	0.0	0.0
HU14-CVPM14S	0.0	0.0	0.0
HU15-CVPM15G	0.0	65.9	0.0
HU15-CVPM15S	0.0	0.0	0.0
HU16-CVPM16G	13.3	15.1	0.4
HU16-CVPM16S	2.7	2.9	2.7
HU17-CVPM17G	34.8	36.9	35.0
HU17-CVPM17S	0.0	0.0	0.0
HU18-CVPM18G	106.0	204.0	103.3
HU18-CVPM18S	0.0	0.0	0.0
HU19-CVPM19G	0.0	0.0	0.0
HU19-CVPM19S	0.0	0.0	0.0
HU20-CVPM20G	21.9	25.9	21.6
HU20-CVPM20S	4.9	5.7	4.8
HU21-CVPM21G	38.6	47.3	36.9
HU21-CVPM21S	0.0	0.0	0.0
Sacramento	44	184	10
San Joaquin	158	243	157
Tulare	222	404	205
Central Valley Total	424	831	372

Table 5.4 compares the average annual Delta pumping for the three cases. Of the 1.2 MAF annual averaged reduction of overdraft in the No Overdraft case (compared to the Base case), approximately 0.4 MAF of that reduction becomes greater scarcity (Table 5.3) and the rest of the reduction is made up by higher Delta exports. For the system to maintain the Delta outflow requirement (discussed in Chapter 4) and have no reductions to southern California water supply, nearly 0.8 MAF/year more water is pumped from the Delta. So to account for the 1.2 MAF of water not available due to having no overdraft supplies in the No Overdraft case, there is 0.4 MAF of increased water scarcity in the Central Valley and 0.8 MAF increased Delta exports. And as expected, when comparing the Base case with the Higher Overdraft case, the increased supply from higher overdraft decreases Delta pumping and water scarcity.

Table 5.4: Overdraft Study Results – Average Annual Delta Exports (TAF/yr)

	Base	No Overdraft	Higher Overdraft
Banks Pumping	4,383	4,470	4,283
Tracy Pumping	942	1,614	726
Total Delta Pumping	5,325	6,084	5,009

Table 5.5 shows average annual groundwater pumping and surface water deliveries. The No Overdraft case significantly reduces average annual groundwater pumping and increases surface water deliveries. Even with the increased surface water use, there is still much scarcity. The Higher Overdraft case has more groundwater pumping, less surface water reliance, and less scarcity.

Table 5.5: Overdraft Study Results – Average Annual Agricultural Water Deliveries (TAF/yr)

Subregion	GW Pumping			SW Deliveries			Total Deliveries		
	Base	No Overdraft	Higher Overdraft	Base	No Overdraft	Higher Overdraft	Base	No Overdraft	Higher Overdraft
1	39	53	39	98	82	98	137	135	137
2	145	140	145	328	314	328	473	454	473
3	109	96	109	1,207	1,220	1,207	1,316	1,315	1,315
4	12	7	12	872	861	872	884	867	884
5	227	218	227	1,258	1,267	1,258	1,485	1,485	1,485
6	171	175	173	532	524	550	703	700	723
7	125	100	125	289	302	288	414	402	413
8	462	389	472	275	289	265	737	677	737
9	78	80	79	1,117	1,086	1,128	1,195	1,166	1,208
10	305	260	264	1,044	1,083	1,084	1,349	1,343	1,348
11	65	55	61	711	712	715	776	767	777
12	106	82	72	629	651	664	735	733	736
13	610	488	623	992	1,046	979	1,602	1,534	1,602
14	599	504	636	530	625	493	1,129	1,129	1,129
15	916	889	1049	912	873	779	1,828	1,762	1,828
16	24	53	144	327	297	221	351	350	365
17	213	159	242	490	543	462	703	702	704
18	793	784	1023	1,221	1,132	993	2,014	1,915	2,016
19	601	413	514	241	429	328	842	842	842
20	215	49	142	399	560	472	614	609	614
21	177	257	29	783	695	934	960	952	962
Sacramento	1,368	1,257	1,382	5,974	5,945	5,994	7,342	7,202	7,376
San Joaquin	1,086	885	1,021	3,376	3,492	3,442	4,462	4,377	4,463
Tulare	3,538	3,108	3,778	4,903	5,152	4,681	8,441	8,260	8,459
Central Valley Total	5,992	5,249	6,181	14,254	14,589	14,117	20,246	19,839	20,298

Table 5.6 shows the average annual urban water deliveries and scarcities. Similar to the results comparison between OLD CALVIN and UPDATED CALVIN, the differences in overdraft cases do not affect urban deliveries in the Central Valley. Slight differences can be seen in the deliveries in Southern California. The No Overdraft case results in a higher scarcity total in Southern California whereas the higher overdraft case results in a slightly lower total scarcity in Southern California. Since differences in urban deliveries are non-existent in the Central Valley and small for Southern California, the rest of this chapter will focus on comparisons of agricultural related aspects of the models.

Table 5.6: Overdraft Study Results – Average Annual Urban Water Deliveries and Scarcities (TAF/yr)

CALVIN Delivery Region	Delivery			Scarcity		
	Base	No Overdraft	Higher Overdraft	Base	No Overdraft	Higher Overdraft
Sacramento	1609	1608	1608	0.3	0.3	0.3
San Joaquin	1571	1571	1571	0	0.0	0.0
Tulare	1279	1279	1279	5.1	5.1	5.1
Central Valley Total	4459	4458	4458	5.4	5.4	5.4
Southern California	6648	6645	6648	192.1	194.8	191.8

Recharge

Table 5.7 shows the average annual return flows and artificial recharge flows to groundwater for each region. Considering just groundwater return flow, the No Overdraft case has less return flow to groundwater and the Higher Overdraft case has slightly more return flow to groundwater. The smaller return flow to groundwater in the No Overdraft case is due to overall decreased delivered water to meet the agricultural demand (hence the increased scarcity); less water delivered proportionally reduces agricultural return flows to groundwater.

The artificial recharge result shows one way that overdraft is detrimental to the overall water system. The No Overdraft case increases use of artificial recharge, an action that should be encouraged and is effective in maintaining groundwater storage overtime. However, maintaining and using artificial recharge is generally more expensive in the short term. CALVIN has a link cost for using artificial recharge. The No Overdraft case drives the system to increase use of artificial recharge capabilities since there is a shortage of water and the no overdraft condition in the groundwater basins needs to be maintained. This conjunctive use approach helps allow more groundwater to be used because it is replenished artificially when surface water is abundant. This allows scarcity to be less than total reductions in available water supply due to the no overdraft constraint (met by increased surface water use and increased Delta exports). In contrast, the Higher Overdraft case reduces use of artificial recharge since it can meet more demands through pumping (the economically cheaper option) and is not required to maintain a condition of no overdraft. Considering that these artificial recharge facilities and capabilities are assumed to be in place for all three cases, general increased use of artificial recharge should be encouraged. This agrees with the results from Harou and Lund (2007), where ending overdraft significantly increases the economic value of additional recharge capacity and when there is overdraft, less artificial recharge occurs since maintaining groundwater storage levels is not a constraint. Adding artificial recharge capacity can help lower the cost of ending overdraft. However, if there is enough available supply from (over)pumping groundwater and nothing to require users to recharge water back to the groundwater basins, it is more economical in the short term to just pump more water and return less to the ground (in real practice and in the CALVIN model). Although it may be more economical in the short term to continue over-pumping groundwater, continued overdraft of groundwater basins will eventually increase pumping costs due to higher depths to groundwater as well as environmental problems. Increased pumping lift over time is not represented in CALVIN.

Considering total recharge to groundwater (groundwater return flow + artificial recharge), the No Overdraft case has the highest recharge of the three cases. In CALVIN, this higher recharge is needed to maintain the no overdraft constraint because the solver will do what satisfies constraints and results in the smallest overall cost, driven primarily by meeting demands since shortage costs are high. CALVIN will maximize the amount of water returned to the ground so that groundwater pumping can increase to levels that fall within the no overdraft constraint.

Table 5.7: Overdraft Study Results – Recharge flows to Groundwater (TAF/yr)

Subregion	GW Return Flow			Artificial Recharge			Total Recharge to GW		
	Base	No Overdraft	Higher Overdraft	Base	No Overdraft	Higher Overdraft	Base	No Overdraft	Higher Overdraft
1	18	17	18	-	-	-	18	17	18
2	123	118	123	-	-	-	123	118	123
3	158	158	158	-	-	-	158	158	158
4	123	120	123	-	-	-	123	120	123
5	225	225	225	-	-	-	225	225	225
6	69	69	71	-	-	-	69	69	71
7	103	100	103	-	-	-	103	100	103
8	82	76	82	-	-	-	82	76	82
9	119	117	121	-	-	-	119	117	121
10	253	253	253	-	-	-	253	253	253
11	161	159	161	-	-	-	161	159	161
12	124	124	124	-	-	-	124	124	124
13	202	193	202	29	49	27	231	242	229
14	203	203	203	-	-	-	203	203	203
15	219	211	219	27	50	27	246	261	246
16	83	82	86	0	48	0	83	130	86
17	91	91	91	90	80	41	181	171	132
18	362	345	363	302	311	250	664	656	613
19	25	25	25	0	0	0	25	25	25
20	50	50	50	0	0	0	50	50	50
21	96	95	96	1	28	1	97	123	97
Sacramento	1,020	999	1,023	-	-	-	1,020	999	1,023
San Joaquin	740	729	741	29	49	27	769	778	768
Tulare	1,129	1,103	1,135	420	516	318	1,549	1,619	1,453
Total Central Valley	2,889	2,831	2,899	449	566	345	3,338	3,397	3,244

Storage

Figures 5.1 – 5.3 show the storages by Central Valley region (Sacramento, San Joaquin, and Tulare) for the three cases. All cases' storages follow similar trends that agree with seasonal variations and year types, but the no overdraft case ensures that the initial storage equals the ending storage. Comparing the Base case with the Higher Overdraft case, the Sacramento region is very similar since it has the same representation; the slight decreases in storage in the Sacramento region for the Higher Overdraft case can be attributed to some water from the north being sent to the south to supply demands.

As seen in Figure 5.2, the Higher Overdraft case actually has less overdraft in the San Joaquin region (it was called the Higher Overdraft case since overall Central Valley overdraft is higher). Figure 5.3 shows the large differences in the overdraft allowances in the Tulare region between the cases. All cases in each region have the same initial storage in the figures below.

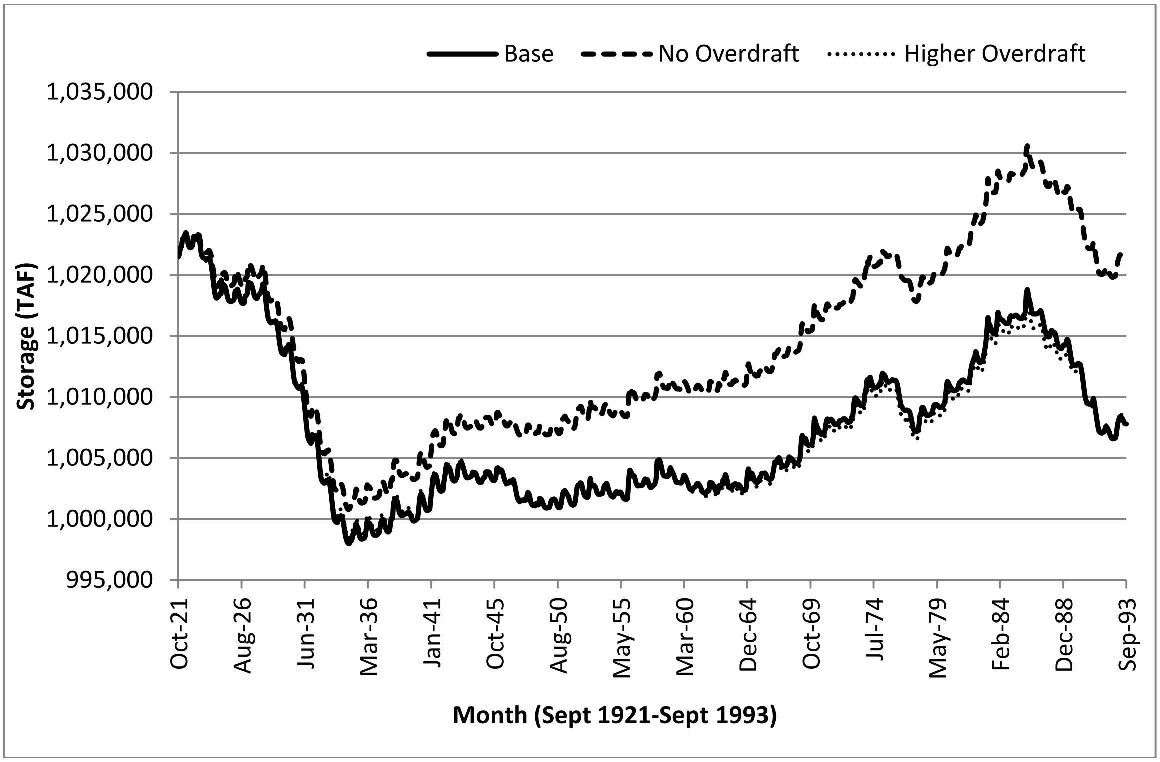


Figure 5.1: Overdraft Study Results – Sacramento Region (Basins 1-9) Storage

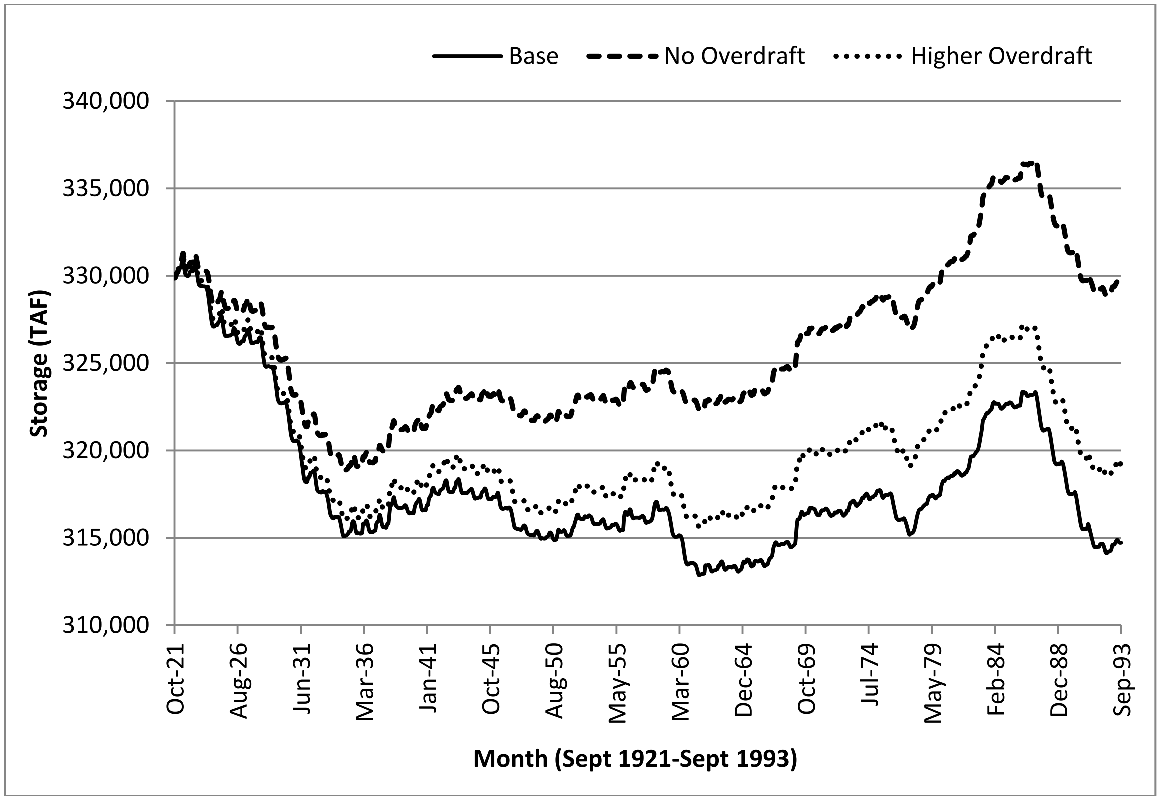


Figure 5.2: Overdraft Study Results – San Joaquin Region (Basins 10-13) Storage

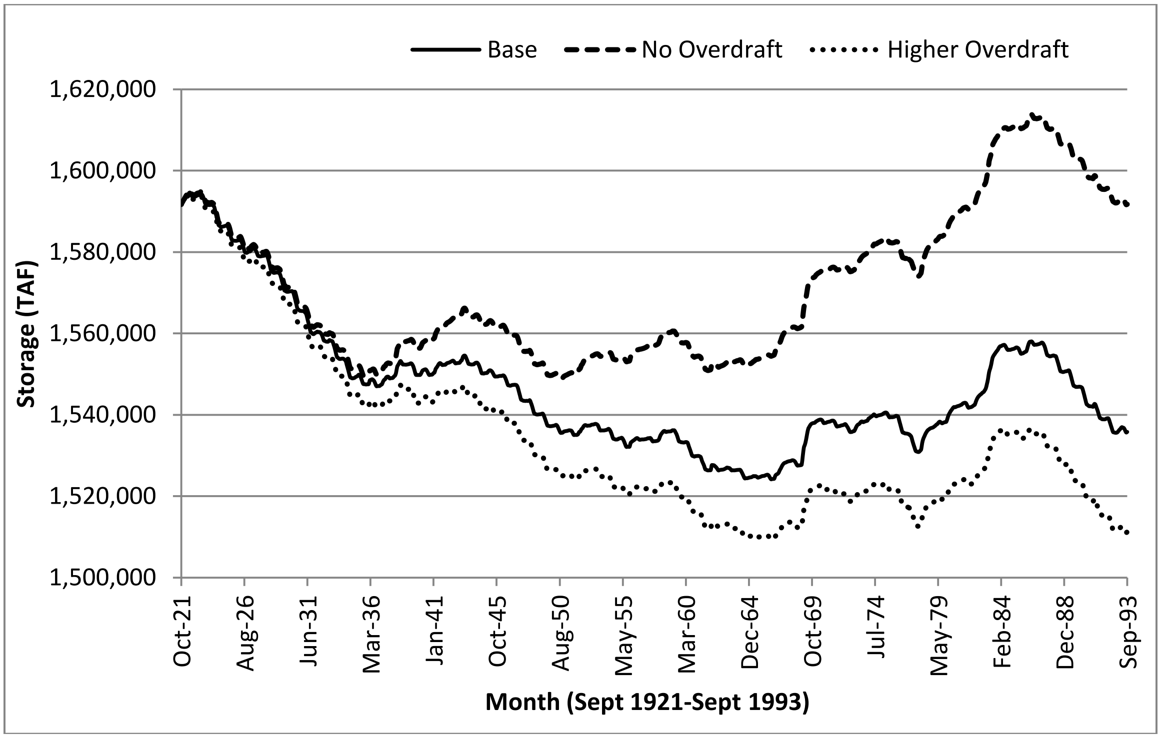


Figure 5.3: Overdraft Study Results –Tulare Region (Basins 14-21) Storage

Willingness-to-pay and Scarcity Costs

The average annual marginal willingness-to-pay (WTP) and scarcity costs are presented in Table 5.8. Marginal WTP reflects what demand areas with shortages would be willing to pay for an additional acre-foot of water; demand areas without scarcity, by definition, have no marginal WTP. Marginal WTP is estimated as the slope of the economic benefit function at the delivered water quantity. Each unit of water goes to the demand area with the highest WTP, if possible, ensuring that the highest value uses are supplied first when possible.

The No Overdraft case has a higher marginal WTP compared to the other two cases because less water is available, creating more scarcity. Comparing the two cases that allow overdraft, the Base case has a higher marginal WTP than the Higher Overdraft case since the Base case has higher scarcities with less available water, and would be willing to pay more for additional water.

Scarcity costs are directly related to the scarcity estimates (Table 5.3), but seasonal variations follow seasonal patterns of demands and availability. Overall, the No Overdraft case has the highest scarcity cost and the Higher Overdraft case has the lowest. The next section compares the Central Valley system costs, including operating costs.

Table 5.8: Overdraft Study Results – Average Annual Marginal Central Valley Agricultural Willingness-to-pay and Scarcity Costs

CALVIN Delivery Link	**Base**		**No Overdraft**		**Higher Overdraft**	
	Marginal WTP ($/AF)	Scarcity Cost (million US $ /yr)	Marginal WTP ($/AF)	Scarcity Cost (million US $ /yr)	Marginal WTP ($/AF)	Scarcity Cost (million US $ /yr)
HU1-CVPM1G	142	0.04	283	0.10	115	0.03
HU1-CVPM1S	68.3	0.05	126	0.09	36.3	0.03
HU2-CVPM2G	0.4	0.0	244	0.89	0.0	0.0
HU2-CVPM2S	0.0	0.0	0.0	0.0	0.0	0.0
HU3-CVPM3G	0.0	0.0	0.0	0.0	0.0	0.0
HU3-CVPM3S	0.0	0.0	0.0	0.0	0.0	0.0
HU4-CVPM4G	2.5	0.0	154	0.72	0.36	0.0
HU4-CVPM4S	22.2	0.0	137	0.01	6.44	0.0
HU5-CVPM5G	0.0	0.0	0.0	0.0	0.0	0.0
HU5-CVPM5S	0.0	0.0	0.0	0.0	0.0	0.0
HU6-CVPM6G	176	1.15	252	1.27	55.1	0.32
HU6-CVPM6S	145	0.02	238	0.03	131	0.02
HU7-CVPM7G	0.0	0.0	177	0.46	0.0	0.0
HU7-CVPM7S	0.0	0.0	0.0	0.0	0.0	0.0
HU8-CVPM8G	0.0	0.0	590	4.16	0.0	0.0
HU8-CVPM8S	8.6	0.0	628	0.34	0.54	0.0
HU9-CVPM9G	37.6	0.46	175	1.49	0.0	0.0
HU9-CVPM9S	0.0	0.0	0.00	0.0	0.0	0.0
HU10-CVPM10G	240	2.01	288	2.19	241	2.01
HU10-CVPM10S	270	0.14	339	0.15	254	0.13
HU11-CVPM11G	6.5	0.04	106	0.49	2.17	0.01
HU11-CVPM11S	0.5	0.0	117	0.03	0.0	0.00
HU12-CVPM12G	208	0.85	249	0.95	202	0.85
HU12-CVPM12S	188	0.05	262	0.06	192	0.05
HU13-CVPM13G	343	3.49	762	10.7	346	3.49
HU13-CVPM13S	363	0.11	802	0.34	356	0.11
HU14-CVPM14G	0.0	0.0	0.0	0.0	0.0	0.0
HU14-CVPM14S	0.0	0.0	0.0	0.0	0.0	0.0
HU15-CVPM15G	0.0	0.0	430	5.35	0.0	0.0
HU15-CVPM15S	0.0	0.0	0.0	0.00	0.0	0.0
HU16-CVPM16G	362	0.64	428	0.73	6.05	0.02
HU16-CVPM16S	385	0.13	467	0.14	377	0.13
HU17-CVPM17G	467	1.53	527	1.62	468	1.54
HU17-CVPM17S	0.0	0.0	0.00	0.0	0.0	0.0
HU18-CVPM18G	537	4.74	1101	14.8	501	4.62
HU18-CVPM18S	0.0	0.0	0.00	0.0	0.0	0.0
HU19-CVPM19G	0.0	0.0	0.00	0.0	0.0	0.0
HU19-CVPM19S	0.0	0.0	0.00	0.0	0.0	0.0
HU20-CVPM20G	677	1.7	836	2.0	659	1.67
HU20-CVPM20S	610	0.38	758	0.44	590	0.37
HU21-CVPM21G	669	3.03	834	3.71	632	2.90
HU21-CVPM21S	0.0	0.0	0.0	0.0	0.0	0.0
Region	Max WTP ($/AF)	Total Scarcity Cost (million US $ /yr)	Max WTP ($/AF)	Total Scarcity Cost (million US $ /yr)	Max WTP ($/AF)	Total Scarcity Cost (million US $ /yr)
Sacramento	176	2	628	10	131	0
San Joaquin	363	7	802	15	356	7
Tulare	677	12	1100	29	658	11
Central Valley	677	21	1100	53	658	18

Operating Costs

The different overdraft cases affect operating costs throughout the Central Valley. Table 5.9 shows the average annual operating costs and Central Valley system costs. The No Overdraft case has lower groundwater pumping costs than the other two cases. This is expected since there is less groundwater pumpage in the No Overdraft case (Table 5.5). The Higher Overdraft case has slightly higher groundwater pumping costs, not reflected in the table due to rounding. As expected, the No Overdraft case has higher surface water pumping costs than the Base case, and the Higher Overdraft case has less surface water pumping costs. Since there is little difference between the groundwater pumping costs of the Base case and the Higher overdraft case, the operating cost results indicate that pumping just a little more groundwater to meet demands is cheaper than using additional surface water. Artificial recharge costs are highest for the No Overdraft case and lowest for the Higher Overdraft case. Total operating costs are highest for the Base case, followed by the No Overdraft case, and then the Higher Overdraft case.

Overall, when also considering the scarcity costs, the No Overdraft case has the highest system costs. Although there are increases in the use of surface water and artificial recharge in the No Overdraft case, their capacities are unable to overcome all reductions in water availability, resulting in larger scarcities and thus larger scarcity costs. The Higher Overdraft case has the lowest system and operating costs, indicating that being able to pump more groundwater is still more economical than pumping less groundwater. If artificial recharge capacities could be increased or if there were higher costs for pumping groundwater (i.e. a tax, policy, or increased lifts represented), then pumping less and reducing overdraft might be economical. With no regulations on groundwater use and not considering the environmental and long-term effects of overdraft, CALVIN results show that it is more economically beneficial to overdraft groundwater to meet demands as best as possible, rather than pump less or end overdraft, if overdraft has no additional cost.

Comparing total Central Valley costs, the cost of ending overdraft in all Central Valley groundwater basins is at least $23 million/year, assuming that the Base case has good overdraft representation. Without economically-minded re-operation, the actual costs could be much higher. Completely ending overdraft in the Central Valley at one time is not possible, but taking steps towards having less reliance on over-pumping groundwater is. This can be done by improving efficiencies, promoting more recharge (artificial or natural), and conjunctive use, with a side-effect of increasing Delta exports unless agricultural deliveries are decreased. More discussion on viable management options for ending overdraft can be found in Harou and Lund 2007.

Table 5.9: Overdraft Study Results – Average Annual Central Valley System Costs ($millions/yr)

Costs	Base	No Overdraft	Higher Overdraft
Groundwater Pumping	361	315	361
Surface Water Pumping	426	460	416
Artificial Recharge	3	4	2
Other[1]	294	295	293
Total Operating Costs*	**$1,084**	**$1,074**	**$1,072**
Scarcity Costs	21	53	18
Total System Costs	**$1,105**	**$1,128**	**$1,090**

[1] Other costs include: treatment, recycled water, and desalination.
*Total Operating Costs does not include hydropower benefits.

Results Summary

Table 5.10 summarizes the average annual results for the entire Central Valley (Subregions 1-21) for this overdraft study and percent differences from the Base case. Overall, there is less total delivery in the No Overdraft case and more delivery in the Higher Overdraft case, with the largest factor for delivery differences being groundwater pumping. The No Overdraft case pumps 12 percent less groundwater than the base and increases surface water use by 2 percent and artificial recharge by 26 percent, but still nearly doubles scarcity. The Higher Overdraft case pumps more groundwater and uses less surface water, and has less overall scarcity. Delta pumping increases by 14% from the Base case to the No Overdraft case since there is less available groundwater in the No Overdraft case; the opposite effect happens for the Higher Overdraft case (decreased Delta pumping). More artificial recharge to groundwater occurs in the No Overdraft case to allow more use of surface water and even out water availability. The Higher Overdraft case has less artificial recharge since more groundwater is available in this case. Total system and operating costs are highest for the No Overdraft case and lowest for the Higher Overdraft case. The marginal willingness-to-pay for extra water and scarcity costs are highest for the No Overdraft case since that case has the most scarcity.

Table 5.10: Overdraft Study Summary – Average Annual Results

Result (TAF)	Base	No Overdraft		Higher Overdraft	
	Avg. Annual	Avg. Annual	% Difference	Avg. Annual	% Difference
Total Central Valley Overdraft (TAF/yr)	1,172	0	-100%	1,450	+24%
Total Central Valley Delivery (TAF/yr)	20,246	19,839	-2%	20,298	+0.3%
GW Pumping (TAF/yr)	5,992	5,249	-12%	6,181	+3%
SW Delivery (TAF/yr)	14,254	14,589	+2%	14,117	-1%
Total Central Valley Ag. Scarcity (TAF/yr)	424	831	+96%	372	-12%
Total Delta Exports (TAF/yr)	5,325	6,084	+14%	5,009	-6%
Banks Pumping (TAF/yr)	4,383	4,470	+2%	4,283	-2%
Tracy Pumping (TAF/yr)	942	1,614	+71%	726	-23%
Total GW Recharge (TAF/yr)	3,338	3,397	+2%	3,244	-3%
Return Flow (TAF/yr)	2,889	2,831	-2%	2,899	+0.3%
Artificial Recharge (TAF/yr)	449	566	+26%	345	-23%
Total System Costs (million $/yr)	1,105	1,128	+2%	1,090	-1%
Operating Costs (million $/yr)	1,084	1,074	-0.9%	1,072	-1%
Scarcity Cost (million $/yr)	21	53	+152%	18	-14%
Maximum WTP ($/AF)	677	1,011	+49%	658	-3%

Conclusions

This overdraft study is just one of the many possible applications of the updated CALVIN model. Many other overdraft cases could be explored with Updated CALVIN, but some would require additional calibration. The cases chosen for this study did not need additional calibration and show some basic comparisons between the groundwater models (CVHM and C2VSIM) and a No Overdraft case, providing some policy and operations insights.

As discussed in Chapter 3, CVHM and C2VSIM have many significant differences in representing Central Valley groundwater. The Higher Overdraft case had only differences for Regions 10-21, but these differences affect the entire system, water diversions, and scarcities. This shows how different regional representations can affect system-wide results and how important it is to pick a model with reasonable results as a base.

The No Overdraft case provides some insight into how the system and system costs would change to end overdraft. It implies that an immediate switch to completely ending overdraft would raise costs, but the results also show that improving recharge and increasing Delta exports would reduce increases in water scarcity. Additional artificial recharge evens out surface water availability, allowing for more surface water to be used and for more consistent deliveries between wet and dry years. However, unless there are direct, immediate benefits to the water users or policies that require less over-pumping or more recharge, it is unlikely that water users will take it upon themselves to pay more for a benefit that they don’t immediately see.

Along with giving useful insights for overall groundwater management and policy, this study also confirmed that Updated CALVIN is behaving as it should and that its results make some practical sense.

CHAPTER 6

Conclusions

Integrated hydro-economic modeling is useful for examining the benefits and drawbacks of existing or proposed water policies, operations, and plans. However, water conditions, regulation, demands, and estimates are constantly changing, so timely updates are needed to maintain and improve the usefulness of models. New models with new data are constantly being developed, and incorporating newer data can make hydro-economic models, like CALVIN, more useful. In an effort to make the most of available resources and include a reasonable groundwater representation in CALVIN, C2VSIM was primarily used in this groundwater update project. This project provides a more accurate and up-to-date representation of Central Valley groundwater in CALVIN, which can lead to studies investigating the economic impacts of Central Valley groundwater use and provide an additional framework for groundwater policy discussions. The CALVIN improvements from this project are summarized below.

CALVIN Improvements

Many improvements were made to the CALVIN model. These include updating and improving the model's representation of Central Valley groundwater, updating the Delta pumping constraints to better reflect actual conditions, and improving the model network and schematic to be more explicit and include some artificial recharge. These improvements are summarized in Table 6.1.

Table 6.1: Improvements to CALVIN

Central Valley
Updated agricultural demands to match current SWAP estimates
Updated existing groundwater term inputs with new, more accurate values
Added some new groundwater terms for more detailed representation of the system
Eliminated 2 MAF of calibration outflows (from the previous version of CALVIN)
Added explicit representation of artificial recharge for some regions in the Tulare Basin
Delta Pumping
Updated Banks Pumping Plant constraint
Updated Delta Export Outflow
Network and Schematic
Added artificial recharge nodes and links for some regions in the Tulare Basin
Added hidden nodes and links for groundwater pumping
Added hidden nodes and links for urban groundwater return flow

Central Valley

The updated agricultural demands based on updated SWAP reduced demands by an average of 117 TAF/year. The changes to the agricultural return flow splits, internal reuse amplitudes, applied water return flow amplitudes, external flows, pumping capacities, pumping costs, storage constraints, and urban return flow amplitudes based primarily on C2VSIM significantly changed how CALVIN models water in the Central Valley. The elimination of 2 MAF of calibration outflows strengthens CALVIN because the model now has a tighter and more explicit representation of Central Valley mass balances of water, more reasonable results, and its groundwater interaction is balanced without the additional calibration flows. The addition of explicit artificial recharge representation allows for an important recharge practice to be represented in the model. The groundwater representation in the updated CALVIN model is more explicit and accurate, making the model more useful.

Delta Pumping

Updates to Delta pumping and outflow were made based on both CALSIM II 2009 and what was previously in CALVIN. Since CALVIN is an optimization model, its Delta pumping and outflows cannot be expected to be the same as a simulation-based model like CALSIM, but incorporating aspects of CALSIM into CALVIN makes CALVIN more relatable to CALSIM and real-life applications.

Network and Schematic

The improvements made to the CALVIN network simplify the direct interactions with the Central Valley groundwater subbasins. The urban and pumping hidden nodes result in fewer direct flows going in and out of each groundwater subbasin, allowing for easier comparisons of results and mass balances.

Conclusions from CALVIN Modeling

The updated CALVIN model was used to study how a few different overdraft cases could affect model results, as well as system economics and management. Three cases were examined: the base case, no overdraft, and higher overdraft. These three cases have significantly different results, as expected. With the no overdraft case, water scarcities were highest and drove the system to increase surface water use and artificial recharge to groundwater. Overall system and operating costs were lowest for the highest overdraft scenario, suggesting that being able to pump more groundwater is the more economical option, which agrees with current, real practices.

This study shows immediately ending overdraft in the Central Valley would have high costs and that including and increasing artificial recharge capacities can benefit the overall water system. Currently, overdrafting groundwater is common, with lower costs. However, with groundwater availability decreasing, pumping costs likely increasing, and environmental effects of overdraft worsening, overdraft will be an increasing problem in the future and may have other costs associated with it not included in CALVIN. Options to mitigate overdraft include: increasing recharge use and capacities (artificial and natural), increase in water reuse, more conjunctive use, more surface water use, and decrease in water use and demands. Although there are many possible solutions, many solutions have higher immediate costs and the long-term benefits are unclear or unknown. Unless policies require water users to follow these solutions, groundwater overdraft will likely continue to be a problem in the years to come.

Limitations and Further Work

“All models are wrong, but some are useful” said George Box (1979).

This CALVIN groundwater update project has improved Central Valley groundwater representation in CALVIN. However, CALVIN is just a model and the models used for this update are just models; they can all be useful, but are not exactly accurate. These models can help draw policy implications and present likely outcomes and effects, but as can be seen in comparisons with measured data and other similar models, there is still much uncertainty in many aspects of these models, albeit probably more accuracy and certainty than most model-free analysis.

Nonetheless, to maintain usefulness, these models should be kept up to date and continue to be improved. This project focused on updating the groundwater in the Central Valley, but CALVIN is a model of California’s entire water system and many more improvements can be made. To gain better understanding and insight to the Central Valley water system, the surface water side of CALVIN could use some updates to rim inflows and deliveries, particularly Valley floor accretions and depletions. Additionally, since the CALVIN network was built using software from the early 2000’s, new machines are having some problems with CALVIN’s network so some updates to the CALVIN software would also be very useful.

As it stands, CALVIN is a unique hydro-economic optimization model of California’s water system and has a variety of applications. Using this CALVIN with updated Central Valley groundwater representation for studies related to groundwater in California could provide some useful results. There have been many CALVIN climate change studies, but none that have updated Central Valley groundwater representation. This study examined just a few overdraft scenarios, but it would be interesting to see what the updated CALVIN model would show under more overdraft cases with added climate changes. Looking more into the economic aspects of climate change adaptation or overdraft mitigation in the Central Valley could also provide some useful results. There is always more research that can be done using CALVIN.

References

Bartolomeo, E. (2011). Economic Responses to Water Scarcity in Southern California [MS thesis]. Davis (CA): University of California, Davis.

Box, GEP (1979). Robustness in the strategy of scientific model building. In: R.L. Launer and G.N. Wilkinson, editors. Robustness in Statistics. 1979, Academic Press: New York.

Brush CF, Dogrul EC, Moncrief M, Galef J, Shultz S, Tonkin M, Wendell D, Kadir T, Chung F. (2008). Estimating hydrologic flow components of the Central Valley hydrologic flow system with the California Central Valley Groundwater-Surface water Model. In**:** Brush, CF; Miller, NL, editors. Proceedings of the California Central Valley Groundwater Modeling Workshop. July 10-11, 2008; Lawrence Berkeley National Laboratory, Berkeley, (CA). Sacramento (CA): California Water and Environmental Modeling Forum.

Connell, CR. (2009). Bring the heat, but hope for rain – adapting to climate warming in California [MS thesis]. Davis (CA): University of California, Davis.

Davis MD and Jenkins MW. (2001). *CALVIN Appendix J: Groundwater Hydrology*. Davis (CA): University of California Davis.

Draper AJ. (2001). Implicit stochastic optimization with limited foresight for reservoir systems [dissertation]. Davis (CA): University of California, Davis.

Draper AJ, Jenkins MW, Kirby KW, Lund JR, Howitt RE. (2003). Economic-engineering optimization for California water management. Journal of Water Resources Planning and Management, ASCE. 129(3).

DWR – California Department of Water Resources. (2003). California’s Groundwater: Bulletin 118-Update 2003. Sacramento (CA): State of California, The Resources Agency.

DWR – California Department of Water Resources. (2011). The State Water Project – Final Delivery Reliability Report. Sacramento (CA): State of California, The Resources Agency.

Faunt, C.C., ed. (2009). Groundwater Availability of the Central Valley Aquifer, California: U.S. Geological Survey Professional Paper 1766, 225 p.

Harou J, Medellin-Azuara J, Zhu TJ, Tanaka SK, Lund JR, Stine S, Olivares MA, Jenkins MW. (2010). Optimized water management for a prolonged, severe drought in California. Water Resour. Res. 46(W05522):1-12.

Harou J, Lund JR. (2007). Ending groundwater overdraft in hydrologic-economic systems. Hydrogeology Journal. (16):1039-1055.

Hersh-Burdick R. (2008). Effects of groundwater management strategies on the greater Sacramento area water supply [MS thesis]. Davis (CA): University of California Davis.

Howitt RE, Medellin-Azuara J, MacEwan D, Lund JR. (2012). Statewide Agricultural Production Model. Davis (CA); [cited 2012 Aug 2]. Available at < http://swap.ucdavis.edu >.

Howitt RE, MacEwan D, Lund JR. (2010). Economic modeling of agriculture and water in California using the Statewide Agricultural Production Model. Davis (CA): University of California Davis.

Jenkins MW. (2001). *CALVIN Appendix O: Hydrologic Calibration.* University of California Davis.

Jenkins MW, Draper AJ, Lund JR, Howitt RE, Tanaka SK, Ritzema R, Marques GF, Msangi SM, Newlin BD, Van Lienden BJ, Davis MD, Ward, KD. (2001). Improving California water management: optimizing value and flexibility. Davis (CA): University of California Davis.

LaBolle EM, Ahmed AA, Fogg GE. (2003). Review of the Integrated Groundwater and Surface-Water Model (IGSM). *Ground Water*: 2003 Mar-Apr; 41(2):238-46. Review.

Lund JR, Howitt RE, Jenkins MW, Zhu T, Tanaka SK, Pulido MA, Tauber M, Ritzema RS, Ferreira I. (2003). Climate warming and California's water future. Davis (CA): University of California Davis.

Lund JR, Howitt RE, Medellín-Azuara J, Jenkins MW. (2010). Water management lessons for California from statewide hydro-economic modeling. Report for the California Department of Water Resources. Davis (CA): University of California Davis.

Medellín-Azuara J, Harou JJ, Olivares MA, Madani K, Lund JR, Howitt RE, Tanaka SK, Jenkins MW. (2008a). Adaptability and adaptations of California's water supply system to dry climate warming. Climatic Change. 87(Suppl 1): S75-S90.

Medellín-Azuara J, Howitt RE, Lund JR, Hanak E. (2008b). Economic effects on agriculture of water export salinity south of the Sacramento-San Joaquin Delta. In

Lund JR et al editors. Comparing Futures for the Sacramento-San Joaquin Delta. San Francisco (CA): Public Policy Institute of California.

Medellín-Azuara J, Connell CR, Madani K, Lund JR, Howitt RE. (2009a). Water management adaptation with climate change. Sacramento (CA): California Energy Commission, Public Interest Energy Research (PIER).

Medellín-Azuara J, Mendoza-Espinosa LG, Lund JR, Harou JJ, Howitt RE. (2009b). Virtues of simple hydro-economic optimization: Baja California, Mexico, Journal of Environmental Management 90:3470-3478.

Medellín-Azuara J, Harou JJ, Howitt RE. (2010). Estimating economic value of agricultural water under changing conditions and the effects of spatial aggregation. Science of the Total Environment. 408:5639-5648.

Newlin BD. (2002). Southern California water markets: potential and limitations [MS thesis]. Davis (CA), University of California Davis.

Null SE, Lund JR. (2006). Reassembling Hetch Hetchy: Water supply without O'Shaughnessy Dam. Journal of the American Water Resources Association. 42(2): 395-408.

Pulido-Velazquez M, Jenkins MW, Lund JR. (2004). Economic values for conjunctive use and water banking in southern California. Water Resour. Res. 40(3): 15.

Ragatz R. (2011). California's water futures: How water conservation and varying Delta exports affect water supply in the face of climate change [MS thesis]. Davis (CA): University of California Davis.

Schmid W, Dogrul EC, Hanson RT, Kadir T, Chung, F. (2011). Comparison of simulations of land-use specific water demand and irrigation water supply by MF-FMP and IWFM.

Sicke WS. (2011). Climate change impacts to local water management in the San Francisco Bay area [MS thesis]. Davis (CA): University of California Davis.

Tanaka SK, Lund JR. (2003). Effects of increased Delta exports on Sacramento Valley's economy and water management. Journal of the American Water Resources Association. 39(6): 1509-1519.

Tanaka SK, Zhu TJ, Lund JR, Howitt RE, Jenkins MW, Pulido MA, Tauber M, Ritzema RS, Ferreira IC. (2006). Climate warming and water management adaptation for California. Climatic Change. 76(3-4): 361-387.

Tanaka SK, Connell CR, Madani K, Lund JR, Hanak E, Medellin-Azuara J. (2008). The economic costs and adaptations for alternative Delta regulations. In Lund JR, et al editors. Comparing Futures for the Sacramento-San Joaquin Delta. San Francisco (CA): Public Policy Institute of California.

USBR – US Bureau of Reclamations. (1997). Central Valley Project Improvement Act: Programmatic Environmental Impact Statement. Sacramento, California: USBR.

Zikalala PG, Connell-Buck CR, Chou H. (2012). *CALVIN Appendix J(2): Groundwater Hydrology*. University of California Davis.

Appendix 1

CVHM Groundwater Term Calculations

This appendix presents some of the different approaches taken when calculating the CALVIN groundwater parameters. The parameters presented as "CVHM" (and in bold) are primarily calculations results from the Zonebudget post-processor; this was the version ultimately used to represent CVHM and the methods are described in Chapter 2. Other versions of these calculations include results from FB_details.OUT and other input files, but these were not chosen to represent CVHM since it involved using terms from different post-processors that did not result in mass balance. However, these calculations still reflect reasonable methods to calculate these terms so some descriptions and results are summarized below.

Table 2.2: CVHM Datasets (from Chapter 2)

Dataset name	Description
CVHM Historical ZB (1980-1993) "CVHM"	Based on historical CVHM run using Zonebudget post-processor; averages based on 1980-1993.
CVHM Historical (1980-2003) "CVHM Hist 1980-2003"	Based on historical CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1980-2003.
CVHM Historical (1961-2003) "CVHM Hist"	Based on historical CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1961-2003.
CVHM 2000 Land Use (1961-2003)* "CVHM 2000"	Based on an updated 2000 land use CVHM run using a combination of FB_details.OUT and Zonebudget; averages are based on 1961-2003.

*Note that this run had obvious problems in some of the Tulare Basin regions so the results from this run were ultimately not used for any formal comparison.

Agricultural Return Flow Split

Different approaches were explored to calculate this term. This was the original approach:

Fraction to SW= RUN/(RUN+DP)
Fraction to GW= DP/(RUN+DP)

Where RUN and DP are part of the Farm Balance found in FB_DETAILS.OUT.

RUN = Overland runoff out of the farm
DP = Deep percolation out of the farm

However, both RUN and DP include precipitation and applied water. CVHM does not separate precipitation out as a separate component to either runoff or deep percolation, as was previously done by the CVGSM model (Direct Runoff was runoff due to rainfall alone). So the above equation is not strictly agricultural return flows, but total return flow.

Since applied water and precipitation are outputs in the CVHM model, a ratio was used to estimate the runoff from applied water and runoff from precipitation.

Applied Water = NRD-in + SRD-in + WELLS-in

Consumptive Use = COMPOSITE EFFICIENCY (%) x Applied Water

Runoff from Applied Water = RUN x [Applied Water / (Applied Water + Precipitation)]

Deep percolation of Applied Water =
Applied Water – Consumptive Use – Runoff from Applied Water

Fraction of Agricultural Return Flow to GW =
Deep percolation of Applied Water / [Applied Water – Consumptive Use]

Fraction of Agricultural Return Flow to SW =
Runoff from Applied Water / [Applied Water – Consumptive Use]

NRD-in = Non-routed deliveries into the farm
SRD-in = Semi-routed deliveries into the farm
WELLS-in = Groundwater well pumping deliveries into the farm
COMPOSITE EFFICIENCY = see term #3 below

The results for return flow to groundwater and return flow to surface water are tabulated below. The "CVHM" set shown in bold is the dataset that was used in the final comparisons.

Table A1.1: Agricultural Return Flow Fractions to Groundwater and Surface Water

Subregion	**CVHM**		Hist CVHM (1980-2003)		Hist CVHM		CVHM 2000	
	GW	**SW**	GW	SW	GW	SW	GW	SW
1	**0.99**	**0.01**	0.65	0.35	0.65	0.35	0.64	0.36
2	**0.98**	**0.02**	0.72	0.28	0.73	0.27	0.7	0.30
3	**0.97**	**0.03**	0.75	0.25	0.76	0.24	0.75	0.25
4	**0.96**	**0.04**	0.68	0.32	0.68	0.32	0.05	0.95
5	**0.97**	**0.03**	0.71	0.29	0.72	0.28	0.63	0.37
6	**0.97**	**0.03**	0.75	0.25	0.76	0.24	0.74	0.26
7	**0.98**	**0.02**	0.69	0.31	0.70	0.30	0.67	0.33
8	**0.98**	**0.02**	0.82	0.18	0.82	0.18	0.83	0.17
9	**0.96**	**0.04**	0.79	0.21	0.80	0.20	0.82	0.18
10	**0.95**	**0.05**	0.83	0.17	0.83	0.17	0.84	0.16
11	**0.97**	**0.03**	0.76	0.24	0.78	0.22	0.77	0.23
12	**0.96**	**0.04**	0.72	0.28	0.74	0.26	0.73	0.27

13	**0.97**	**0.03**	0.84	0.16	0.85	0.15	0.86	0.14
14	**0.92**	**0.08**	0.88	0.12	0.84	0.16	0.89	0.11
15	**0.94**	**0.06**	0.92	0.08	0.91	0.09	0.9	0.10
16	**0.98**	**0.02**	0.91	0.09	0.91	0.09	0.92	0.08
17	**0.97**	**0.03**	0.86	0.14	0.87	0.13	0.87	0.13
18	**0.96**	**0.04**	0.90	0.10	0.90	0.10	0.89	0.11
19	**0.97**	**0.03**	0.93	0.07	0.93	0.07	0.92	0.08
20	**0.97**	**0.03**	0.94	0.06	0.93	0.07	0.94	0.06
21	**0.96**	**0.04**	0.93	0.07	0.92	0.08	0.93	0.07

Agricultural Reuse

This version of CVHM did not "reuse" water on a farm for repeated irrigation. 1 was used for all regions for this term, indicating no reuse.

Return Flow of Total Applied Water

Table A1.2: Return Flow Fraction of Total Applied Water

Subregion	Composite Efficiency (ETAW)		Return Flow (1-ETAW)	
	2000's	1990's	2000's	1990's
1	0.74	0.76	**0.26**	0.24
2	0.73	0.75	**0.27**	0.25
3	0.83	0.82	**0.17**	0.18
4	0.79	0.78	**0.21**	0.22
5	0.8	0.8	**0.2**	0.2
6	0.77	0.77	**0.23**	0.23
7	0.77	0.77	**0.23**	0.23
8	0.75	0.78	**0.25**	0.22
9	0.78	0.79	**0.22**	0.21
10	0.79	0.8	**0.21**	0.2
11	0.77	0.78	**0.23**	0.22
12	0.76	0.77	**0.24**	0.23
13	0.79	0.8	**0.21**	0.2
14	0.87	0.86	**0.13**	0.14
15	0.76	0.76	**0.24**	0.24
16	0.81	0.79	**0.19**	0.21
17	0.8	0.79	**0.2**	0.21
18	0.79	0.79	**0.21**	0.21
19	0.77	0.79	**0.23**	0.21
20	0.81	0.81	**0.19**	0.19
21	0.81	0.81	**0.19**	0.19

External Flows: Inter-basin Flows

Table A1.3: Average Annual Inter-basin Flow (TAF/yr)

Subregion	**CVHM**	Hist CVHM (1980-2003)	Hist CVHM	CVHM 2000
1	**-312.1**	-310.2	-314.4	-288.1

2	**44.2**	32.3	41.3	-10.0
3	**-225.8**	-218.4	-219.6	-178.8
4	**558.6**	552.3	542.1	379.6
5	**-184.9**	-171.4	-178.3	-14.1
6	**-47.2**	-55.2	-22.7	-121.6
7	**19.4**	36.0	-10.3	101.3
8	**50.3**	60.9	49.4	0.2
9	**237.7**	205.5	249.9	220.5
10	**-79.9**	-70.2	-96.9	-88.7
11	**-54.9**	-44.6	-49.7	-9.9
12	**-73.4**	-80.9	-72.4	-88.7
13	**-0.8**	-0.3	0.1	36.7
14	**85.2**	108.7	166.1	247.1
15	**621.8**	514.9	484.2	189.9
16	**-196.1**	-144.7	-169.6	-49.7
17	**-176.8**	-179.5	-153.9	-176.0
18	**-20.1**	-3.4	-33.5	-67.7
19	**212.2**	183.9	201.8	142.3
20	**-164.4**	-146.9	-173.8	140.1
21	**-292.9**	-268.7	-239.8	-364.4
SAC TOTAL	**140.1**	131.7	137.4	89.0
SJ TOTAL	**-209.0**	-196.1	-219.0	-150.6
TL TOTAL	**68.8**	64.4	81.6	61.6
TOTAL	**0.0**	0.0	0.0	0.0

External Flows: Stream Leakage

Table A1.4: Average Annual Stream Leakage (TAF/yr)

Subregion	**CVHM**	Hist CVHM (1980-2003)	Hist CVHM	CVHM 2000
1	-131.5	-121.1	-143.8	-108.5
2	-293.1	-293.3	-293.6	-373.1
3	-234.0	-228.5	-211.1	-167.7
4	-533.4	-531.6	-492.1	-250.7
5	-213.3	-216.1	-198.5	-280.8
6	13.8	32.7	33.8	31.2
7	-42.9	-41.8	-38.0	-34.1
8	84.8	91.6	94.7	84.9
9	551.8	656.0	703.6	496.9
10	38.2	53.7	65.0	46.1
11	-102.3	-102.0	-97.7	-89.2
12	20.7	33.8	39.4	31.8
13	125.3	146.1	164.0	128.4
14	5.6	5.9	5.5	5.5
15	177.6	245.7	238.3	250.9

16	35.0	36.3	33.3	41.8
17	174.8	179.4	169.5	210.9
18	106.9	113.6	103.6	142.7
19	0.0	0.0	0.0	0.0
20	19.3	19.7	18.8	18.8
21	107.2	121.8	130.4	91.8
SAC TOTAL	-797.8	-652.0	-545.0	-601.9
SJ TOTAL	81.9	131.6	170.7	117.1
TL TOTAL	626.4	722.3	699.2	762.4
TOTAL	-89.6	202.0	325.0	277.6

External Flows: Deep Percolation from Precipitation

Many different approaches were taken to calculate this term. The final calculations were based on using ratios from output terms in FB_Details.OUT and applying them to the Zonebudget output “Farm Net Recharge.” The older calculations used the ratio from FB_details.OUT and applied it to FB_details.OUT’s DP-out.

Applied Water = NRD-in + SRD-in + WELLS-in

Precipitation = P-in

Deep Percolation = DP-out

Deep Percolation of Precipitation = DP-out x (P-in / (P-in + NRD-in + SRD-in + WELLS-in))

Table A1.5: Average Annual Deep Percolation from Precipitation (TAF/yr)

Subregion	**CVHM**	CVHM Hist (1980-2003)	CVHM Hist	CVHM 2000
1	**440.2**	481.8	478.3	480.6
2	**631.4**	679.7	643.2	670.1
3	**613.5**	683.9	636.4	656.4
4	**260.6**	385.7	366.2	370.0
5	**690.1**	796.6	767.7	794.3
6	**556.4**	632.4	594.4	600.0
7	**278.0**	333.3	333.6	312.3
8	**546.4**	595.2	568.5	547.8
9	**263.2**	540.9	506.0	512.3
10	**158.0**	245.3	236.6	240.2
11	**180.7**	213.9	204.6	197.3
12	**137.5**	177.4	167.6	166.0
13	**350.6**	428.9	416.3	398.8
14	**100.5**	94.9	92.1	100.4
15	**177.4**	174.1	173.9	196.2
16	**106.4**	111.7	111.6	110.0
17	**159.7**	167.0	159.9	154.0
18	**217.6**	233.6	237.1	229.7
19	**93.7**	76.0	72.6	73.3

20	**62.2**	58.6	57.7	54.3
21	**79.3**	91.0	82.8	62.7
SAC TOTAL	**4279.9**	5129.6	4894.4	4943.8
SJ TOTAL	**826.8**	1065.5	1025.1	1002.3
TL TOTAL	**996.7**	1006.8	987.7	980.6
TOTAL	**6103.4**	7201.9	6907.2	6926.7

External Flows: Boundary Inflow

Table A1.6: Average Annual Boundary Inflow (TAF/yr)

Subregion	**CVHM**	CVHM Hist (1980-2003)	CVHM Hist	CVHM 2000
1	**0**	0	0	0
2	**0**	0	0	0
3	**0**	0	0	0
4	**0**	0	0	0
5	**0**	0	0	0
6	**0**	0	0	0
7	**0**	0	0	0
8	**0**	0	0	0
9	**-90.5**	-134.7	-102.9	-130.8
10	**0**	0	0	0
11	**0**	0	0	0
12	**0**	0	0	0
13	**0**	0	0	0
14	**0**	0	0	0
15	**0**	0	0	0
16	**0**	0	0	0
17	**0**	0	0	0
18	**0**	0	0	0
19	**0**	0	0	0
20	**0**	0	0	0
21	**0**	0	0	0
SAC TOTAL	**-90.5**	-134.7	-102.9	-130.8
SJ TOTAL	**0.0**	0.0	0.0	0.0
TL TOTAL	**0.0**	0.0	0.0	0.0
TOTAL	**-90.5**	-134.7	-102.9	-130.8

External Flows: Evapotranspiration / Non-recoverable losses

Some of the Agricultural Recharge terms calculated from the Farm Net Recharge terms in Zonebudget are negative. Rather than expressing negative recharge, the negative values were separated out to be the estimated ET losses from groundwater. This was the method used for the final CVHM terms. But the previous versions of the calculations took the time series of EGW-in and TGW-in from FB_Details.OUT, which are evaporation from groundwater and transpiration from groundwater to the farm. These estimated ET values are compared with the ones calculated from the Zonebudget in Table A1.7.

Table A1.7: Average Annual ET from Groundwater (TAF/yr)

Subregion	**CVHM**	CVHM Hist (1980-2003)	CVHM Hist
1	**8.0**	34.4	35.8
2	**0.0**	64.9	62.6
3	**124.5**	310.3	298.6
4	**262.2**	395.1	399.7
5	**227.8**	405.6	402.6
6	**69.3**	305.2	282.4
7	**75.8**	144.0	146.5
8	**0.7**	93.1	74.5
9	**515.5**	863.9	824.6
10	**101.4**	378.4	395.3
11	**4.3**	120.0	118.7
12	**29.2**	148.5	149.4
13	**3.6**	306.6	326.0
14	**0.0**	1.6	4.0
15	**0.0**	57.1	99.5
16	**0.0**	1.3	1.4
17	**0.0**	10.8	11.5
18	**0.0**	17.2	18.6
19	**0.0**	0.8	1.5
20	**0.0**	0.0	0.0
21	**0.0**	56.2	67.5
SAC TOTAL	**1283.7**	2616.6	2527.3
SJ TOTAL	**138.5**	953.6	989.4
TL TOTAL	**0.0**	145.0	203.8
TOTAL	**1422.2**	3715.2	3720.5

Net External Flows

Summing the respective terms from each of the datasets results in the net external flows shown in Table A1.8.

Table A1.8: Average Annual External Flows (TAF/yr)

Subregion	**CVHM**	CVHM Hist (1980-2003)	CVHM Hist	CVHM 2000
1	**6.8**	16.2	-15.7	84.0
2	**406.1**	353.8	328.4	287.0
3	**30.9**	-73.3	-92.9	309.9
4	**23.2**	11.4	16.5	498.9
5	**64.2**	3.4	-11.7	499.4
6	**453.5**	304.6	323.1	509.6
7	**186.2**	183.4	138.7	379.5
8	**685.8**	654.7	638.2	632.9

9	**446.1**	403.7	532.1	1098.9
10	**30.0**	-149.8	-190.7	197.6
11	**19.8**	-52.7	-61.5	98.2
12	**57.9**	-18.2	-14.7	109.1
13	**564.2**	268.1	254.4	563.9
14	**260.4**	207.8	259.7	353.0
15	**1117.0**	877.6	796.9	637.0
16	**-8.8**	2.0	-26.1	102.1
17	**197.9**	156.1	164.1	188.9
18	**564.3**	326.5	288.6	304.7
19	**409.7**	259.1	272.9	215.6
20	**20.9**	-68.5	-97.3	213.2
21	**-63.9**	-112.1	-94.1	-209.9
SAC TOTAL	**2302.9**	1857.9	1856.6	4300.1
SJ TOTAL	**671.8**	47.5	-12.5	968.8
TL TOTAL	**2497.5**	1648.5	1564.7	1804.6
TOTAL	**5472.2**	3553.9	3408.8	7073.5

Maximum Pumping Capacity

Some of the older calculations use the absolute maximum monthly pumping values from FB_Details.OUT. The final CVHM values used were based on “Farm Wells” from Zonebudget.

Table A1.8: Agricultural Maximum Monthly Pumping (TAF/month)

Subregion	**CVHM**	CVHM Hist (1980-2003)	CVHM Hist	CVHM 2000
1	**2.3**	2.6	2.6	2.4
2	**354.7**	149.2	157.3	84.7
3	**4.4**	55.3	77.8	42.1
4	**2.4**	4.8	11.8	0.0
5	**25.1**	6.3	72.4	3.1
6	**181.8**	142.7	183.2	96.6
7	**73.8**	19.8	39.0	0.0
8	**474.5**	217.3	249.0	116.0
9	**90.0**	131.3	269.7	16.5
10	**7.9**	81.9	81.9	104.2
11	**22.8**	53.8	100.5	74.8
12	**19.0**	59.3	71.0	74.6
13	**524.5**	261.0	327.8	292.3
14	**214.8**	236.7	485.6	338.9
15	**1066.5**	430.5	436.2	432.7
16	**32.1**	52.1	108.6	60.8
17	**275.5**	157.3	178.7	148.4
18	**570.8**	377.0	448.3	361.5

19	**471.2**	226.2	243.6	240.5
20	**162.2**	98.9	122.5	113.0
21	**113.3**	93.5	93.5	0.0

Representative depth to Groundwater (Pumping Lift)

Before it was decided that DWR 2000 average measured well data would be used to represent depth to groundwater, values were calculated based on CVHM using the following method:

Depth to Groundwater = Lift = GSE – Water Elevation

GSE = Ground surface elevation, used "cvr2_lay1_topm.txt" (from CVHM input, model_arrays folder)

Water Elevation = heads outputted in LIST file

NOTE: the head value given from MODFLOW is actually the average head, and not the effective water level. This would mean that head is actually an overestimate (this is in addition to all the other assumptions). So the calculated lift is an underestimate.

This method was based on using the well indices specified in the FMP file (a CVHM input file) that specifies, by element, where wells are located as of year 2000. For this calculation, an average of 2000 water year heads was used.

An alternative method involved using subregion indices from dwr_subregions file (CVHM input file) – to match, and then extract groundwater elevation at each element. However, this method involved sometimes using subregion elements where a well does not actually exist, or at least was not modeled in CVHM. Using the well indices file was determined to be a better representation since only elements with known, existing wells were used for the calculation.

An issue that arose was that GSE was less than Water Elevation in many elements. Elements where this occurred were excluded from the calculations.

Table A1.9: Groundwater Pumping Lift (feet)

Subregion	CVHM	CVHM 2000
1	153	154
2	43	43
3	63	63
4*	NA	NA
5	14	14
6	57	57

7	19	18
8	17	16
9	43	43
10	73	73
11	22	22
12	42	43
13	113	134
14	176	206
15	36	55
16	123	151
17	80	102
18	186	230
19	165	194
20	366	413
21	250	276

*For this region, all GSE values were less than the water elevation so no value for lift could be calculated.

Maximum Storage Capacity

The term “Storage” from the Zonebudget was used for all calculations here. Effective storage was calculated for this term to represent the absolute maximum available water. Calculation is as follows:

1. Arbitrarily set the initial storage to a very large number such that the created storage time series is never negative. Used $1x10^9$.
2. Once storage values are converted from change in storage to storage, the effective storage can be calculated: Absolute Maximum storage – Absolute Minimum Storage (note that the original arbitrarily high number is subtracted out by doing this).

Table A1.10: Maximum (Effective) Storage (TAF)

Subregion	**CVHM Historical (1980-1993)**	CVHM Historical	CVHM 2000
1	**19,543**	24,969	18,984
2	**33,133**	33,133	30,105
3	**22,782**	30,291	28,094
4	**15,730**	25,993	20,348
5	**23,850**	33,887	26,713
6	**34,350**	41,230	35,657
7	**12,190**	13,308	13,030
8	**31,153**	31,153	30,177
9	**81,528**	128,968	96,095
10	**20,844**	29,718	27,502

11	**10,704**	15,972	14,237
12	**16,651**	32,495	21,168
13	**48,168**	48,168	49,794
14	**32,789**	90,541	52,038
15	**38,000**	49,214	39,397
16	**27,274**	47,732	32,371
17	**31,370**	39,890	38,811
18	**58,956**	83,700	34,740
19	**28,006**	44,875	59,136
20	**20,229**	39,587	27,953
21	**58,804**	58,804	64,187
SAC TOTAL	**274,260**	362,934	299,203
SJ TOTAL	**96,367**	126,354	112,701
TL TOTAL	**295,428**	454,344	348,633
TOTAL	**666,055**	943,631	760,537

Initial & Ending Storage Capacity

The initial storage was calculated to be the effective initial storage, the maximum amount of water available in September 2003. This was calculated: Storage in 2003-Absolute Minimum storage. The results are shown in Table 14. The initial storage values used for CALVIN here are taken directly from CALVIN model inputs.

Table A1.11: Initial Storage (TAF)

Region	**CVHM Historical (1980-1993)**	CVHM Historical	CVHM 2000
1	**16,346**	21,773	12,908
2	**19,031**	19,031	14,355
3	**10,350**	10,350	11,244
4	**8,552**	8,552	9,989
5	**16,587**	16,587	13,656
6	**11,683**	11,683	16,066
7	**10,180**	11,297	8,185
8	**12,230**	12,230	10,565
9	**18,419**	18,419	32,512
10	**11,311**	11,311	9,344
11	**4,905**	4,905	4,435
12	**3,683**	3,683	5,518
13	**33,636**	33,636	39,214
14	**32,789**	90,541	44,445
15	**22,341**	33,555	25,833
16	**27,274**	47,732	31,158
17	**24,960**	33,480	34,051

18	**58,956**	83,700	33,598
19	**28,006**	44,875	59,136
20	**20,229**	39,587	27,953
21	**58,699**	58,699	64,187
SAC TOTAL	**123,377**	129,922	129,481
SJ TOTAL	**53,536**	53,536	58,510
TL TOTAL	**273,254**	432,170	320,361
TOTAL	**450,167**	615,627	508,353

Overdraft scenarios were not examined when initially calculating groundwater terms so the CVHM dataset ending storages were just set to the initial storages (no change in storage).

Appendix 2

Table A2.1 shows the summary calculation for pumping lift cost. The first column presents the DWR 2000 averaged well data. The Technical Note by Buck 2012 (below) describes how the pumping lift depths were determined. Column 2 shows drawdown values used in the previous version of CALVIN (Appendix J). Column 3 is the Pumping Head, which is estimated by summing the drawdown and the pumping lift. Column 4 shows the change in lift values that were used in the previous version of CALVIN, which are used to determine Total Dynamic Head in Column 5. Column 6 is the estimated pumping cost in year 2000 dollars ($.20af/ft). The 2000 costs are then hit with a multiplier (x1.296) to reflect 2008 costs (last column in the table).

Table A2.1: Estimated Agricultural Pumping Costs

Subregion	Estimated Pumping Lift (ft)*	Drawdown (ft)	Pumping Head (ft)	Change in Lift (ft)	Total Dynamic Head (ft)	Pumping Cost, 2000$ ($.20af/ft)	Pumping Cost, 2008$ ($/AF)
1	71	20	91	0	91	$ 18.20	$ 23.59
2	40	20	60	1	61	$ 12.20	$ 15.82
3	27	20	47	-1	46	$ 9.20	$ 11.93
4	16	20	36	0	36	$ 7.20	$ 9.33
5	27	20	47	-1	46	$ 9.20	$ 11.93
6	25	20	45	1	46	$ 9.20	$ 11.93
7	40	30	70	19	89	$ 17.80	$ 23.07
8	90	30	120	3	123	$ 24.60	$ 31.89
9	24	20	44	2	46	$ 9.20	$ 11.93
10	17	20	37	-2	35	$ 7.00	$ 9.07
11	47	30	77	-2	75	$ 15.00	$ 19.45
12	68	30	98	-2	96	$ 19.20	$ 24.89
13	75	30	105	-5	100	$ 20.00	$ 25.93
14	235	30	265	2	267	$ 53.40	$ 69.22
15	93	30	123	-7	116	$ 23.20	$ 30.08
16	57	30	87	-11	76	$ 15.20	$ 19.70
17	34	30	64	-2	62	$ 12.40	$ 16.07
18	80	30	110	-4	106	$ 21.20	$ 27.48
19	139	30	169	4	173	$ 34.60	$ 44.85
20	298	30	328	-4	324	$ 64.80	$ 84.00
21	191	30	221	8	229	$ 45.80	$ 59.37

* Averaged DWR 2000 well data

Technical Note:

Pumping Lift from DWR Well Data

By: Christina R. Buck
September 20, 2011
Updated October 10, 2011

Introduction

An estimated pumping lift for each CVPM region is required for calculating pumping costs in CALVIN. Recent efforts to update the representation of groundwater in CALVIN have explored using the Central Valley Hydrologic Model (CVHM), developed by the United States Geological Survey (USGS), and the California Central Valley Simulation (C2VSIM) model, developed by the Department of Water Resources (DWR), to improve required terms. For estimating pumping lift in CALVIN, it was decided that using measured data of groundwater heads would be best.

The pumping lift is the length (often in feet) that water must be pumped from the water surface in the well to ground surface elevation. DWR monitors water levels throughout the Central Valley typically twice per year, once in the spring and then in the fall. This data provides a snapshot of the head in wells at the time of measurement. This is usually close to the start and end of the irrigation season. A variety of well types make up their monitoring network, including irrigation, domestic, stock, monitoring, industrial, observation, recreation wells and some that are no longer in use. Data from this monitoring effort is available online from the Water Data Library (http://www.water.ca.gov/waterdatalibrary/).

Method

In CALVIN, one number is used to represent typical pumping lifts in irrigation wells in each sub-region. Therefore, water level data was obtained (by Aaron King, UC Davis Center for Watershed Sciences, Graduate Student) from contacts at DWR. The full data set includes wells in CVPM regions 2 thru 21 from years 1990-2011. Data for CVPM region 1 was obtained separately. The year 2000 was chosen to establish a representative pumping lift.

Data was filtered by year (2000). Measurements were tagged as Spring or Fall measurements based on a cutoff of July (July and earlier being a spring measurement, August and later being a fall measurement). This allowed for calculating the average 2000 spring measurement and fall measurement independently. DWR data includes a number of columns: ground surface elevation, RPWS, GSWS, WSE, etc. Ground Surface Water Surface (GSWS) is the measured distance from the ground surface to the water level in the well. This was the data used to calculate a representative pumping lift.

There are a variety of well types in DWR’s monitoring network. Wells in the categories of irrigation, irrigation and domestic, stock, unused irrigation wells, observation, and undetermined were used in the calculation. This served to focus mainly on irrigation related wells while still including enough categories to maintain a good sample size. The distribution of wells with measurements taken in 2000 that were used for the calculation is shown in Figure A2.

Measured water levels indicate the piezometric head in the well and are dependent on the screened intervals of the well. This should be distinguished from the “depth to groundwater” which can refer to the distance below ground surface to the water table. Piezometric head in the wells can be higher or lower than the water table depending on the well screening and aquifer dynamics. For this effort, we want the average pumping lift for irrigation wells in each region, so averaging the GSWS measurements in each region to obtain a representative lift for that area assumes that the sample of measured wells is generally representative of wells in that region.

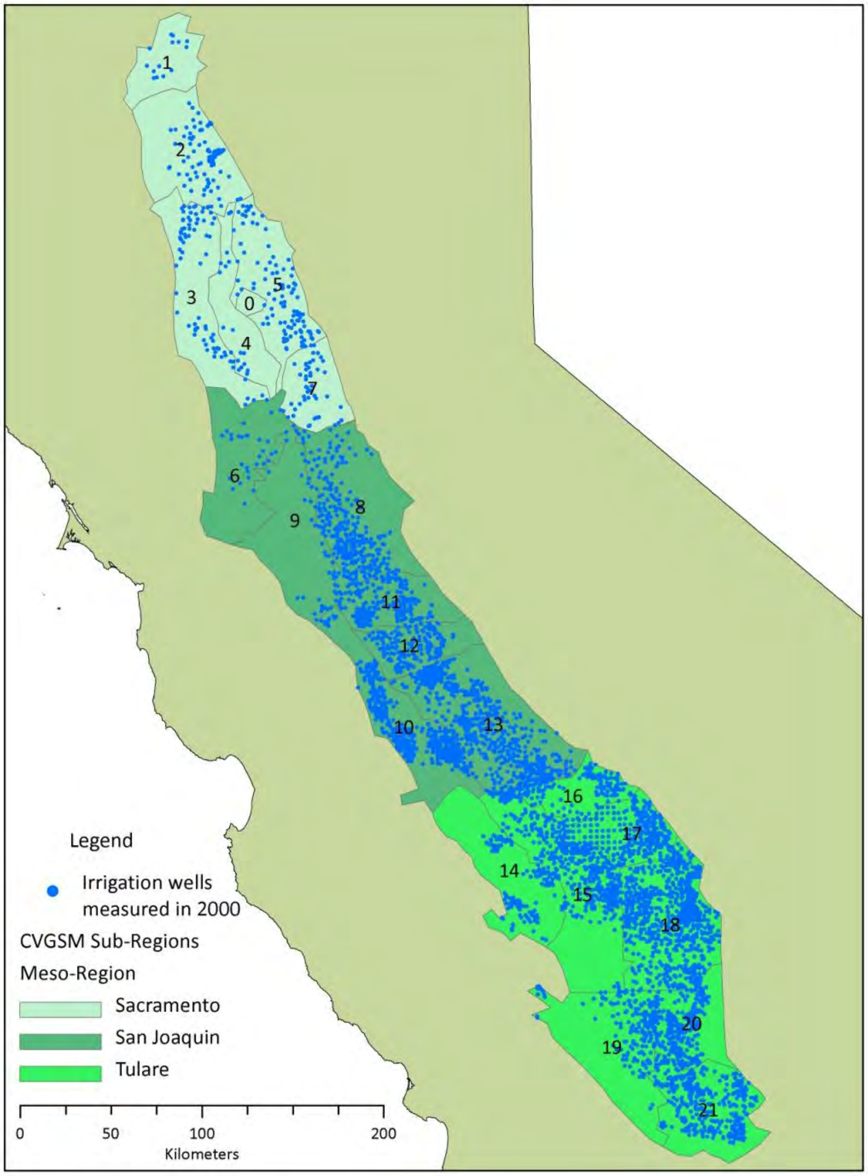


Figure A2: Distribution of wells measured in 2000 used for the estimate of pumping lift (courtesy of Aaron King)

Results

Table A1 presents averaged measurements taken any time during year 2000, average of fall and spring measurements, and the total number of measurements used for the year 2000 average (Count).

Table A1.2: Average GSWS (feet) for measurements taken in 2000, Fall 2000, Spring 2000 and the total count of measurements used for the Year 2000 average

CVPM region	GSWS (ft)			
	Year 2000	***Fall 2000***	***Spring 2000***	***Count****
1	71	70	73	31
2	40	45	38	529
3	27	33	23	258
4	16	19	13	221
5	27	29	26	294
6	25	26	23	155
7	40	39	42	210
8	90	99	84	589
9	24	27	22	104
10	17	77	16	439
11	47	45	48	319
12	68	#DIV/0!	68	177
13	75	#DIV/0!	75	641
14	235	245	150	136
15	93	140	92	377
16	57	#DIV/0!	57	145
17	34	#DIV/0!	34	271
18	80	#DIV/0!	80	857
19	139	#DIV/0!	139	179
20	298	178	298	282
21	191	#DIV/0!	191	379

*Measurement count for Year 2000

Cells that have #DIV/0! indicate that no data was available during that time or for that area. Spring values tend to be less than fall indicating that water levels in the spring and early summer are closer to the ground surface than by the end of irrigation season. This is due to winter recharge that "refills" the groundwater basin and summer extraction that draws water levels down. In some places where irrigation serves as a major source of recharge, fall levels can be higher than spring levels (example, region 20).

In reality, pumping lift is dynamic and changes between years and within a year. For the purposes of CALVIN, which uses a single number for all time and for each region, Year 2000 values were used because they approximate the overall average of available measured data for groundwater head in wells.

Appendix 3

CALVIN Schematic & Network Improvements

Updates to the CALVIN schematic were made to better accommodate components related to groundwater for the agricultural and urban sectors and to facilitate the calibration process. Hidden nodes and nodes for artificial recharge have been added to the PRMNetBuilder network. The following hidden nodes were added:

- Return flow of applied water to surface water from agricultural areas (HSD)
- Return flow of applied water to groundwater for urban areas (HGU)
- Infiltration of surface diversions allocated for spreading-Artificial Recharge (HAR)
- Pumping to all demand areas (HGP)

The added hidden nodes link to physical downstream and upstream nodes and carry amplitude functions that can represent losses. Hidden nodes for pumping (HGP) link groundwater to demand areas and have amplitudes of 1. It is assumed that pumps are located close to the demand areas so that no losses occur.

Hidden nodes for return flow (HGD and HGU) to groundwater for agricultural and urban areas link demand areas to groundwater and have a return flow amplitude representative of fraction of applied water that is returned to the ground. Artificial recharge nodes (HAR) consists of upstream and downstream links such that upstream links to surface water diversions allocated for spreading and carry amplitude that reflect fractions of diverted water that is lost to evaporation and the downstream link is artificial recharge flow to the groundwater basin. Hidden node for return flow to surface water (HSD) for agricultural and urban areas link demand areas to surface water and have return flow amplitude representative of fraction of applied water that is returned to surface water.

Figures A3.1 and A3.2 below show the updated, detailed schematic for agricultural and urban sectors, respectively.

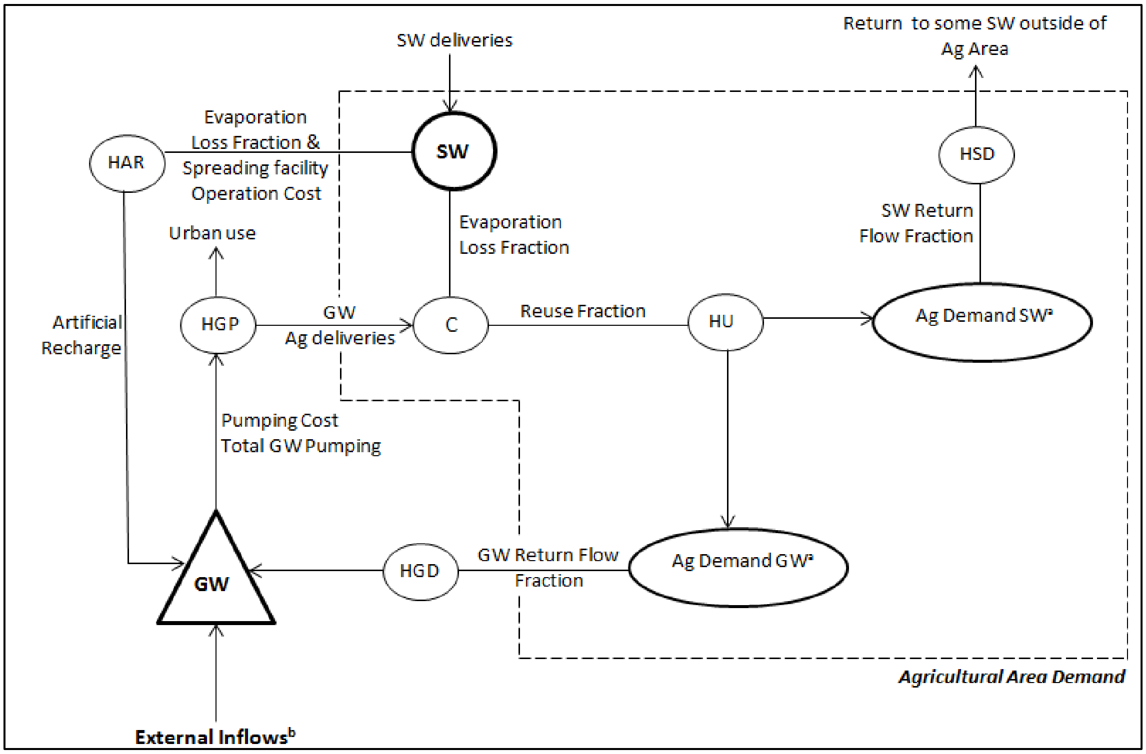


Figure A3.1: Updated CALVIN Schematic for Agricultural Sector

Notes: a) Ag Demand GW represents the non-consumptive use portion of irrigation water that deep percolates to groundwater, and Ag Demand SW represents the portion that returns to surface water systems as tailwater.
b) External Inflows represent net monthly time series inflows to groundwater from Streams, Lakes, Deep Percolation of Precipitation, Diversion losses, Boundary Inflows, Interbasin Inflows, Subsidence and Tile Drain Outflows

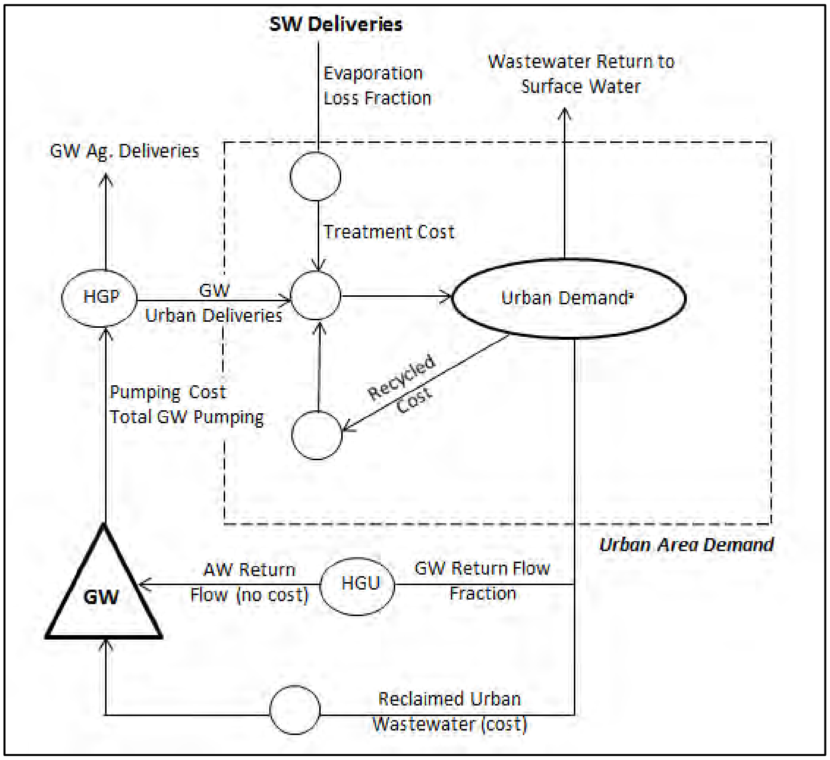


Figure A3.2: Updated CALVIN Schematic for Urban Sector

Notes: a) Urban Demands is represented in CALVIN as Int: CVPM, represent urban demands for water for indoor use and Ext: CVPM is demand for outdoor use, following Bartolomeo (2011).

Appendix 4

C2VSIM Streamflow Adjustments

Differences in streamflow exchange before and after 1951 could be due to the change in aquifer levels and changes in the interactions between surface-groundwater. There are changes in direction and magnitude of flow between groundwater basins and rivers over time so streams that may have been gaining streams before 1951 could have reversed to being losing stream after 1951 or vice versa. Another possibility is that less water goes from groundwater to streams after this time as a result of groundwater depletion and thus smaller stream-aquifer hydraulic connectivity. If the historical time series of streamflows were used, there would likely be a million acre-feet per year of water that may not be accounted for correctly in the Central Valley, which would result in some exaggerated availability of surface water or groundwater.

Because the possible inflated availability, streamflow exchanges before 1951 were adjusted using the annual average difference for subregions above 50 TAF/yr. Adjusted subregions are 2, 4, 5, 6, 9, 11, 13, 15, 18, 19 and 21. In order to maintain mass balance of water available within the subregions, the difference between historical and adjusted stream inflows were accounted for in the depletion areas of respective subregions or as depletions or accretions to major streams in these subregions. Table A4.1 shows monthly flows added or subtracted in the subregion depletion study areas: (-) add to depletion area and (+) subtract from depletion area. Details on depletion areas and how they are used in CALVIN are in the Appendix I (Draper et al. 2000). Table A4.1 also shows depletion and accretion areas and streams corresponding to subregions, as well as nodes per CALVIN network. Depletion and Accretion areas are listed in Appendix I and checked in CALVIN Schematic; stream information is as modeled in C2VSIM - version R356.

Table A4.1: Adjusted monthly flows to depletion and accretion areas in the Central Valley due to changes in historical streamflow exchanges before 1951

Subregion	Depletion Area or Stream	Nodes in CALVIN network	Adjusted monthly inflows (TAF/month)
2	10	D76a - DA10 Depletion	11.9
4	15	D66 - DA15 Depletion	5.8
5	69	D37 - DA69 Depletion	4.9
6	65	C20 - DA65 Depletion	9.3
9	55	D509 - D55 Depletion and Accretion	10.3
11	San Joaquin River to Tuolumne to Stanislaus	D688 - Depletion	6.4
13	Merced River	D643 - Depletion Upper Merced River	0.2
		D647 - Depletion Lower	0.3

		Merced River	
	Chowchilla River	D634 - Depletion Chowchilla River	0.4
	Fresno River	D624 - Depletion Fresno River	1.4
	San Joaquin River	D605 - Depletion San Joaquin River	1.9
15	Kings River	C53 - Depletion Kings River	19.5
18	Kaweah River	C89 - Accretion Kaweah River	0.1
	Tule River	C57 - Accretion Tule River	4.5
19 and 21	Kern River	C97 - Depletion Kern River	18.2

Table A4.2 shows annual average Net External Inflows calculated to be used in CALVIN based on C2VSIM in column 3. The 2nd column shows the adjusted values actually used in CALVIN. Columns 4 and 5 show comparisons of average yearly flows under this term from CVHM and CVGSM.

Table A4.2: Annual Average Net External Inflows in the Central Valley

	Net External Inflows to Groundwater (TAF/yr)			
	C2VSIM			
Subregion	**w/ Adjustments to Streamflow Exchange**	**w/out Adjustment to Streamflow Exchange**	**CVHM**	**CVGSM**
1	28	28	6.8	-96
2	235	177	406.1	189
3	-9	-9	30.9	77
4	-68	-96	23.2	227
5	91	67	64.2	6
6	225	180	453.5	302
7	168	168	186.2	242
8	402	402	685.8	686
9	134	85	446.1	-118
10	72	72	30.0	262
11	29	-1	19.8	303
12	49	49	57.9	129
13	365	344	564.2	781
14	278	278	260.4	267
15	688	594	1117.0	1130
16	51	51	-8.8	273
17	96	96	197.9	309
18	241	263	564.3	402
19	424	368	409.7	121
20	101	101	20.9	194
21	322	290	-63.9	322
Sacramento Total	**1206**	**1002**	2497.5	**1515**

San Joaquin Total	**515**	**464**	671.8	**1474**
Tulare Total	**2201**	**2041**	2302.9	**3017**
Central Valley Total	**3922**	**3507**	5472.2	**6006**

Appendix 5

C2VSIM Surface Water Recoverable and Non-recoverable Losses

Table A5.1shows the C2VSIM surface water recoverable (primarily diversion) and non-recoverable (evaporation and transpiration) losses and how they correspond to CALVIN nodes and links. The 5th column shows the previous version of CALVIN's Recoverable and Non-recoverable loss amplitudes. Column 6 shows the new values used. If a parentheses ( ) is shown, that indicates that amplitude was adjusted to the value inside of the parentheses during the calibration process.

Table A5.1: Surface Water Recoverable & Non-Recoverable Loss Amplitudes

C2VSIM Surface Water Diversion Source Node	Subregion	Fraction Non-Recoverable Losses	Land Use	Old CALVIN RL & NRL Amplitude	New CALVIN RL & NRL Amplitude	Diversion Description & CALVIN Nodes & Links for Fraction Update
Subregion 1						
Import	1	0.01	Ag			Whiskeytown and Shasta imports for SR1 Ag
		0.01		**0.97**	**0.96**	**HSU1SR3_C3**
Import	1	0.01	M&I			Whiskeytown and Shasta imports for SR1 M&I
206	1	0.01	M&I			Sacramento River to Bella Vista Conduit SR1 M&I
206	1	0.01	M&I			Sacramento River Keswick to Red Bluff SR1 M&I
		0.03		**1**	**0.88 (1)**	**T41_Ext: Redding & T41_Int: Redding**
206	1	0.02	Ag			Sacramento River to Bella Vista Conduit SR1 Ag
	1	**0.02**		**0.97**	**0.95**	**HSU1D5_C3**
216	1	0.02	Ag			Sacramento River Keswick to Red Bluff SR1 Ag
212	1	0.02	Ag			Cow Creek riparian diversions to SR1 Ag
221	1	0.02	Ag			Battle Creek riparian diversions to SR1 Ag
Import	1	0.02	Ag			Cottonwood Creek riparian diversions to SR1 Ag
	1	**0.08**		**0.97**	**0.52**	**HSU1D74_C3**
Subregion 2						
234	2	0.02	Ag			Antelope Creek diversions to Los Molinos MWC SR2 Ag
245	2	0.02	Ag			Mill Creek to Los Molinos MWC SR2 Ag
258	2	0.02	Ag			Deer Creek to Los Molinos MWC SR2 Ag

231	2	0.02	Ag			Sacramento River diversions to Corning Canal SR2 Ag
Import	2	0.02	Ag			Clear Creek riparian diversions to SR2 Ag
		0.1		**0.93**	**0.47 (0.88)**	**HSU2D77_C6**
242	2	0.02	Ag			Elder Creek riparian diversions SR2 Ag
253	2	0.02	Ag			Thomas Creek riparian to SR2 Ag
262	2	0.02	Ag			Sacramento River to SR2 Ag
	2	**0.06**		**0.93**	**0.64 (0.88)**	**HSU2C1_C6**
231	2	0.02	Ag			Sacramento River diversions to the Tehama Colusa Canal to SR2 Ag
	2	**0.02**		**0.93**	**0.95**	**HSU2C11_C6**
264	2	0.02	Ag			Stony Creek to North Canal SR2 Ag
Import	2	0.02	Ag			Stony Creek to South Canal from Black Butte Reservoir SR2 Ag
		0.04		**0.93**	**0.88**	**HSU2C9_C6**
Subregion 3						
264	3	0.02	Ag			Stony Creek to Tehama Colusa Canal and SR3 Ag
231	3	0.02	Ag			Sacramento River diversions to the Tehama Colusa Canal to SR3 Ag
		0.04		**0.95**	**0.9**	**HSU3C11_C302**
264	3	0.02	Ag			Stony Creek to Glenn-Colusa Canal and SR3 Ag
261	3	0.02	Ag			Sacramento River to Glenn Colusa Canal to SR3 Ag
261	3	0.02	Refuge			Sacramento River to Glenn Colusa Canal to SR3 Refuge (Ag)
		0.06		**0.95**	**0.85**	**HSU3C13_C302**
282	3	0.02	Ag			Sacramento River to SR3 Ag
		0.02		**0.95**	**0.88**	**HSU3D66_C303**
327	3	0.02	Ag			Colusa Basin Drain to SR3 Ag
324	3	0.02	Refuge			Colusa Basin Drain to SR3 Ag
		0.04		**0.95**	**0.76 (0.88)**	**HSU3C305_C303**
Subregion 4						
331	4	0.02	Ag			Sacramento River to SR4 Ag
		0.02		**0.97**	**0.88**	**HSU4D30_C14**
IN CALVIN: Butte Creek and Little Chico Creek --> SURPLUS DELTA OUTFLOW OR TO NORTH BAY AQUEDUCT TO URBAN NAPA-SOLANO						
285	4	0.02	Ag			Butte Creek to RD 1004 SR4 Ag
284	5	0.02	Ag			Butte Creek at Parrott-Phelan Dam to SR5 Ag

286	5	0.02	Ag			Butte Creek at Durham Mutual Dam to SR5 Ag
287	5	0.02	Ag			Butte Creek at Adams and Gorrill Dams to SR5 Ag
291	5	0.02	Refuge			Butte Creek to Sutter & Butte Duck Clubs to SR5 Ag
Import	5	0.02	Ag			Little Chico Creek to SR4 Ag
292	4	0.02	Ag			Butte Slough to SR4 Ag
Subregion 5: URBAN in CALVIN receives only GW supplies, Yuba receives both GW and SW supplies & Palermo Canal serves Ag						
Import	5	0.02	Ag			Tarr Ditch SR5 Ag (55% is used inside the model area)
		0.02		**0.96**	**0.88**	**HSU5C35_C26**
Import	5	0.02	Ag			Miocene and Wilenor Canals SR5 Ag
Import	5	0.02	Ag			Oroville-Wyandotte ID through Forbestown Ditch SR5 Ag
347	5	0.02	Ag			Feather River to SR5 Ag (replaced by Thermalito)
347	5	0.02	Ag			Feather River to SR5 Ag
Import	5	0.02	Ag			Bangor Canal SR5 Ag (Miners Ranch Canal)
		0.08		**0.96**	**0.52 (0.88)**	**HSU5C77_C26**
Import	5	0.02	M&I			Feather River to Thermalito ID SR5 M&I
352	5	0.01	M&I			Feather River to Yuba City SR5 M&I
Import	5	0.02	M&I			Palermo Canal from Oroville Dam SR5 M&I
351	5	0.01	M&I			Yuba River to SR5 M&I
		0.06		**1**	**0.82 (1)**	**T61_Ext: Yuba and T61_Int: Yuba**
Import	5	0.02	Ag			Thermalito Afterbay to SR5 Ag
358	5	0.02	Ag			Bear River to Camp Far West ID North Side SR5 Ag
		0.04		**0.96**	**0.76 (0.88)**	**HSU5C80_C26**
351	5	0.02	Ag			Yuba River to SR5 Ag
				0.96	**0.88**	**HSU5C83_C26**
Subregion 6						
329	6	0.02	Ag			Knights Landing Ridge Cut diversions (Baseflow) SR3 Ag
371	6	0.02	Ag			Sacramento R Rt Bk btwn Knights Landing & Sacramento to SR6 Ag
		0.04		**0.93**	**0.76 (0.88)**	**HSU6C314_C17**
381	6	0.01	M&I			Sacramento River to West Sacramento SR6 M&I
400	6	0.02	M&I			Putah South Canal SR6 M&I
413	6	0.02	M&I			Delta to North Bay Aqueduct to SR6 M&I

		0.05		**1**	**0.84 (1)**	**T14_ERes: Napa-Solano, T14_Ind: Napa-Solano and T14_IRes: Napa-Solano**
Import	6	0.02	Ag			Cache Creek to SR6 Ag
				0.93	**0.88**	**HSU6C16_C17**
398	6	0.02	Ag			Yolo Bypass to SR6 Ag
400	6	0.02	Ag			Putah South Canal SR6 Ag
404	6	0.02	Ag			Putah Creek riparian diversions SR6 Ag
413	6	0.02	Ag			Delta to North Bay Aqueduct to SR6 Ag
		0.08		**0.93**	**0.59 (0.88)**	**HSU6C21_C17**
Subregion 7						
364	7	0.02	Ag			Feather River to SR7 Ag
				0.93	**0.88**	**HSU7D42_C34**
358	7	0.02	Ag			Bear River to Camp Far West ID South Side SR7 Ag
358	7	0.02	Ag			Bear River to South Sutter WD SR7 Ag
Import	7	0.02	Ag			Bear River Canal to South Sutter WD SR7 Ag
		0.06		**0.93**	**0.64 (0.88)**	**HSU7C33_C34**
372	7	0.02	Ag			Sacramento R Lt Bank btwn Knights Landing & Sacramento to SR7 Ag
				0.93	**0.88**	**HSU7C67_C34 (Include diversions from Butte Creek & Little Chico)**
Subreigon 8						
Import	7	0.01	M&I			Folsom Lake to SR7 M&I
377	7	0.01	M&I			American R to Carmichael WD SR7 M&I
378	7	0.01	M&I			American R LB to City of Sacramento SR7 M&I
381	8	0.01	M&I			Sacramento River Left Bank to City of Sacramento SR8 M&I
375	8	0.01	M&I			Folsom South Canal to SR8 M&I
		0.05		**1**	**0.76 (1)**	**T4_Ext: Sacramento and T4_Int: Sacramento**
375	8	0.01	M&I			Folsom South Canal to SR8 M&I
				1	**0.94 (1)**	**T43_Ext: CVPM8 and T43_Int:CVPM8**
Import	7	0.02	Ag			American River to North Fork and Natomas Ditches to SR7 Ag*
375	8	0.02	Ag			Folsom South Canal to SR8 Ag
		0.04		**0.92**	**0.76 (0.88)**	**HSU8C173_C36**
193	8	0.02	Ag			Cosumnes R riparian to SR8 Ag
				0.92	**0.88**	**HSU8C37_C36**
Import	8	0.02	Ag			Mokelumne R to SR8 AgS

195	8	0.02	Ag			Mokelumne R to SR8 Ag
		0.04		**0.92**	**0.76 (0.88)**	**HSU8D98_C36**
165	8	0.02	Ag			Calaveras R to SR8 Ag*
*In CALVIN Calaveras diversions are not allocated for SR8 (Calaveras_SR-New Hogan Lake_etc).						
Central San Joaquin ID from Stanislaus River diversion to CVPM 8 in CALVIN but not in C2VSIM (_C43_HSU8C43_C36_CVPM8 Ag)						
Subregion 9						
418	9	0.02	Ag			Delta to SR9 Ag
				1	**0.88 (0.93)**	**HSU9D507_C68**
Import	9	0.02	Ag			Delta Mendota Canal to Subregion 9 Ag
				1	**0.93**	**HSU9D521_C68 and HSU9D515_C68**
Subregion 10						
145	10	0.03	Ag			San Joaquin R riparian (Fremont Ford to Vernalis) SR10 Ag
				0.9	**0.82**	**HSU10C10_C84**
Import	10	0.02	Ag			Delta Mendota Canal to Subregion 10 Ag
Import	10	0.02	Refuge			Delta-Mendota Canal to SR10 Refuges (Ag)
				0.9	**0.93**	**HSU10C30_C84**
Import	10	0.02	Ag			Mendota Pool to SR10 Ag
Import	10	0.02	Refuge			Mendota Pool to SR10 Refuges (Ag)
				0.9	**0.82**	**HSU10D731_C84**
Import	10	0.02	Ag			O'Neill Forebay to SR10 Ag
Import	10	0.02	Refuge			O'Neill Forebay to SR10 Refuges (Ag)
				0.9	**0.88**	**HSUD803_C84 (IN CALVIN as CA Aqueduct, Harvey Bank Pumping Station, should confirm this)**
Import	10	0.02	Ag			San Luis Canal to SR10 Ag
Import	10	0.02	Refuge			San Luis Canal to SR10 Refuges (Ag)
				0.9	**0.93**	**HSU10C85_C84**
Subregion 11						
147	11	0.03	Ag			Stanislaus R to South San Joaquin Canal to SR11 Ag
147	11	0.03	Ag			Stanislaus R to Oakdale Canal to SR11 Ag
		0.06		**0.8**	**0.64 (0.82)**	**HSU11D16_C172**
147	11	0.01	M&I			Stanislaus R to South San Joaquin Canal to SR11 M&I
147	11	0.01	M&I			Stanislaus R to Oakdale Canal to SR11 M&I
152	11	0.01	M&I			Stanislaus R riparian to SR11 M&I
Import	11	0.01	M&I			Modesto Canal to SR11 M&I
142	11	0.01	M&I			Tuolumne R RB riparian to SR11 M&I

		0.05		**1**	**0.7 (1)**	**T45_Ext:CVPM11 and T45_Int:CVPM11**
152	11	0.03	Ag			Stanislaus R riparian to SR11 Ag
				0.88	**0.82**	**HSU11D672_C172**
Import	11	0.03	Ag			Modesto Canal to SR11 Ag
				0.88	**0.82**	**HSU11D662_C172**
142	11	0.03	Ag			Tuolumne R RB riparian to SR11 Ag
				0.88	**0.82**	**HSU11D664_C172**
145	11	0.03	Ag			San Joaquin R riparian (Fremont Ford to Vernalis) SR11 Ag
				0.88	**0.82**	**HSU11D689_C172**
Subregion 12						
142	12	0.03	Ag			Tuolumne R LB riparian to SR12 Ag
				0.9	**0.82**	**HSU12D664_C45**
142	12	0.01	M&I			Tuolumne R LB riparian to SR12 M&I
123	12	0.01	M&I			Merced R Right Bank riparian to SR12 M&I
117	12	0.01	M&I			Merced R to Merced ID Northside Canal to SR12 M&I
Import	12	0.01	M&I			Turlock Canal to SR12 M&I
		0.04		**1**	**0.76 (1)**	**T66_Ext:CVPM12 & T66_Int:CVPM12**
Import	12	0.03	Ag			Turlock Canal to SR12 Ag
				0.9	**0.82**	**HSU12D662_C45**
117	12	0.03	Ag			Merced R to Merced ID Northside Canal to SR12 Ag
				0.9	**0.82**	**HSU12D645_C45**
123	12	0.03	Ag			Merced R Right Bank riparian to SR12 Ag
				0.9	**0.82**	**HSU12D649_C45**
134	12	0.03	Ag			San Joaquin R riparian (Fremont Ford to Vernalis) SR12 Ag
				0.9	**0.82**	**HSU12D699_C45**
Subregion 13						
			AG	**0.9**	**0.94**	**HSU13D606_C46**
123	13	0.03	Ag			Merced R Left Bank riparian to SR12 Ag
				0.9	**0.82**	**HSU13D649_C46**
117	13	0.03	Ag			Merced R to Merced ID Main Canal to SR12 Ag
				0.9	**0.82**	**HSU13D645_C46**
Import	13	0.03	Ag			Madera Canal to Chowchilla WD SR13 Ag
Import	13	0.03	Ag			Madera Canal to Madera ID SR13 Ag
Import	13	0.02	Ag			Madera Canal to SR13 Ag
		0.05		**0.9**	**0.75(0.88)**	**HSU13C72_C46**
84	13	0.03	Ag			Chowchilla R riparian

						SR13 Ag
				0.9	**0.82**	**HSU13D634_C46**
74	13	0.03	Ag			Fresno R riparian SR13 Ag
				0.9	**0.82**	**HSU13D624_C46**
60	13	0.03	Ag			San Joaquin R riparian (Friant to Gravelly Ford) SR13 Ag
115	13	0.03	Ag			San Joaquin R riparian (Fremont Ford to Vernalis) SR13 Ag
				0.9	**0.82**	**HSU13D694_C46**
Import	13	0.02	Ag			Delta-Mendota Canal to SR13 Ag
Import	13	0.02	Ag			Mendota Pool to SR13 Ag
		0.04		**0.9**	**0.75(0.88)**	**HSU13D731_C46**
Subregion 14						
Import	14	0.02	Ag			Mendota Pool to SR14 Ag
				0.9	**0.82**	**HSU14D608_C91**
Import	14	0.02	Ag			San Luis Canal to SR14 Ag
Import	14	0.02	Refuge			San Luis Canal to SR14 Refuges (Ag)
				0.9	**0.93**	**HSU14C92_C91**
Import	14	0.01	M&I			San Luis Canal to SR14 M&I
				1	**0.94**	**D750_Ext:CVPM14**
Import	14	0	Seepage			San Luis Canal Seepage Losses SR14
Subregion 15						
28	15	0.04	Ag			Kings R Main Stem to SR15 Ag
43	15	0.04	Ag			Kings R North Fork to SR15 Ag
37	15	0.04	Ag			Kings R South Fork to SR15 Ag
52	15	0.04	Ag			Kings R Fresno Slough to SR15 Ag
				0.84	**0.8**	**HSU15C52_C90**
Import	15	0.02	Ag			Mendota Pool to SR15 Ag
Import	15	0.02	Refuge			Mendota Pool to SR15 Refuges (Ag)
				0.84	**0.82**	**HSU15D608_C90**
Import	15	0.02	Ag			San Luis Canal to SR15 Ag
Import	15	0.02	Refuge			San Luis Canal to SR15 Refuges (Ag)
Import	15	0.02	Ag			Friant-Kern Canal to SR15 Ag
				0.84	**0.93**	**HSU15C49_C90**
Subregion 16						
60	16	0.03	Ag			San Joaquin R riparian (Friant to Gravelly Ford) SR16 Ag
				0.8	**0.82**	**HSU16D606_C50**
24	16	0.03	Ag			Kings R to Fresno ID SR16 Ag

				0.8	**0.85**	**HSU16C53_C50**
Import	16	0.02	Ag			Friant-Kern Canal to SR16 Ag
				0.8	**0.93**	**HSU16C49_C50**
60	16	0.01	M&I			San Joaquin R riparian (Friant to Gravelly Ford) SR16 M&I
Import	16	0.01	M&I			Friant-Kern Canal to SR16 M&I
		0.02		**1**	**0.88 (1)**	**T24_Ext: City of Fresno and T24_Int: City of Fresno**
Subregion 17						
25	17	0.04	Ag			Kings R to Consolidated ID SR17 Ag
25	17	0.04	Ag			Kings R to Alta ID SR17 Ag
				0.9	**0.8 (0.88)**	**HSU17C53_C55**
Import	17	0.02	Ag			Friant-Kern Canal to SR17 Ag
				0.9	**0.93**	**HSU17C76_C55**
Import	17	0	Seepage			Friant-Kern Canal to SR17 Seepage Loss
Subregion 18						
420	18	0.03	Ag			Kaweah R Partition A to SR18 Ag
422	18	0.03	Ag			Kaweah R Partition B to SR18 Ag
422	18	0.03	Ag			Kaweah R Partition C to SR18 Ag
420	18	0.03	Ag			Kaweah R Partition D to SR18 Ag
426	18	0.03	Ag			Kaweah R to Corcoran ID SR18 Ag
				0.9	**0.83**	**HSU18C56_C60**
18	18	0.03	Ag			Tule R riparian to SR18 Ag
				0.9	**0.83**	**HSU18C58_C60**
Import	18	0.02	Ag			Friant-Kern Canal to SR18 Ag
				0.9	**0.93**	**HSU18C688_C60**
Import	18	0.01	M&I			Friant-Kern Canal to SR18 M&I
				1	**0.94 (1)**	**C688_T51 (New supply for 2100 from FKC to CVPM18)**
Subregion 19						
7	19	0.01	Ag			Kern R to SR19 Ag
				0.9	**0.92**	**HSU19C73_C100**
Import	19	0.02	Ag			California Aqueduct to SR19 Ag
Import	19	0.02	Refuge			California Aqueduct to SR19 Refuges (Ag)
				0.9	**0.93**	**HSU19D847_C100 and HSU19D850_C100**
Import	19	0.02	Ag			Friant-Kern Canal to SR19 Ag
Import	19	0.02	Refuge			Friant-Kern Canal to SR19 Refuges (Ag)
				0.9	**0.93**	**HSU19C62_C100**

Import	19	0.02	Refuge			Cross-Valley Canal to SR19 Refuges (Ag)
				0.9	**0.93**	**HSU19C74_C100**
Subregion 20						
2	20	0.03	Ag			Kern R to SR20 Ag
				0.9	**0.84**	**HSU20C65_C63**
Import	20	0.02	Ag			Friant-Kern Canal to SR20 Ag
				0.9	**0.93**	**HSU20C64_C63**
Import	20	0.02	Ag			Cross-Valley Canal to SR20 Ag
				0.9	**0.93**	**HSU20C74_C63**
2	20	0.01	M&I			Kern R to SR20 M&I
Import	20	0.01	M&I			Friant-Kern Canal to SR20 M&I
		0.02		**1**	**0.88 (1)**	**T53_Int:CVPM20 and T53_Ext:CVPM20**
Subregion 21						
2	21	0.02	Ag			Kern R to SR21A Ag
3	21	0.02	Ag			Kern River to Subregion 21B Ag
4	21	0.02	Ag			Kern River to Subregion 21C Ag
				0.8	**0.9**	**HSU21C65_C66**
Import	21	0.02	Ag			California Aqueduct to SR21 Ag
Import	21	0.02	Ag			Friant-Kern Canal to SR21 Ag
				0.8	**0.93**	**HSU21C689_C66**
Import	21	0.02	Ag			Cross-Valley Canal to SR21 Ag
				0.8	**0.93**	**HSU21C74_C66**
Import	21	0.01	M&I			California Aqueduct to SR21 M&I
				1	**0.94 (1)**	**T28_Int:Bakersfield and T28_Ext:Bakersfield**

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY **EDMUND G. BROWN JR.,** *Governor*

DEPARTMENT OF WATER RESOURCES
NORTHERN REGION OFFICE
2440 MAIN STREET
RED BLUFF, CA 96080-2356

February 3, 2015

Glenn County Board of Supervisors
525 West Sycamore Street, Suite B1
Willows, California 95988

Glenn County Water Advisory Committee
Post Office Box 351
Willows, California 95988

Dear Supervisors and Committee members:

The purpose of this letter is to provide land subsidence results from the Global Positioning System (GPS) surveys performed in Glenn County. GPS surveys were performed to monitor changes in ground surface elevation to detect subsidence throughout the county and ultimately the entire Sacramento River Valley. The enclosed comparison showed two areas of the county exhibiting land subsidence.

The Glenn County subsidence network was installed and initially monitored in 2004. It consisted of 58 stations; about half were existing survey monuments, and the other half were installed as part of this project. Initial GPS surveying took place during March and April 2004. The network was resurveyed in spring 2008 as part of a larger Sacramento Valley GPS subsidence project.

The two surveys did not follow the same observation schedule and monitoring plan, and therefore, direct comparison was not possible at some locations within the county. By performing data analysis and review, the Northern Region Office of the Department of Water Resources (DWR) was able to develop the enclosed map showing the land surface change along the defined paths, or vectors, between the years of 2004 and 2008. The data analysis and review performed to complete the map included identifying and using similar vectors, where available, from both years. It also included using auto leveled monuments, where necessary, to be able to include the monuments that were relocated between the survey years. This was performed only when there was a direct relationship between the points in order to preserve the accuracy of the survey data.

Using the best methodologies available at the time, the GPS vertical accuracy, or threshold, for this monitoring effort was estimated to be 0.164 feet or approximately 2 inches. Any changes that show greater than the defined threshold are considered statistically significant and indicate possible ground movement.

In general, the analysis did not show that the county experienced widespread ground movement during this four-year time frame. However, two areas determined from the analysis indicate ground movement. The first area, to the south and east of Hamilton City, did exhibit a change in ground surface elevation that is statistically significant. The monument designated “WILD” on the enclosed figure showed an average change of 0.38 feet or about 4.5 inches when compared to the nearest monuments to the west. This monument is on the eastern edge of the Glenn County network and additional surveying would need to be performed comparing 2008 to current levels in a larger area of Glenn and Butte counties to determine if this is an ongoing concern or just an anomaly.

The second area is near Sunset Avenue and County Road E to the southwest of Orland. This area showed a change just below the level of being statistically significant at 0.125 feet or about 1.5 inches. This may have indicated an area of concern and warrant additional surveying to determine whether this is an onset of land subsidence or not.

Ideally, the entire Sacramento Valley GPS Subsidence Monitoring Network should be resurveyed and compared to the valley wide 2008 survey to determine changes caused by the increased groundwater pumping and the persistent drought impacts. It is possible to check small areas without resurveying the entire network as mentioned above. DWR will further investigate the opportunities to work with the Sacramento Valley counties to resurvey the Sacramento Valley GPS Subsidence Monitoring Network. As an intermediate step, DWR may resurvey the two local areas that showed subsidence in 2008 to investigate any additional land elevation changes.

A formal presentation of the results will be provided by DWR to the Glenn County Water Advisory Committee at a future date.

If you have any questions or need additional information, please contact me at (530) 528-7403, or Roy Hull, Engineering Geologist, at (530) 529-7337.

Sincerely,

Bill Ehorn, Chief
Groundwater and Geologic Investigations

Enclosure

ec: (See attached list.)

Ms. Lisa Hunter, Glenn County
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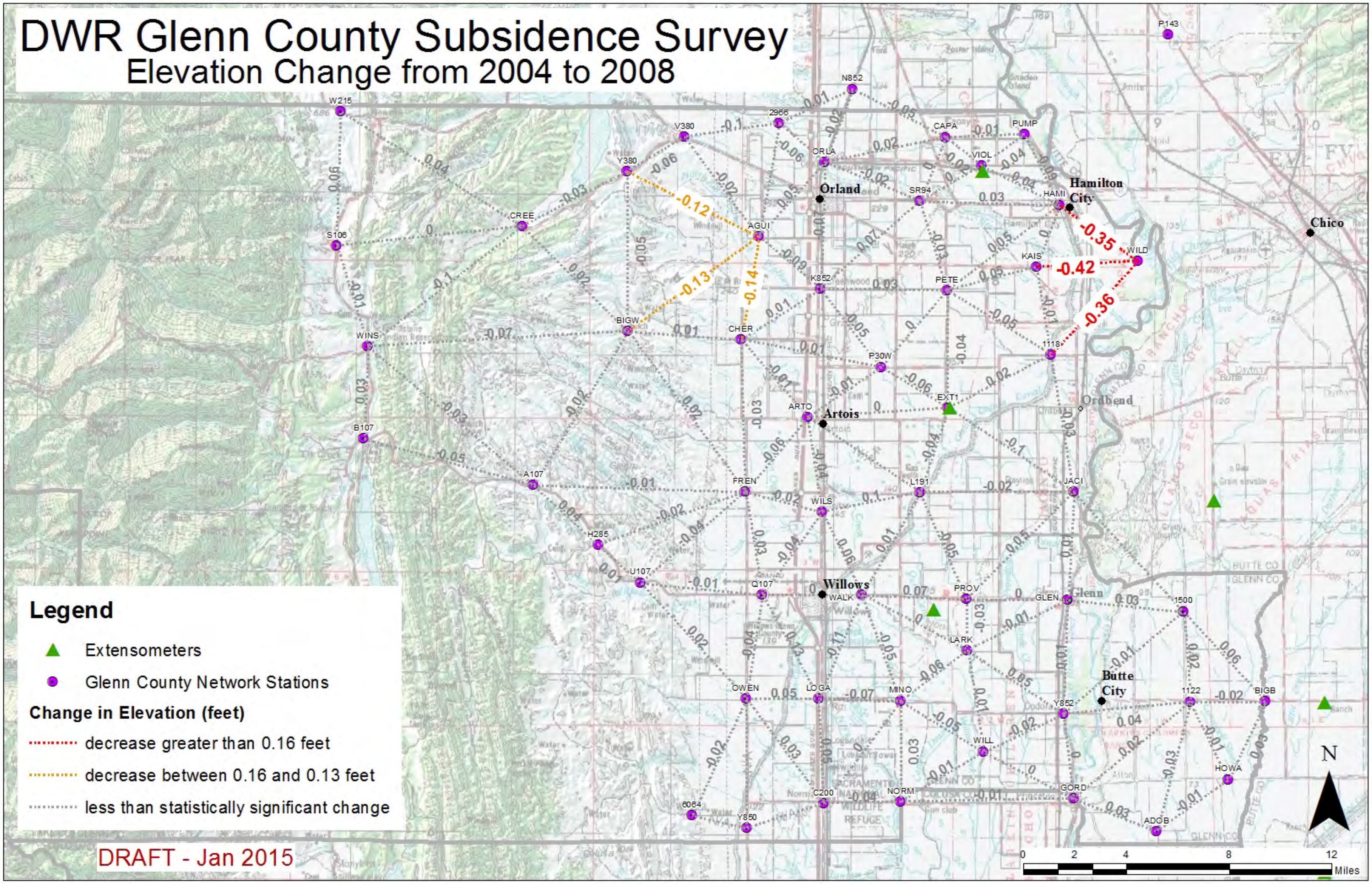

DWR Glenn County Subsidence Survey
Elevation Change from 2004 to 2008

Legend

▲ Extensometers

● Glenn County Network Stations

Change in Elevation (feet)

decrease greater than 0.16 feet

decrease between 0.16 and 0.13 feet

less than statistically significant change

DRAFT - Jan 2015

Testimony on
Water Availability Analysis
for Trinity, Sacramento, and San Joaquin River Basins
Tributary to the Bay-Delta Estuary

Submitted by
Tim Stroshane
Senior Research Associate
California Water Impact Network (C-WIN)

and on behalf of
California Sportfishing Protection Alliance
and AquAlliance

October 26, 2012

for

Workshop #3
Analytical Tools for Evaluating the Water Supply,
Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan
November 13 and 14, 2012

The State Water Resources Control Board called for workshops to receive information from and discuss with participating parties the scientific and technical bases for considering potential changes to the 200 Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta Estuary for Phase II of the Board's comprehensive review of this plan.

According to the State Board's public notice for these workshops, the prompts for Workshop 3 testimony are:

1. What types of analyses should be completed to estimate the water supply, hydrodynamic, and hydropower effects of potential changes to the Bay-Delta Plan?

2. What analytical tools should be used to evaluate these effects? What are the advantages, disadvantages and limitations of these tools?

Water Availability Analysis

Workshop 3 Testimony, Bay Delta Plan
Submitted by California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance

The California Water Impact Network, the California Sportfishing Protection Alliance, and AquAlliance (hereinafter, C-WIN) are pleased to submit this testimony to the State Water Resources Control Board. This testimony addresses the close linkage between the Board's public trust responsibilities on behalf of the State of California, its water quality control planning function, and its duty to regulate water rights in California. Water quality control planning efforts to date have led the Board to consider proportional tributary contributions needed to meet Delta inflow objectives from the Sacramento and San Joaquin River Basins to improve water quality and protect all beneficial uses, including fish and wildlife, in the Delta. The State Water Resources Control Board has authority over water rights in the Basins that would enable it to reallocate water usage and ensure compliance with the Board's new instream flow objectives.

Water availability analysis is an important method for modeling how the Board would implement new flow objectives. Our testimony illustrates the use of a planning-level water availability analysis for the Trinity River (much of whose flows are diverted to the Central Valley watershed of the Bay-Delta Estuary) and the major tributaries of the Sacramento and San Joaquin River Basins. We incorporate into the analysis the Basins' hydrologic variability, instream flow requirements based on the Board's 2010 public trust Delta flow determinations, and then operate publicly available water rights data and priorities on the divertable flows that remain in the system. We find that under public trust protective flow determinations, the promised water represented in water rights claims far exceed flow conditions available to these claims in most years.

We recommend for the Bay-Delta Plan's implementation program that the State Water Resources Control Board draw on its new flow determinations to increase the seasons during which rivers in the Bay-Delta Estuary's Central Valley watershed are fully appropriated, and push back the water rights priority date on which Term 91 curtailments are now based. Our water availability analysis suggests distinct parameters for both actions.

Finally, we conclude that the Board should use the Bay-Delta Plan process to tighten up its regulation of surplus water usage and export by the State Water Project and Central Valley Project to avoid permanently damaging Sacramento Valley groundwater resources. The Board's Delta flow determinations, coupled with comprehensive enforcement of water rights priorities, can help to protect both groundwater and surface water resources in the Sacramento Valley over the long term.

Government's Public Trust Responsibility

Governments have a permanent fiduciary responsibility and obligation to protect the public trust. In *National Audubon Society v. Superior Court* (1983) 33 Cal 3d 419, 441, the court held that "the public trust is more than an affirmation of state power to use public property for public purposes. It is an affirmation of the duty of the state to protect the people's common heritage of streams, lakes, marshlands and tidelands, surrendering that right of protection only in rare cases when the abandonment of that right is consistent with the purposes of the trust." The act of appropriating water is an acquisition of a property right from the waters of the state, an act that is therefore subject to regulation under the state's public trust responsibilities.

The State Water Resources Control Board has invoked its public trust responsibilities in regulating the waters of California and now acknowledges that the public trust is one of its ongoing regulatory responsibilities. Its most publicly prominent instance came in Water Rights Decision 1631 (D-1631) in 1994. In D-1631 the Board balanced the needs of the City of Los Angeles for water supply from the tributaries of Mono Lake with the lake's own needs for water to sustain its ecosystem. It required Los Angeles to make releases from each of its tributaries that would sustain riparian ecosystems and help restore fish populations to the tributaries by prescribing lake level targets in a specified time period (State Water Resources Control Board 1994 The Board has also adopted regulations governing how it treats the public trust in matters of the appropriation of water in California. (State Water Resources Control Board 2011b Article 14 Standard Permit Terms and Conditions)

The trial court in *United States v State Water Resources Control Board* (1986 18 Cal.App.3d 82 determined that the State Water Resources Control Board had the authority to modify an appropriative water right permit once it had been issued and that it could reduce the US Bureau of Reclamation's Central Valley Project permits to gain compliance from the Bureau. But the trial court held new fish and wildlife objectives the Board had approved in Water Rights Decision 1485 (D-1485 in 1978 to be invalid because the Board failed to identify the *source* of its authority. Justice John Racanelli, the author of the subsequent appellate court decision cited above, stated that the source of the Board's authority to issue and enforce new fish and wildlife objectives such as those contained in Water Rights Decision 148 (D-1485) was the Public Trust Doctrine:

> ...the state as trustee of the public trust retains supervisory control of the state's waters such that no party has a vested right to appropriate water in a manner harmful to the interests protected by the public trust. (18 Cal.App.3d 82 149)

Stevens (2005 summarizes the present range of coverage that American and California law gives the public trust doctrine:

1. It applies to all navigable streams.
2. It applies to ecological preservation.
3. It applies to wetland areas.
4. It applies underground (citing the Waiahole decision from Hawai'i).
5. It applies to artificially enlarged waters.
6. It applies to wild animals including fish.[1]

The Public Trust and Paper Water

In the next few years, the State Water Resources Control Board is expected to make several crucial decisions on California's water future. These decisions include:

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[1] The California Constitution also provides an absolute right to fish among the fundamental declared rights it accords all California citizens. Article I, Section 25 states:

> ARTICLE 1 DECLARATION OF RIGHTS
>
> Section 25. The people shall have the right to fish upon and from the public lands of the State and in the waters thereof, excepting upon lands set aside for fish hatcheries, and no land owned by the State shall ever be sold or transferred without reserving in the people the absolute right to fish thereupon; and no law shall ever be passed making it a crime for the people to enter upon the public lands within this State for the purpose of fishing in any water containing fish that have been planted therein by the State; provided, that the legislature may by statute, provide for the season when and the conditions under which the different species of fish may be taken.

In combination with California Fish and Game Code Section 5937, which provides that owners of dams must preserve fish populations downstream in "good condition", preservation of this right logically should be construed as an important aspect of the public trust responsibilities of government. It retains meaning as a right only when there exist sufficient fish to catch sustainably.

- Determining how to provide sufficient flows from the Sacramento and San Joaquin River's major tributaries to the Bay-Delta Estuary.
- Updating its 200 Bay-Delta Water Quality Control Plan to include those new Sacramento and San Joaquin River flow and South Delta salinity objectives.
- Deciding whether to extend the water rights *permits* of the California State Water Project and the federal Central Valley Project, or instead *license* them at levels that represent reasonable and public trust protective water usage.
- Deciding whether and/or how to permit a "north Delta diversion"—a diversion that is now more familiarly known as the Peripheral Tunnels Project.
- Deciding whether and/or how to permit new reservoirs on the San Joaquin River and in the southwestern Sacramento Valley (and/or to raise existing dams to increase storage elsewhere) that would be added to the storage capacities of the Central Valley Project and the State Water Project.

As a regulatory agency, the State Water Resources Control Board is not known for making and holding to courageous or visionary decisions that protect beneficial uses of water throughout California. Their record of delay and incrementalism has contributed to the poor condition of the Bay Delta Estuary and the great rivers of its watershed, the great Sacramento and San Joaquin Rivers.

The State Water Resources Control Board has authority to make bold decisions and hold to them. (Cahill 2008)

The State Water Resources Control Board will need to balance protection of the public trust with other competing beneficial uses of water reliant on the Delta The Board has already determined the flows that fish and other aquatic species need (State Water Resources Control Board 2010: 114-123 In completing and implementing the Bay-Delta Plan the Board's next step is to evaluate the feasibility of measures needed to protect public trust resources fully. (California Supreme Court 1983 Kibe 2011 6 These steps will need to include determination of flow needs of public trust resources, water rights reallocation, flow modification benefit-cost analysis, and habitat restoration. In the process. key questions must be answered:

1. How does the State Water Resources Control Board intend to prioritize water use in terms of coequal goals of public trust balancing How does its long-established water rights priority system fit into this policy framework?

2. What does water supply reliability mean in an arid state where we have granted rights to far more water than actually exists? Should water supply reliability be conditioned upon specific requirements to maximize reclamation, reuse, conservation and development of alternative local sources of water?

3. Is the standard by which we measure water supply reliability the same for junior and senior appropriators? Do uses of water that require vast public subsidies have the same priority as uses that don't require subsidy or public funds Are uses that internalize adverse impacts equal in priority to uses that externalize them?

4. Should the worth of water be confined only to its economic value in use Or does water supply reliability apply to both public trust resource needs as well as consumptive uses (i.e. is legislation needed for better protection of public resources through water rights)?

5. Are statutory requirements to protect water quality and listed species equivalent to water supply reliability for lawns or surplus subsidized, and non-food crops? Are food crops more

important than non-food commodities when it comes to allocating water? Does health and safety take precedence over certain agricultural uses of water?

6. Does efficient use of water have higher priority over wasteful and inefficient use? Is protection of the Bay-Delta Estuary as a “national treasure” and one of the world’s great estuaries more valuable to society than irrigating impaired soils that by their nature when irrigated, discharge prodigious quantities of salt and toxic wastes back to our waterways and aquifers?

Answers to these questions are central to resolving California’s water problems.

The California Legislature consolidated the State of California’s water rights and water quality control responsibilities in the State Water Resources Control Board in 1967. Since that time, the Board has considerable authority to grapple with these questions and arrive at answers and solutions from them. The Board has authority to:

- Plan for water quality control.
- Receive, condition, and approve new water rights applications as permits.
- Regulate and license water rights permits specifying the point of diversion, diversion flows, place of use, and purpose of use for water.
- Investigate pre-1914 and riparian water rights to determine whether such claims to divert and use water are legal, including follow-up enforcement against illegal uses when determined (discussed below).
- Investigate and enforce the state’s prohibition of waste and unreasonable use and wasteful and unreasonable methods of diversion of water under the California Constitution, Article X, Section 2.
- Protect the public trust. As an agency of the state, the Board is charged with ensuring the state of California carries out its fiduciary responsibility to protect air, running water, the sea and the seashore, “these things that are common to all,” as stated originally in Roman law (the Institutes of Justinian).

California’s constitution promises water rights only up to what is a reasonable use. No one has a right in California to use water unreasonably, not even the federal government. (California Constitution, Article X, Section 2.) The Public Trust Doctrine provides that no one has a vested right to appropriate water in a manner harmful to the interests protected by the public trust. (*National Audubon Society v. Superior Court* 3 Cal.3d 419, 189 Cal.Rptr 346, 65 P.2d 709.) And the dictionary definition of usufructuary rights, of which both riparian and appropriative water rights are examples, indicates that a fundamental principle of usufruct is that it connotes only a right to *use* a resource like water, not to waste or use it unreasonably. The State Water Resources Control Board, in taking up all of the key questions we outline above, will be deciding whether and how California’s abundant legal authorities apply to the Bay-Delta Estuary’s Central Valley watershed.

The Public Trust and Proportional Delta Inflows

In mid-2009, the State Water Resources Control Board updated its review of the Water Quality Control Plan which its Water Right Decision 1641 (D-1641) implements. The Board took the position that to change its water quality and flow criteria it needed more scientific information about flows reasonably needed to protect fish and wildlife beneficial uses (State Water Resources Control Board, 2009, 17). Its impetus to consider making changes at that time included pronounced fisheries declines among both open water resident and migratory fish and the still-unfolding impacts of climate change and its impacts on the Bay-Delta estuarine system (State Water

Resources Control Board, 2009: 9) The California Department of Fish and Game sought to build a salmon survival model to assist the Board's need for additional information. (California Department of Fish and Game 2010)

Later in 2009, the California Legislature directed the State Water Resources Control Board to prepare a report on Delta flow criteria that would "develop new flow criteria for the Delta ecosystem necessary to protect public trust resources" and in so doing "use the best available scientific information." The Legislature directed the Board to gather the information as part of an "informational proceeding" rather than through an evidentiary hearing. And the Legislature charged the Board with including volume, quality and timing of water necessary for the Delta ecosystem under different conditions (California Water Code: Section 85086(c)).

The Board produced its Delta flow criteria report after taking detailed testimony on the best available science for key fish species and ecosystems. The report identified a set of broad flow regimes for upstream tributaries providing inflow to the Bay-Delta Estuary that fish need to survive and recover. They represent the Board's consideration of the best available fishery and hydrologic science it considered during 2010 addressing the question: what flows do fish need? The Board confirms this when it stated in a footnote, "...the flow criteria developed in this proceeding are intended to halt population decline and increase populations of certain species," and acknowledged that, "Recent Delta flows are insufficient to support native Delta fishes for today's habitats….Flow and physical habitat interact in many ways, but they are not interchangeable." (State Water Resources Control Board 2010: 5, 120)

The Board states that the flow criteria "must be considered" in context:

- The flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- The State Water Board does not intend that the criteria should supersede requirements for health and safety such as the need to manage water for flood control.
- There is sufficient scientific information to support increased flows to protect public trust resources; ***while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making.*** (State Water Resources Control Board 2010: 4; emphasis added)

The Board's flow determinations are:

- 75 percent of unimpaired Delta outflow from January through June.
- 75 percent of unimpaired Sacramento River inflow from November through June.
- 60 percent of unimpaired San Joaquin River inflow from February through June.
- Increased fall Delta outflow in wet and above normal years.
- Fall pulse flows on the Sacramento and San Joaquin Rivers to stimulate migrating fish.
- Flow criteria in the Delta interior to help protect fish from mortality in the central and southern Delta caused by operations of the state and federal water export pumps.

In essence, these flow determinations represent the Board's answer to the question "what flows do fish need in the Central Valley watershed and the Bay-Delta Estuary?" The State Water Resources Control Board's 2010 Delta flow criteria report acknowledged that protective Delta outflows start with protective tributary inflows to the Delta. The Board's Delta inflow criteria rely on a percentage of unimpaired flow measure, which enables the flow criteria on the Sacramento and San Joaquin rivers to more closely mimic their natural hydrographs than now occurs.

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For the San Joaquin River, the State Water Resources Control Board approved its determination that 6 percent of unimpaired flow from February through June for the river basin would protect juvenile Chinook salmon during their peak emigration period. For the Sacramento River, the Board adopted the criterion of 7 percent of unimpaired flow from November through June. (This is because numerous runs of migratory salmon use the Sacramento River Basin for more of the year.) These constrained periods would also benefit the rearing period of juvenile salmon in the basin's major tributaries upstream. The Board also adopted in that report (2010) a fall season Delta inflow criterion calling for an average flow of 3,600 cubic feet per second for 10 days sometime during late October.

Nearly all scientists testifying to the Board in March 201 agreed that mimicking the natural hydrograph (in shape if not in magnitude and volume of flow) is necessary to improve conditions for native fish species, and to counter invasive species in the Delta. Existing Board water quality and flow objectives intended to protect fish and wildlife beneficial uses in the south Delta are not working, as shown in abundant evidence presented to the Board at its hearings for the Delta Flow Criteria report. The Board included much of that data in its report. (State Water Resources Control Board 2010.) C-WIN provides a brief evaluation of the Vernalis Adaptive Management Plan to supplement this record of failure in Appendix to this testimony.

In August 2010, the State Water Board approved these currently nonbinding Delta inflow determinations for the Sacramento and San Joaquin rivers. (State Water Resources Control Board 2010: 114-123.) The State Water Resources Control Board observed that using such flow criteria would mean that "to achieve the attributes of a natural hydrograph, the criteria are advanced as a percentage of unimpaired flow over a 14-day average, *to be achieved on a proportional basis from the tributaries to the San Joaquin River.*" (State Water Resources Control Board, 2010: 120, emphasis added.) The Board makes an important point that mimicking natural hydrograph and improving prospects for species recovery depends on achieving proportional flow allocations from all the major tributaries. Proportional tributary contributions would be needed to implement the Board's broader Delta inflow criteria. The Board will need to answer key questions including: what should those proportions be? how should responsibility for them be assigned? and who will be responsible for providing them? And when will the upper San Joaquin River be included by the Board in making these determinations? (Right now, the Board excludes the upper San Joaquin River from its Bay-Delta Estuary planning deliberations. C-WIN evaluates the Board's stance in Appendix B.)

The question for the Board is how to do proportional flows *legally*. Proportional tributary contributions from Delta inflow are not new. In 1992, the California Department of Fish and Game proposed a method to identify tributary contributions to Delta inflows based on the pro rata share of unimpaired runoff each tributary generates to the Delta, as identified in the California Department of Water Resource's Bulletin 12 each year (California Department of Fish and Game 1992). Other allocation methods could be devised as well, such as one based on reservoir storage on these same tributaries. The State Water Board in its Draft Water Right Decision 163 presented such a method, but which excluded contributions from the San Joaquin River above Mendota Pool (State Water Resources Control Board, 1992: Tables I and V).

Proportional tributary contributions needed to fulfill Delta inflow determinations from the Trinity River, and the major tributaries of the Sacramento and San Joaquin River Basins will require changes to the water rights of major water users in these Basins. The State Water Resources Control Board has authority over water rights to reallocate water usage and ensure compliance with the Board's Delta inflow objectives.

Paper Water Means Boundary Disputes and Clouded Titles

Property is often legally conceived as a bundle of rights representing “investment-backed expectations” of a future stream of benefits accruing to its owner, usually in the form of money. Water rights are a form of property, conveying to their owners rights to use water from a stream. Unlike real property in land however, we have a situation in which far more in rights to use water have been granted by the state or claimed by right holders than Nature and reality actually provide.

California’s modern water code and its body of water rights case law is the result of more than a hundred and sixty years of legislation and legal precedent. Riparian water rights are the most paramount rights, followed by pre-1914 appropriative rights and, lastly, post-191 appropriative rights, as determined by the seniority requirements of first-in-time-and-use.

But despite this accumulated legal tradition, human promises of water exceed Nature’s provisions. A shorthand description of this condition is “paper water.” The paper water problem in the area of water and rivers in California has close analogies in concepts like “clouded title,” and “boundary dispute” for a piece of real property (say, a house or a plot of land that has more than one owner claiming the same piece or portion of ground. Typically, boundary disputes are resolved by one or more disputants engaging the services of a surveyor to establish where the boundary is actually located. From there, the owners have a common set of facts on which they may agree to resolve their boundary dispute.

“Clouded title” has relevance here as well. A clouded title means the ownership of a title in water has some defect or potential defect arising from a competing claim for the same source of water.

One of the earliest recognitions of the problem of paper water in California occurred over a century ago and helps illustrate the clouded condition of paper water. In 1900, Frank Soulé, a professor of civil engineering at the University of California, was retained by the US Department of Agriculture’s Office of Irrigation Investigations to study water rights claims in the San Joaquin River basin. Soulé found that the San Joaquin River’s average winter and spring months flows were approximately 5,00 to 6,00 cubic feet per second. In drier late summer and fall months flows could get as low as 150 cubic feet per second. Soulé researched water rights claims to all tributaries of the San Joaquin River watershed to see how they matched up with flows in the river. Actual flows from the 1895-190 period averaged about 2.02 million acre-feet, according to state records. (State Water Resources Board 1951: Table 62) He visited the recorders’ offices for Stanislaus, Merced, and Fresno counties and itemized 31 claims to San Joaquin River waters totaling 36,571,471 miners inches of flow (there are 5 miners inches to a cubic foot per second). This converts to 731,42 cubic feet per second. Stretched out over a year (Soulé did not specify the seasons for which the claims were made), this translated into an annual claim of water rights of 529. million acre-feet of water, over 260 times greater than average flow of the San Joaquin River in that period. For an eight-month irrigation season of about 24 days, such flows would amount to 356. million acre-feet, nearly 180 times greater than San Joaquin River flows. These Soulé contended, were the “definite claims,” ones that had well-defined diversion points and amounts claimed. Six separate individuals claimed “all the water flowing in the San Joaquin River,” a definite claim is exaggerated. His summary for the San Joaquin did not include claims to the Fresno and Chowchilla rivers, which are much smaller watersheds, but the grandiosity continued there. On the Fresno River, some 670,79 miner’s inches were the subject of 5 claims (about 13,41 cubic feet per second or 9. million acre-feet a year), and on the Chowchilla just 1 claims aggregated to 31,00 cubic feet per second (or about 22.5 million acre-feet annually). (Soulé 1901: 222, 232)

Clouded titles in water have been allowed to fester since before Professor Soulé began studying the problem in 1900. Failure by the State of California to quiet titles to water since assuming authority for appropriative water rights in 191 contributes untold expectations for benefit streams that fuel controversy in California water resources planning and development ever since.

C-WIN is not lone contemporary voice on the problem of paper water. In September 2008, State Water Resources Control Board staff informed the Delta Vision Blue Ribbon Task Force about water rights, use, and flows in the Delta watershed. It stated in part:

- The "total face value of the approximately 6,300 active water right permits and licenses within the Delta managed by the State Water Board, including the already assigned portion of state filings is approximately 24 million AFA [acre-feet annually]." Our organizations note that this 245 million acre-feet of face value in water rights was permitted by the Board and its predecessors in the Central Valley watershed (including imports from watersheds like that of the Trinity River). (State Water Resources Control Board 2008)

- Face value "does not include pre-1914 and riparian water rights." Riparian water rights, in the absence of some form of watershed adjudication, are usually unquantified but nonetheless require real, wet water. (State Water Resources Control Board 2008) And,

- That "the total face value of the unassigned portion of state filings for consumptive use (excluding state filings for the beneficial use of power) within the Delta watershed is approximately 6 million [acre-feet annually]." These are claims the State has filed to reserve water for further expansion of the State Water Project. (State Water Resources Control Board 2008; see also Appendix C.)

Other matters exacerbate the paper water problem:

- The SWRCB does not know how much water is actually used (and by whom) since state law has yet to require full accounting of either surface or ground water use.

- The SWRCB does not know the extent of paramount riparian or senior pre-1914 water rights either.

- Climate change is likely to alter the timing and reduce the volume of runoff into California's rim dams and overall state and federal water systems. (Knowles and Cayan 2002) It is also likely to decrease natural groundwater recharge as well, which would further reduce runoff volumes where river reaches benefit from groundwater inflows.

- Increased cold water pools and groundwater support from gaining streams will be needed to maintain water temperatures below rim dams according to estimates by the SWRCB and Department of Fish and Game of the increased inflow and outflow necessary to protect rivers and the Delta public trust resources. (California Department of Fish and Game 2010: 51, Table 5)

Given these constraints, the obligation to achieve a public trust balancing of water supply reliability with fish and ecosystem survival cannot rest on maintenance of existing levels of supply from either Delta exports or the rim dams on all major Central Valley tributaries in the Delta watershed. The State Water Resources Control Board must use its water rights authority in the service of meeting these water quality challenges on behalf of public trust resources.

The Delta Watermaster acknowledges the problem of paper water in recent report on the State Water Resources Control Board's role in the Delta Stewardship Council's Delta Plan process (Wilson 2011). He expresses concern, however, that "the face value of water rights is not a sufficient measure of water that can be used to determine the over-allocation of water in the [Delta watershed." He cites four main reasons for his concern:

- The face value of many water rights are for nonconsumptive uses, such as hydropower.
    - **C-WIN Response:** As much as possible, water availability analysis should factor out water rights claims that are primarily devoted to nonconsumptive uses and hydropower generation in particular. C-WIN's analysis factors out all single-purpose hydropower generation water rights claims, whether pre- or post-1914. Where multiple purposes of use claims include hydropower generation, we assume these rights are still primarily consumptive use claims, especially when irrigation is one of the other purposes of use for which claims are made. Hydropower generation is considered incidental to the other consumptive uses.

- The face value represents a maximum possible water diversion, which is far greater than what is actually used;
    - **C-WIN Response:** We agree that face value often represents a maximum possible diversion (and/or storage amount). We also agree that it may be far greater than what is actually used in many cases. But C-WIN's review of water right claims shows that some rivers' claims far exceed maximum unimpaired flows and even reservoir capacity of that river. (The Trinity River is a good example of this.) This is less a criticism of face value than an acknowledgement of paper water by the Delta Watermaster. Nor does it justify continuation of the practice by the State Water Resources Control Board. Since the maximum possible flow (and use) can occur only relatively rarely in California's hydrology, C-WIN suggests that this extra increment of claims be eliminated because it will occur in the future with even less frequency than now occurs. Reliable rights are only meaningful when they can be exercised with relative frequency.

- Permit/license terms, such as those for protection of instream uses, further reduce below the face value the amount of water that can be diverted;
    - **C-WIN Response:** The State Water Resources Control Board needs to continue having some standard method for quantifying the value of water rights as property. This is the only way that increments of title to water as property can be described and titles cleared or quieted in the event of dispute. Moreover, quantified water rights are the only way to conduct reality-based water resources planning and development. This extends to employing a standard method for quantifying and measuring instream flows that benefit public trust resources. If the Board and Delta Watermaster are to enforce instream flows, they must quantify instream flow commitments and ensure that they are fulfilled *prior* to the exercise of permitted or licensed water rights claims.

- Water, when applied, is typically not consumed up to the full face value and the same water (return flow) is often used multiple times as it runs downstream.
    - **C-WIN Response:** While C-WIN acknowledges the reality of return flow in diversions of water for consumptive irrigation uses, there is no consistently available data that measures the volume and occurrence of return flow to rivers. Some estimates, both recent (California Department of Water Resources 2005 water balances for Sacramento and San Joaquin River Basins) and historical (Wiel 1928: 259) put return flow at between 6 and 6 percent of originally diverted volumes. Of course, the reality of return flow, however, means that river flow can decrease by as much as a third of diversion quantities each time it is applied; the more frequently water is diverted to consumptive use, the sooner surface flows are depleted in the immediate

> river reach downstream. Return flows do not reach the river from which they were diverted instantaneously. Once diverted there occurs a time lag between the diversion and its application, and when water actually returns to the river, and even then it may only reach the river in small increments, depending on the surface return flow and/or subsurface transmissivity getting back to the river. Meanwhile, the diverted water is gone from the river, thereby depleting its flow until some later time and lower location. If return flow is truly important to determining water availability and avoiding boundary disputes and clouded water titles, then California needs to invest in getting data from each watershed that quantifies the volume, timing, and duration of return flow, instead of ignoring it. (State Water Resources Control Board 1983, 9-10)

C-WIN's methodology recognizes each of these facets of "face value" or face amount of water rights. Unfortunately, the Delta Watermaster's remarks do not clarify whatever else it is that face value quantities in water rights are supposed to positively describe. If the quantities in water rights are not relevant to face value, then on what basis can separable, stable and reliable rights to water use be analyzed and judged? The Watermaster acknowledges that "while actual water use may be only a fraction of the face value of water rights, the state's water supplies have been over-allocated in many areas."[2] (Delta Watermaster 2011b, 5) C-WIN shows in this testimony that it is possible to use the "data" of water rights in combination with data on flows and diversions to generate a consistent and meaningful picture of the problem of overallocation of water supplies and rights in the San Joaquin River Basin. Our water availability analysis illustrates the usefulness of having *some idea* of the magnitude of the paper water problem as compared with having *no idea*. All of California needs better data on all facets of the problem of paper water.

Tables 1 and 2 provide static (snapshot) views of total water rights in the Trinity, San Joaquin River and Sacramento River Basins. Total water rights reported in these two tables are for consumptive uses. Hydropower generation water rights have been excluded from this analysis.

In Table 1, average annual unimpaired flow for the San Joaquin River Basin is about 6. million acre-feet compared with 32. million acre-feet of consumptive water rights claims. The ratio of total claims to average unimpaired flow for the San Joaquin Basin is 5. acre-feet of consumptive use claims to every acre-foot of unimpaired flow in the Basin. About 4 percent of total consumptive water claims are by riparian and pre-1914 claimants while 5 percent is by post-191 claimants (that is permits and licenses) regulated by the State Water Resources Control Board.

Specifically on the major tributaries of the San Joaquin River Basin the ratio of total consumptive use claims to unimpaired flow ranges from about 5. on the Stanislaus to 6. acre-feet of claims to every unimpaired acre-foot of flow on the San Joaquin River (including valley floor and upper watershed claims).

In Table 2, average annual unimpaired flow in the Sacramento Valley (essentially, average Sacramento River inflow to the Delta) is about 21.6 million acre-feet. Consumptive water rights claims are estimated at about 120. million acre-feet. The ratio of total consumptive use claims to averge unimpaired flow in the Sacramento River Basin is about 5. acre-feet of claims per acre-foot of unimpaired flow. Ratios of claims to unimpaired flow to range from 2. on the Yuba River to 6.8 on the Trinity River.

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[2] The Delta Watermaster suggests that for the Delta the process for determination of fully appropriated streams from the Water Code Sections 1205 through 1207 be used (p. 5).

Table 1
Consumptive (Irrigation) Water Rights Summary for San Joaquin River Basin

Flows and Consumptive Water Rights	Thousands of Acre-Feet Stanislaus River	Tuolumne River	Merced River	San Joaquin	Basin Total
Average Annual Unimpaired Flow	957	1,851	956	1,728	6,181
Total Consumptive Water Right Claims	5,318	11,015	5,495	10,828	32,656
Ratio of Total Claims to Unimpaired Flow	5.56	5.95	5.75	6.27	5.28
Total Riparian & Pre-1914 Claims	1,401	8,185	4,525	2,014	16,125
Ratio of Riparian & Pre-1914 Claims to Unimpaired Flow	1.46	4.42	4.73	1.17	2.61
Total Post-1914 Claims	3,917	2,831	970	8,814	16,532
Ratio of Post-1914 Claims to Unimpaired Flow	4.09	1.53	1.01	5.10	2.67

Sources: State Water Resources Control Board (e-WRIMS); Public Records Act responses from various public water and irrigation districts; California Water Impact Network. Sum of major tributaries' unimpaired flow does not equal Valley total due to omission of other watersheds from the table.

Table 2
Consumptive (Irrigation) Water Rights Summary for Trinity and Sacramento River Basins

Flows and Consumptive Water Rights	Thousands of Acre-Feet Trinity River	Feather River	Yuba River	American River	Sacramento Valley Total
Average Annual Unimpaired Flow	1,283	4,370	2,287	2,621	21,619
Total Consumptive Water Right Claims	8,725	15,717	5,093	9,847	120,571
Ratio of Total Claims to Unimpaired Flow	6.80	3.60	2.23	3.76	5.58
Total Riparian & Pre-1914 Claims	134	3,855	92	286	47,883
Ratio of Riparian & Pre-1914 Claims to Unimpaired Flow	0.10	0.88	0.04	0.11	2.21
Total Post-1914 Claims	8,591	11,863	3,596	9,561	72,688
Ratio of Post-1914 Claims to Unimpaired Flow	6.70	2.71	1.57	3.65	3.36

Sources: California Department of Water Resources, 2007; State Water Resources Control Board (e-WRIMS); Public Record Act responses from various public water and irrigation districts; California Water Impact Network. Sum of major tributaries' unimpaired flow does not equal Valley total due to omission of other watersheds from the table. Trinity River is included because a large portion of its runoff is exported to the Sacramento River via federal Central Valley Project facilities.

On basin-wide basis riparian and pre-1914 water claims account for about 4 percent of total consumptive use claims of 120. million acre-feet, and post-191 claims (permits and licenses in the Sacramento River Basin amount to about 6 percent of total consumptive use claims.

The largest water claims on Sacramento River Basin tributaries belong to the Feather River and the American River. The mainstem Sacramento (which is incorporated into the total for the Valley) includes the Pit and McCloud rivers and numerous small creeks that enter it from the east and west. C-WIN estimates that the largest component of pre-1914 water rights claims is held by the Glenn-Colusa Irrigation District. This District claims 2 million acre-feet in rights to divert directly from the Sacramento, as well as another 1 million acre-feet in rights from west side creeks.

On the Trinity River, the U Bureau of Reclamation is significant claimant of post-1914 water rights, and given the small amount of riparian and pre-1914 water rights claims on the Trinity, the Bureau's Trinity River rights are reliable, as conditioned and limited by the Trinity River Record of Decision (U Department of the Interior 2000 The Trinity's ratio of total consumptive claims to average unimpaired flow is 6. acre-feet of claims to every acre-foot of unimpaired flow.

There is another, more dynamic approach that we also include in this testimony to characterize excess claims to water use relative to flows. This planning-level analysis of water availability incorporates into the model hydrologic variability, instream flow requirements and publicly available water rights priorities on the divertable flows that remain in the system.

Applying Water Availability Analysis

In Tables 3 and 3 and accompanying charts we present results of applying both diversion cap (derived from the State Board's 2010 Delta flow determinations) and the water rights priority system in the manner that the State Water Resources Control Board is legally authorized to proceed. The unimpaired flow hydrology for this analysis was obtained from the California Department of Water Resources (2007) This analysis proceeds from the basic water rights premises that:

1) Instream flows needed to meet water quality and flow objectives have top priority.
2) When applying water rights, riparian rights are paramount, followed by—
3) Pre-1914 water rights claim water based on seniority date, followed by—
4) Any water left over is provided to junior water rights holders in order of priority date (whether pre-1914 rights or post-1914 permits and licenses).

Detailed model results, water rights, and flow data employed in the analysis are found in Appendix D. Assumptions embedded in the method are itemized in Appendix of this report.

To apply the water rights priority system in the context of providing new Delta inflows from the major tributaries C-WIN's analysis builds in range of flows from the 10th through 90th percentiles of the 82-year unimpaired flow hydrology available from the California Department of Water Resources (2007). 25th 50th (median) and 75th percentile (quartile) flows are also considered. C-WIN's analysis summarizes total regulated period unimpaired flow, the Delta inflow contribution and calculates "diversion cap." (See Appendices D.1, D.2, and E.)

Water rights priorities are then assigned to allocate the diversion cap flows for the regulation period to paramount riparian and senior water right holders first. Detailed tables of our model results are provided in Appendix D.1 for the Trinity and the major Sacramento and San Joaquin River Basin tributaries On the major tributaries there are generally few significant water rights holders and relatively small bloc of riparians may be known and allocated flows prior to pre-1914

Table 3A
Summary of Water Availability Analysis Results Incorporating Water Right Claims for Major Tributaries of the San Joaquin River Basin

River/ Instream Flow Objective	Annual Total		
	Riparians and Senior Pre-191 Right Holders	**Major Water Right Claimants**	**Other Junior Major Claimants**
Stanislaus	**Various including Tuolumne Utilities District**	**Oakdale & South San Joaquin Irrigation Districts**	**US Bureau of Reclamation**
40% Diversion Cap	2 TAF in all percentile flows.	19 to 75 TAF in all percentile flows.	81 to 250 TAF in the 50th to 90th percentile flows.
Tuolumne	**Various including Tuolumne Utilities District**	**Turlock Irrigation District, Modesto Irrigation District**	**City and County of San Francisco**
40% Diversion Cap	2 TAF across all percentile flows.	40 to 1,66 TAF across all percentile flows.	95 TAF in only the 90th percentile flows.
Merced	**Various including Gallo interests**	**Merced Irrigation District**	**Not applicable**
40% Diversion Cap	218 to 283 TAF across all percentile flows.	to 59 TAF from 40th to 90th percentile flows, about 14% of all claims.	Not applicable
San Joaquin	**Below Friant Dam, and along Fresno Slough**	**San Joaquin River Exchange Contractors**	**US Bureau of Reclamation**
40% Diversion Cap	172 TAF in all percentile flows.	24 to 81 TAF in all percentile flows.	89 to 413 TAF in 75th to 90th percentile flows.

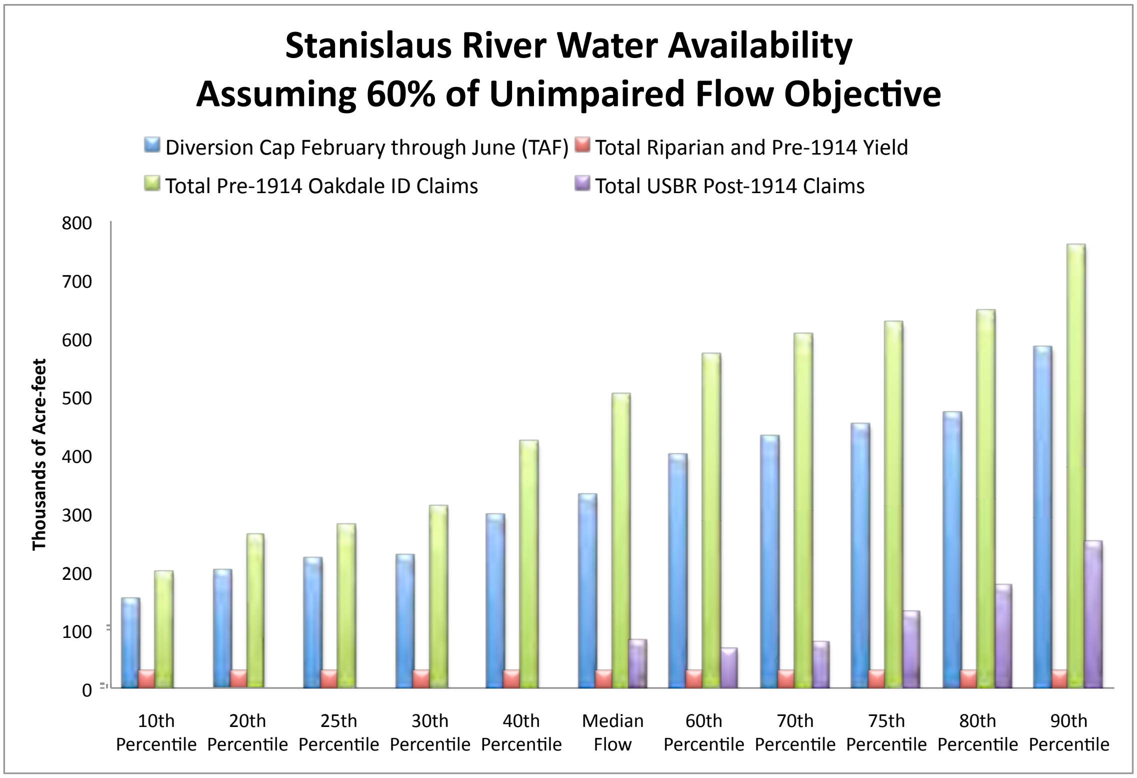
Sources: California Department of Water Resources, 2007 State Water Resources Control Board, 2010, 2012 other primary and secondary sources compiled by the California Water Impact Network. See Appendix for details of data and supporting model results.

right holders Pre-1914 water right claims tend to comprise the majority, or in most cases exceed the unimpaired flows in most (and in some cases all decile flows reported in the analysis.

Table 3B
Summary of Water Availability Analysis Results Incorporating Water Rights Claims for the Trinity River and the Major Tributaries of the Sacramento River Basin

River/ Instream Flow Objective	Annual Total		
	Riparians and Senior Pre-1914 Right Holders	**Major Water Right Claimants**	**Other Junior Major Claimants**
Trinity	**Various small claimants**	**US Bureau of Reclamation**	**Not applicable**
25% Diversion Cap	13 TAF in all percentile flows.	7 to 454 TAF across all percentile flows.	Not applicable.
Sacramento River above Feather River Confluence	**Various including Anderson-Cottonwood ID and Glenn Colusa ID**	**Early Post-191 to early 1927 claimants**	**CVP and Feather River Project Filings from 1927 through 1961**
25% Diversion Cap	2,094 to 5,98 TAF ranging across all percentile flows.	0 TAF across range of all percentile flows.	0 TAF across range of all percentile flows.
Feather River	**Western Canal W and Joint Water Districts, adjudication decrees**	**South Feather and Thermalito 1920 Rights**	**DWR 1927, 1951, and 1956 Claims**
25% Diversion Cap	72 to 1,97 TAF ranging across all percentile flows.	4 to 3 TAF from 20th to 90th percentile flows.	7 to 23 TAF in all percentile flows.
Yuba River	**Various including Nevada ID, City of Nevada City**	**Nevada ID and Yuba C WD 1920 Rights**	**Yuba County Water Agency 1927 Claims**
25% Diversion Cap	25 to 1,00 TAF ranging across all percentile flows.	1 to 1 TAF only at 25th to 80th percentile flows.	2 to 8 TAF among 50th to 80th percentile flows.
Bear River	**Various including Nevada ID**	**Camp Far West and Nevada ID Claims**	**South Sutter Water District Claims**
25% Diversion Cap	2 to 9 TAF ranging across all percentile flows.	1 to 5 TAF across all percentile flows.	4 to 9 TAF from 50th to 90th percentile flows.
American River	**Various including San Juan Water District Nevada ID and City of Sacramento Post-1914 Claims**	**Georgetown Divide PUD and Placer County Water Agency**	**U Bureau of Reclamation**
25% Diversion Cap	29 to 1,00 TAF ranging across all percentile flows.	8 to 18 TAF from 50th from all percentile flows.	9 to 13 TAF in all percentile flows.

Sources: California Department of Water Resources 2007 State Water Resources Control Board 201 and 2012 other primary and secondary sources compiled by the California Water Impact Network. See Appendix for details of data and supporting model results.



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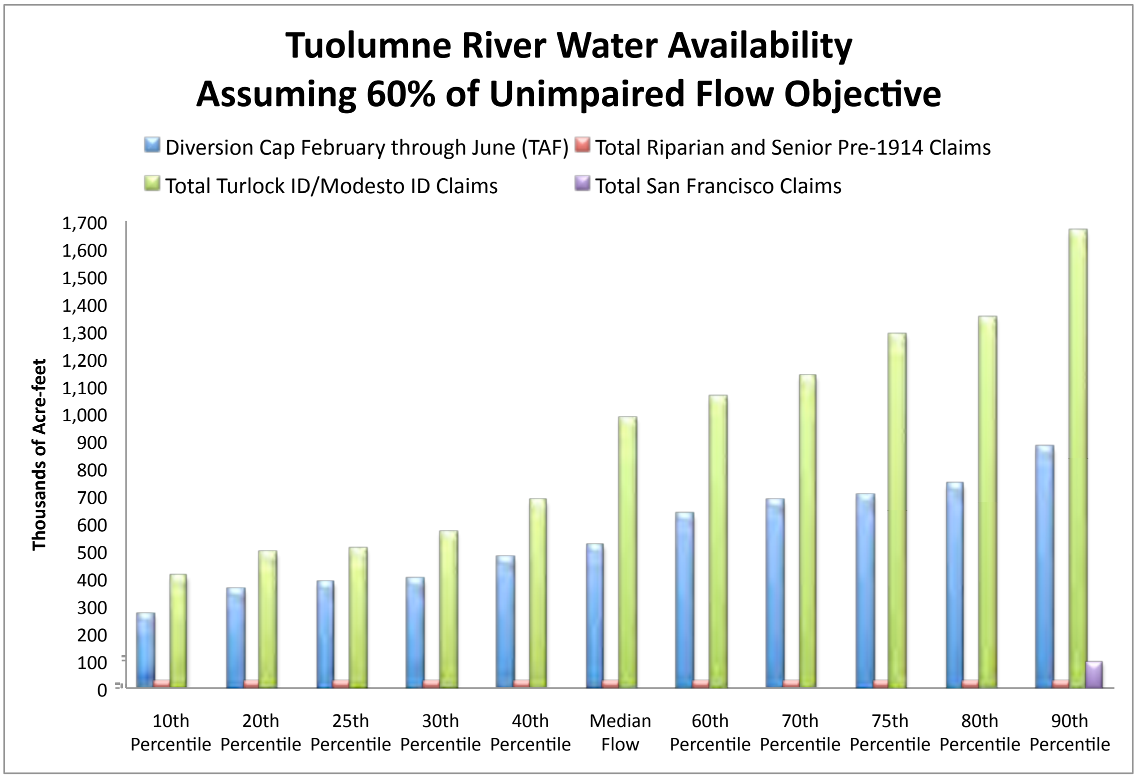

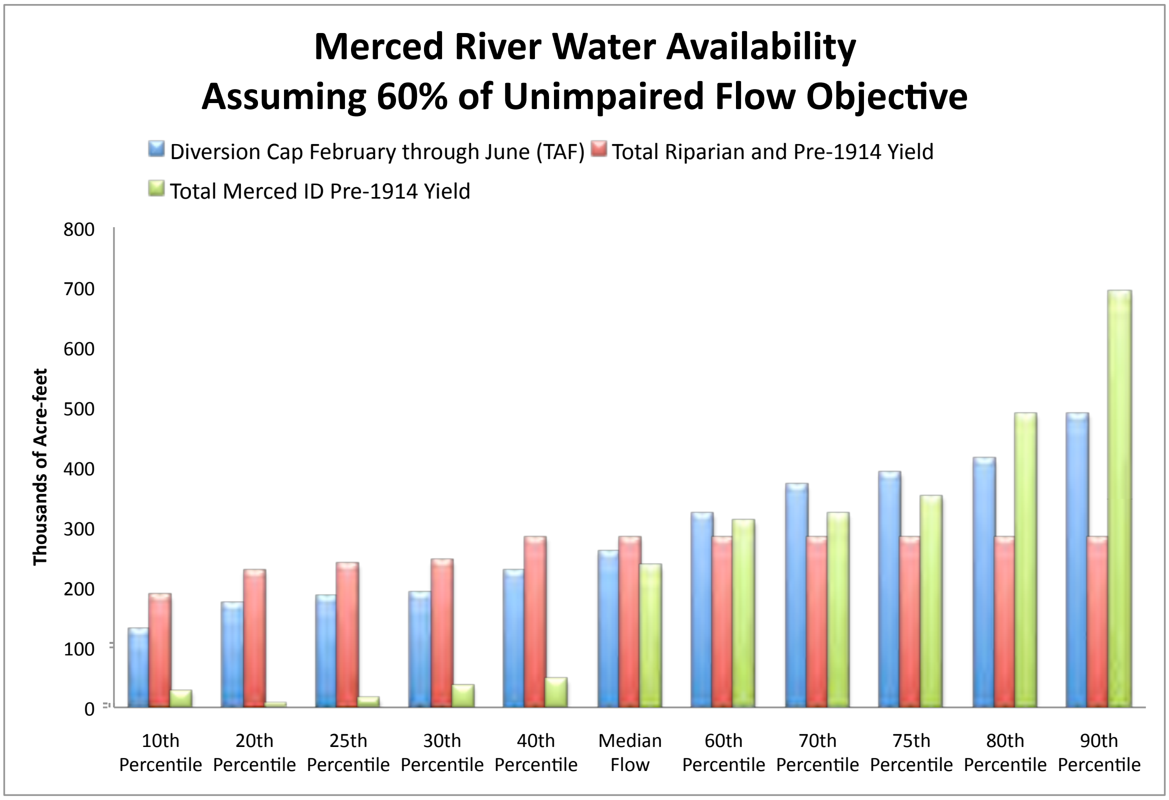

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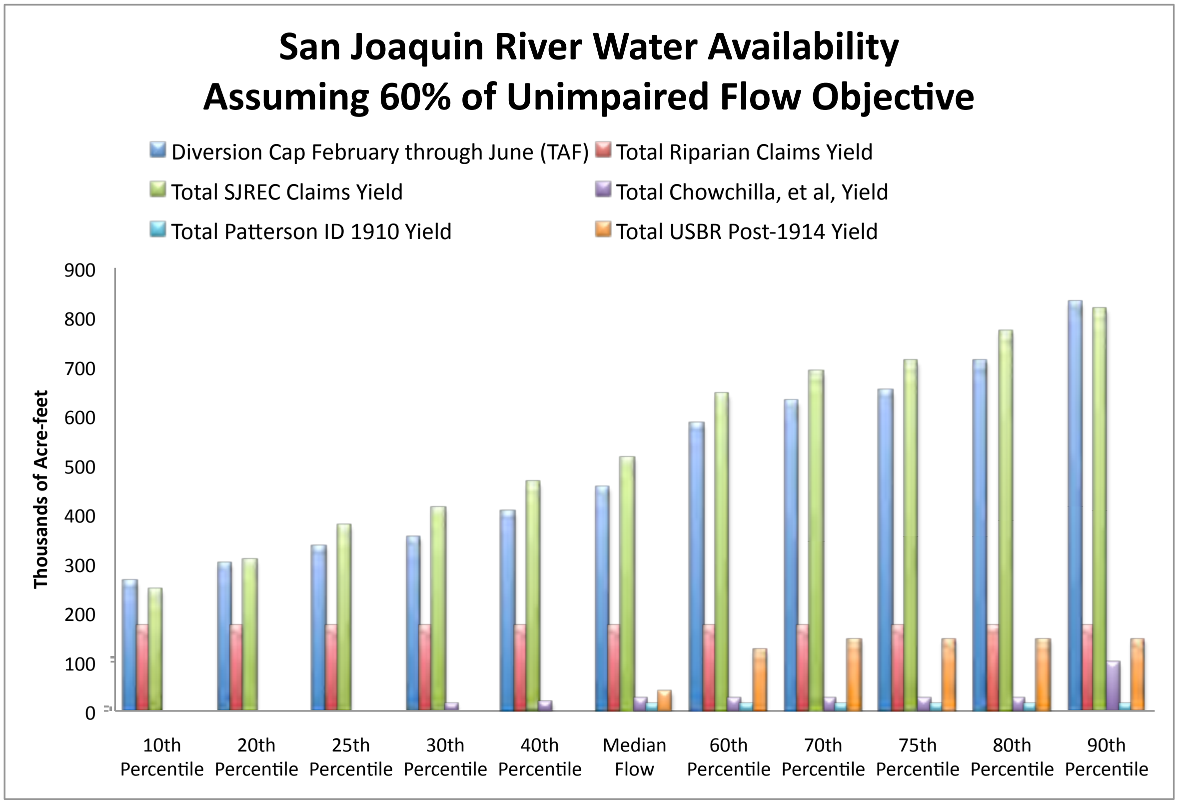

Stanislaus River (Figure 1)

Implications: Under strict application of both the 40 percent diversion cap and the water rights priority system in the Stanislaus River watershed, the US Bureau of Reclamation's water rights for New Melones Reservoir yield only a small fraction of Bureau claims in actual supplies.

Tuolumne River (Figure 2)

Implications: Under strict application of both the 40 percent diversion cap and the water rights priority system, the City and County of San Francisco would have reliable rights to water only in the wettest 10 percent of flows.

Merced River (Figure 3)

Implications: Under strict application of the water rights priority system to the 40 percent diversion cap, Merced Irrigation District's pre-1914 water rights exceed its post-1914 claims significantly, but are junior to a large amount of riparian and senior pre-1914 right holders.

San Joaquin River (Figure 4)

Implications: Only the small riparian allocations along the upper San Joaquin River would have fully reliable flows. The Exchange Contractors would have full claims on flows about 30 percent of the time (at the 70th percentile flows and above). The Bureau of Reclamation would not receive allocations except in the wettest 30 percent of years at all and would receive its full allocation no more than about 1 percent of the time.

Trinity River (Figure 5)

Implications: Riparian and pre-1914 water right holders on this river system are few. The Bureau's post-1914 water rights to develop Trinity Reservoir and Lewiston Dam, and the hydropower complex linked to Keswick Dam along Clear Creek are the dominant water rights on the Trinity River. As noted in Table 2, however, the consumptive use rights alone appear to be quite excessive relative to Trinity River's unimpaired flow hydrology.[3]

Sacramento River Above Feather River Confluence (Figure 6)

Implications: Because of large pre-1914 water rights claims by Glenn-Colusa Irrigation District along the Sacramento River, no water would be available to the US Bureau of Reclamation, except from Trinity River exports. Strict application of this pattern of water rights claims would dramatically reduce water available for export from the Sacramento River Basin and potentially undermine the San Joaquin River Exchange Contract.

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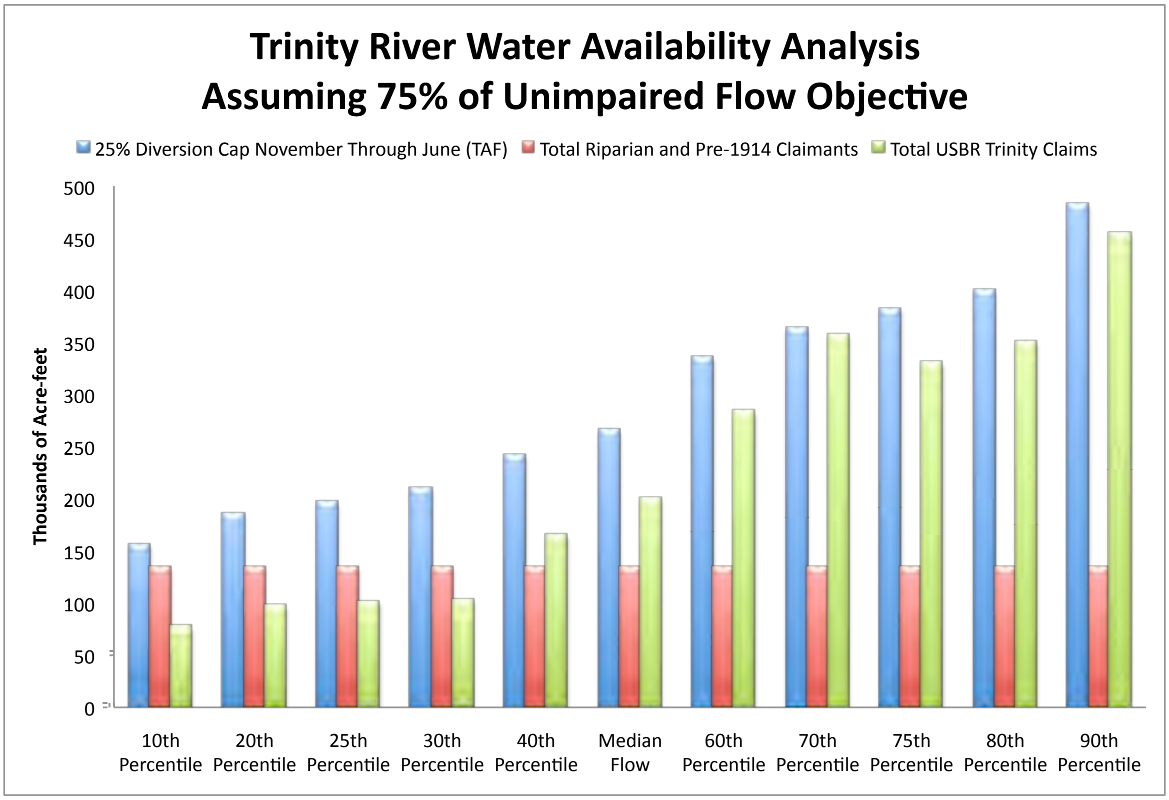
[3] Our analysis applies to the Trinity the Board's 75 percent of unimpaired flow determination for November through June. This flow determination exceeds those of the 2000 Trinity Restoration Record of Decision. (US Department of the Interior 2000)



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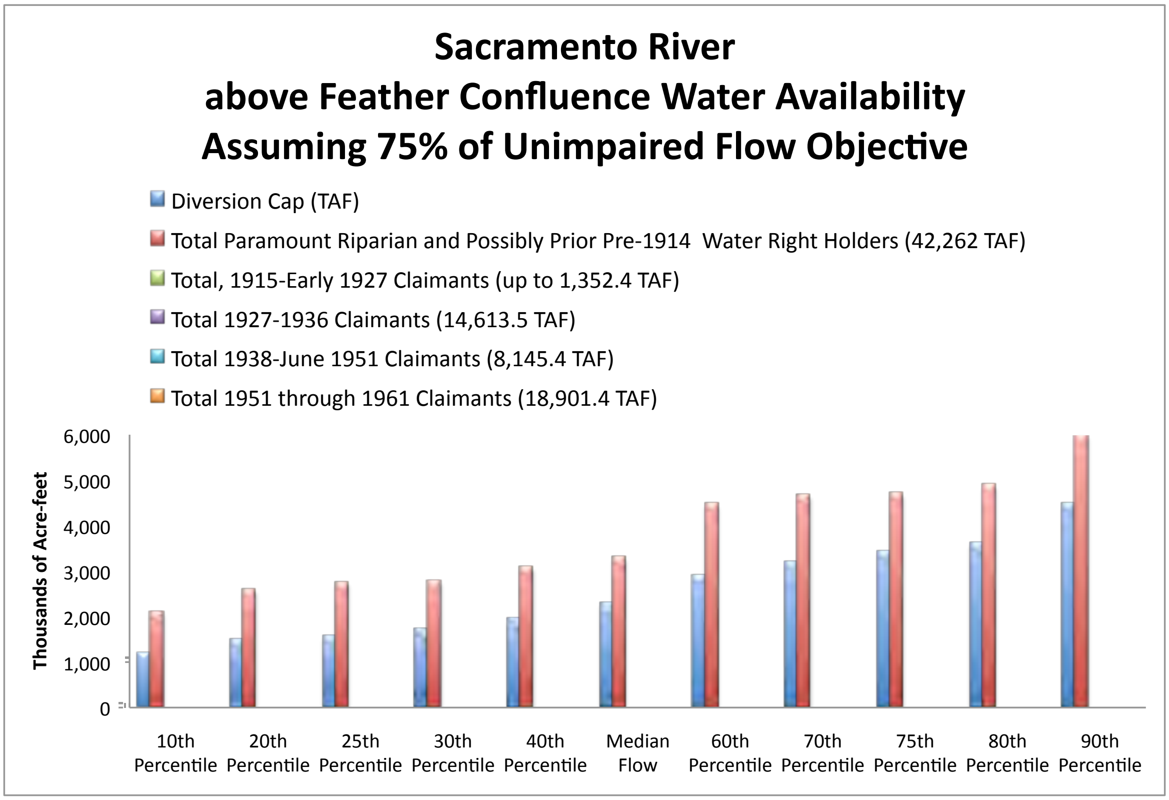

Feather River (Figure 7)

Implications The Department of Water Resources' 1927, 1951, and 195 water rights claims for the Feather River Project (now the State Water Project) would receive almost no water under a 25 percent diversion cap scenario. In drier years, even at relaxed diversion cap scenarios, DWR would receive only very small amounts. This is due to senior pre-1914 water rights claimants such as the Joint Water Districts[4] and Western Canal Water District, whose rights predate the cultivation of rice in the Butte County region, and were adjudicated in 1923. DWR's claims amount to about 10.4 million acre-feet (MAF) on the Feather River alone for consumptive uses.

Yuba River (Figure 8)

Implications Nevada Irrigation District and Yuba County Water District, through their pre-1914 claims and 1920s water rights claims, would have senior claims to Yuba River flows. Full operation of these claims would nearly eliminate Yuba County Water Agency diversions under a 2 percent diversion cap scenario.

Bear River (Figure 9)

Implications Because of senior water rights claims by Nevada Irrigation District and Camp Far West Irrigation District, South Sutter Water District would see its supplies reduced significantly relative to its claimed rights under a 2 percent diversion cap scenario.

American River (Figure 10)

Implications: The US Bureau of Reclamation's Central Valley Project facilities along the American River would receive very little water supplies from operation of the water rights priority system under a 2 percent diversion cap, despite having claimed up to 5.3 million acre-feet.

Discussion

Assuming that the State Water Board adopts the 7 percent unimpaired flow determination for the upstream tributaries of the Sacramento River Basin, the 6 percent of unimpaired flow determination for the San Joaquin River Basin, and that the water rights priority system is applied, it becomes evident that several significant water rights claimants that are junior in priority contribute dramatically to the problem of paper water: They have been promised water far in excess of flow conditions available to them in most years.

Table summarizes the major water rights claimants whose titles to water in the Central Valley watershed tributaries should be considered clouded, whose property "boundaries" are in dispute.

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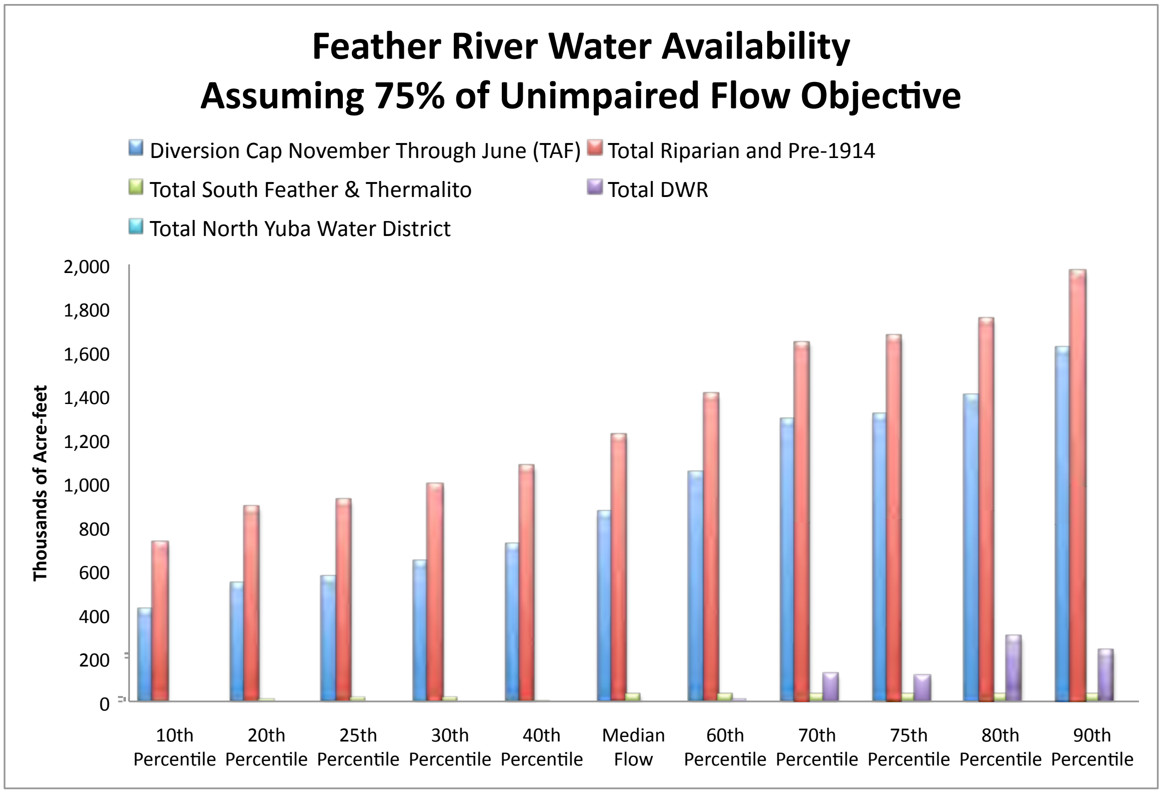
[4] The Joint Water Districts include Butte Water District, Biggs-West Gridley Water District, Richvale Irrigation District, and Sutter Extension Water District, the successors to pre-1914 water rights accumulated by the Sutter Butte Canal Company.



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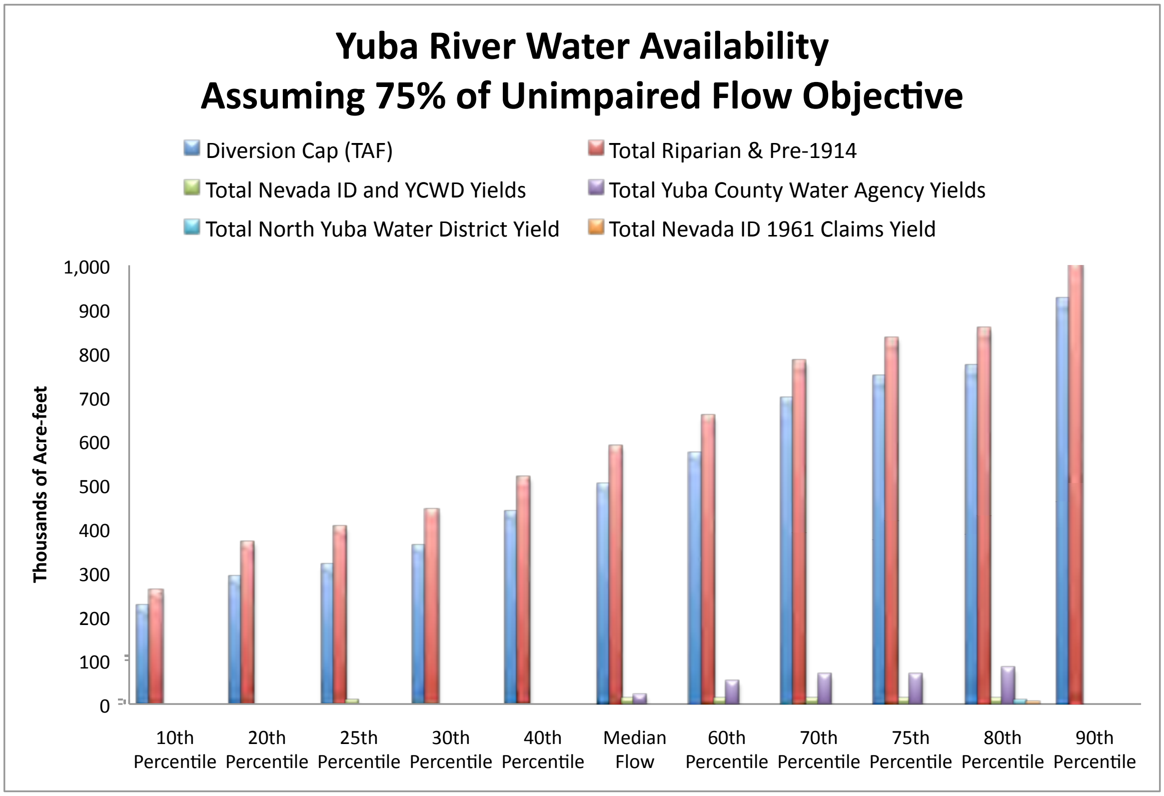

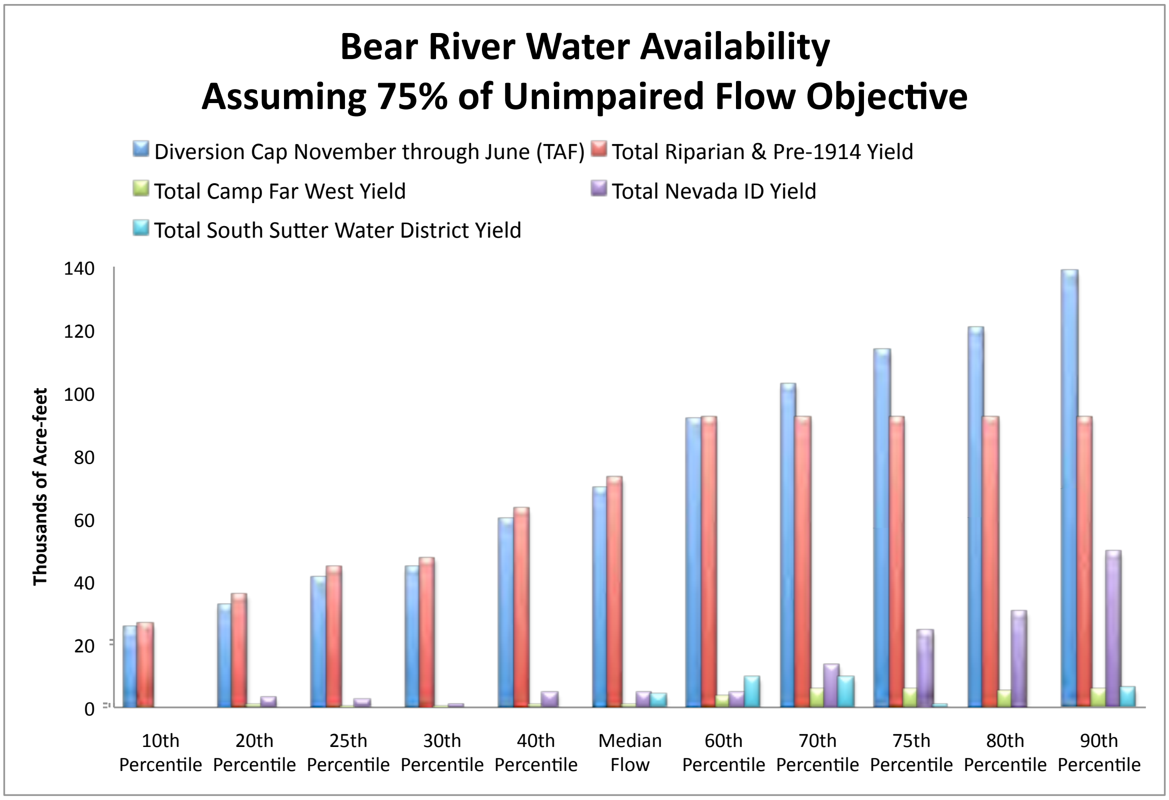

Figure 9, above. Figure 10, below.

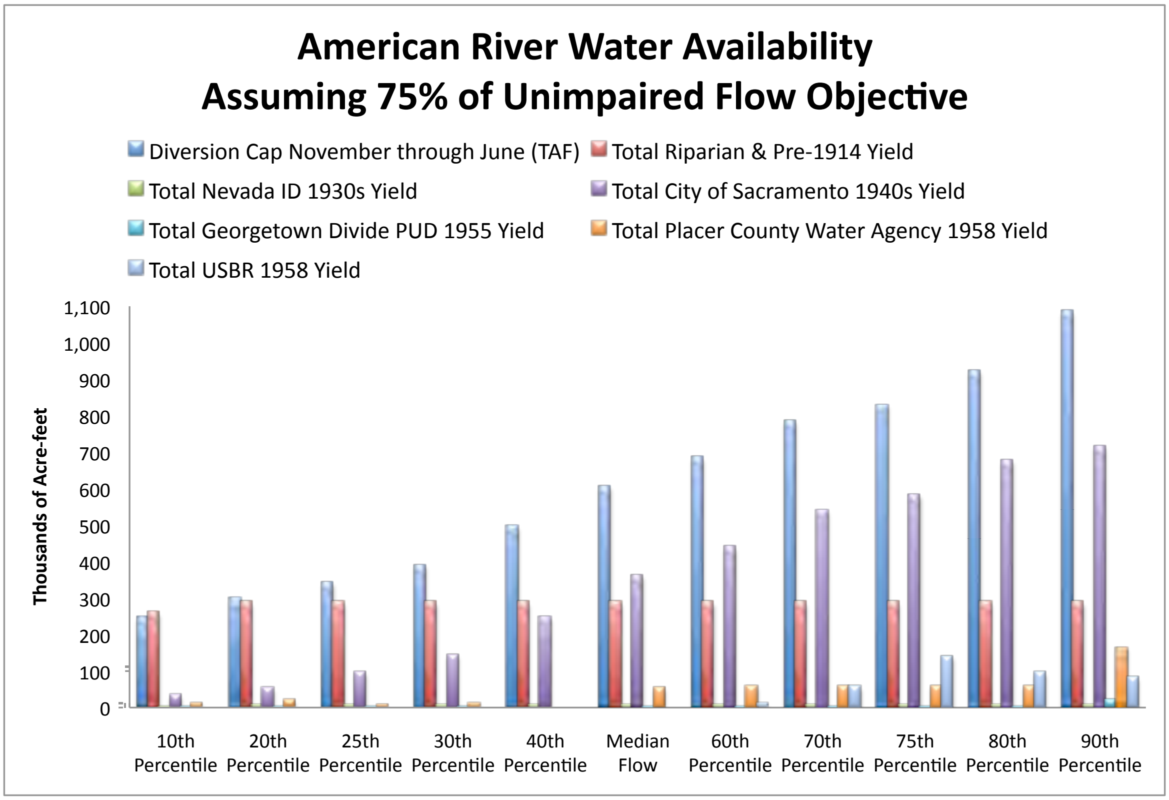

Table 4
Summary of Watershed Consumptive Water Rights Claimants by Reliability (Based on Legal Priority) of Claims

Watershed	Claimants with Highly Reliable Rights	Claimants with Potentially Clouded Title to Water
Stanislaus River	Various claimants covered by Stanislaus River decree of 1929; Oakdale ID, South San Joaquin ID	US Bureau of Reclamation (New Melones)
Tuolumne River	Tuolumne Utilities District, Turlock Irrigation District, Modesto Irrigation District	City and County of San Francisco (190 through 1911 rights)
Merced River	Gallo, various riparian and pre-1914 parties to early Merced River decrees	Merced Irrigation District (post-191 rights)
San Joaquin River	Paramount riparian claimants, San Joaquin River Exchange Contractors, Chowcilla WD, Tranquillity & James IDs, Patterson ID	US Bureau of Reclamation (post-191 rights)
Trinity River	Various small riparian and pre-1914 claimants US Bureau of Reclamation	US Bureau of Reclamation (has overstated water claims compared with actual basin hydrology)
Sacramento River (including west and east creeks, Pit and McCloud Rivers)	Various small riparian and pre-1914 claimants claimants among adjudicated watersheds in Pit River region, Anderson-Cottonwood Irrigation District, Glenn-Colusa Irrigation District	US Bureau of Reclamation (Shasta Lake)
Feather River	Upper watershed adjudicated claimants, Joint Water Districts, Western Canal WD	California Department of Water Resources (Lake Oroville)
Yuba River	Browns Valley ID, Nevada ID, Yuba County WD	Yuba County Water Agency (192 rights), Nevada ID (1930s rights), and North Yuba Water District (1958 rights)
Bear River	Nevada ID, Camp Far West ID	South Sutter Water District (195 and 1981 rights)
American River	City of Folsom, San Juan WD, Georgetown Divide PUD, El Dorado ID, Nevada ID, Placer County Water Agency, City of Sacramento	US Bureau of Reclamation (Folsom Lake), Foresthill PUD

Sources: California Department of Water Resources; State Water Resources Control Board; California Water Impact Network.

By adopting its public trust Delta inflow determinations as flow objectives in the Bay-Delta Plan for each major tributary, and applying water rights priorities—in that order—the State Water Resources Control Board can use its authority to eliminate paper water (water claims that do not have a basis in water rights law) in the Bay-Delta Estuary's Central Valley watershed. The California Constitution reminds us that no one in California has a right to use or divert water wastefully or unreasonably. The state's public trust responsibility requires protection of the waters of the state for the benefit of all beneficial users, not just water rights holders. The state's water quality control planning obligations carry out this responsibility. It also helps the state meet its public trust obligations as well. The doctrine of prior appropriation requires that senior water right holders be served before junior water right holders. The water quality control planning process and the water rights priority system of the major tributaries of the Sacramento and San Joaquin River Basins should be used as tools for eliminating paper water—that is, for quieting water titles and ending trespasses and boundary disputes that compromise public trust resources—from the Bay-Delta Estuary's Central Valley watershed.

Paths for Aligning Water Rights with All Other Beneficial Uses and River Flows

We see three primary paths by which the State Water Resources Control Board can align water rights with all other beneficial uses and river flows:

- Water quality control plan implementation,
- Fully-appropriated streams declaration and Term 91, and
- Court adjudication.

Water Quality Control Plan Implementation. The State Water Resources Control Board has approved a Delta inflow determination for the San Joaquin River at Vernalis of 6 percent of unimpaired flow during the February through June period. For the Sacramento the Board approved a 75 percent of unimpaired flow determination for the November through June period. In doing so, the Board would implicitly place a cap on total diversions for each major tributary of 4 percent of unimpaired flow for the San Joaquin River and 2 percent of unimpaired flow for the Sacramento River Basin. These objectives would result in instream flows that are substantially greater in most years than current instream flow requirements now provide. In our water availability analysis, we also apply the Sacramento River Basin 7 percent objective rather than the Trinity Record of Decision flow objectives to the water availability analysis for the Trinity River. (US Department of the Interior 2000: 12)

Key water rights holders in these basins possess riparian and pre-1914 water rights that exist prior to the regulatory powers of the State Water Resources Control Board. On the question of implementing water quality control plans and adhering to state water rights law, the issue has arisen of the Board's jurisdiction over those water rights that the Board did not originally consent to.

Attorney Tim O'Laughlin, representing the San Joaquin River Group Authority (SJRGA), has asked the State Water Resources Control Board to "identify the legal theory or approach it will use at the implementation proceeding in order to obtain the necessary flows to meet the additional flow requirements identified" in the Board's flow studies. Without that legal theory or approach, O'Laughlin argues, the State Water Resources Control Board will be unable to complete economic or other impacts analysis in its Substitute Environmental Document on the San Joaquin River Flow and South Delta salinity objectives. He further contended in February 201 that the Board is operating according to *some* kind of theory since it

> blatantly **suggests** that additional flows will come from the Stanislaus, Tuolumne, and Merced Rivers. [State Water Resources Control Board 2011c, pp. 78 81, and 85-89. This foreshadowing demonstrates that the SWRCB not only believes that, regardless of the Vernalis flow alternative eventually adopted, it will be able to obtain flow from all the tributaries but that it intends to do so. That approach, however, completely ignores the existence of the water right priority system. (See, e.g. *Pleasant Valley Canal Company v. Borror* (1998) 6 Cal.App.4th 742, 770; *City of*

> *Barstow v. Mojave Water Agency* (2000) 23 Cal. 4th 1224, 1243; see also *El Dorado Irrigation District v. State Water Resources Control Board* (2006) 14 Cal. App.4th 937, 961.) As the SJRGA has pointed out to the SWRCB on numerous occasions, any approach to allocating responsibility for new Vernalis flow requirements must incorporate the water rights priority system. That said, the SJRGA recognizes that strict application of the water right priority system does not produce straightforward results such that the water required to meet the selected Vernalis flow alternative would come from a particular waterway or tributary, or that such water would roughly be divided equally or proportionally among such waterways and tributaries. (O'Laughlin 2011a, 1-2, emphasis in original)

O'Laughlin, on behalf of SJRGA, asserts that the Board has no jurisdiction to regulate pre-1914 appropriative water rights or riparian rights, regardless of any legal theory the Board intends to use in the implementation phase. If responsibility for new Vernalis flow requirements is determined solely based on the water rights priority system, writes O'Laughlin, "junior water right holders will be required to reduce or completely cease their water use before senior appropriators will be required to reduce theirs" as required in California's doctrine of prior appropriation. (O'Laughlin 2011a)

He wrote to the Board subsequently in June 201 about its jurisdiction in the Bay-Delta proceedings. There he stated, "It now appears that the [Substitute Environmental Document] is being prepared solely on the basis of percentage of natural flow, without regard to the nature or priority of the water rights affected, and will therefore be the subject of immediate litigation." (He is here apparently referring to the Board's proposed use of a percentage of unimpaired flow as the basis for limiting diversions.) O'Laughlin also reiterated in this letter to the Board that it

> does not have jurisdiction over pre-1914 appropriative water rights for any reason, including the implementation of water quality objectives adopted pursuant to the State Water Resources Control Board's authority under Porter-Cologne. Given the prevalence of pre-1914 appropriative rights held in the San Joaquin River Basin, and the scope of the percentage of natural flow that the [Board] is considering, it is almost certain that there will be times and conditions where the [Board] will not be able to implement a percentage of natural flow. It is arbitrary and capricious for the [Board] to continue to consider a percentage of natural flow as one of its objectives without knowing how often, if ever, it will be able to require such percentages be met. (O'Laughlin 2011b)

O'Laughlin argues that the Board's flow objective results may not be achievable if, for example, flow is 100 cfs and the Board applies a 6 percent instream flow criterion to this waterway while pre-1914 water right holders may claim 80 percent of the flow in the stream. In that case the Board, contends O'Laughlin, "would not be able to obtain the full 60 percent flow it desired." O'Laughlin contends that this not only renders the Delta flow criterion infeasible, it means that evaluation of criterion alternatives under the California Environmental Quality Act in the Substitute Environmental Document will also be infeasible and the SED thus inadequate.

Of course, contrary to the Racanelli decision, O'Laughlin elevates the water rights priority system to paramount status in California water and environmental law. It is plain from a review of state water case law that water rights priorities, while important, are not paramount considerations when the Board takes up the protection of beneficial uses of water. As Justice Racanelli stated, water quality control planning must concern itself with the regulation of *beneficial uses*, not water rights strictly speaking. Beneficial uses include, and go well beyond, water rights and their relative priorities. (See sidebar, page 26.) The Racanelli decision made clear that the State Water Resources Control Board has authority to implement its water quality control plan by regulating all beneficial uses. Adjusting quantities in water rights is within its authority.

Moreover, the Board retains authority to regulate pre-1914 water rights under its constitutional authority to prohibit waste and unreasonable use of water. The Legislature provided in the California Water Code key sections that do not limit the Board's authority to investigate rivers and streams in the service of the state's constitutional provisions (emphases added).

Beneficial Uses Served in the Bay-Delta Water Quality Control Plan:

- **Municipal and Domestic Supply**
- **Industrial Service Supply**
- **Industrial Process Supply**
- **Agricultural Supply**
- **Ground Water Recharge**
- **Navigation**
- **Water Contact Recreation**
- **Non-Contact Water Recreation**
- **Shellfish Harvesting**
- **Commercial and Sport Fishing**
- **Warm Freshwater Habitat**
- **Cold Freshwater Habitat**
- **Migration of Aquatic Organisms**
- **Spawning, Reproduction, and/or Early Development**
- **Estuarine Habitat**
- **Wildlife Habitat**
- **Rare, Threatened, or Endangered Species**

Source: State Water Resources Control Board 2006: 8-9.

> 275. *The department and board shall take all appropriate proceedings or actions* before executive, legislative, or judicial agencies *to prevent waste, unreasonable use unreasonable method of use or unreasonable method of diversion of water in this state.*
> ...
> 1050. This division is hereby declared to be in furtherance of the policy contained in Section 2 of Article of the California Constitution and in all respects for the welfare and benefit of the people of the state, for the improvement of their prosperity and their living conditions, and *the board and the department shall be regarded as performing a governmental function in carrying out the provisions of this division.*
>
> 1051. The board for the purpose of this division may:
> (a) *Investigate all streams stream systems portions of stream systems, lakes or other bodies of water.*
> (b) Take testimony in regard to the rights to water or the use of water thereon or therein.
> (c) *Ascertain whether or not water heretofore filed upon or attempted to be appropriated is appropriated under the laws of this State.*
> ...
> 1052. (a) The *diversion or use of water subject to this division other than as authorized in this division is trespass.*
> (b) Civil liability may be administratively imposed by the board pursuant to Section 105 for a trespass as defined in this section in an amount not to exceed five hundred dollars ($500) for each day in which the trespass occurs.
> (c) The Attorney General, upon request of the board, shall institute in the superior court in and for any county wherein the diversion or use is threatened, is occurring, or has occurred appropriate action for the issuance of injunctive relief as may be warranted by way of temporary restraining order, preliminary injunction or permanent injunction.
> (d) Any person or entity committing a trespass as defined in this section may be liable for a sum not to exceed five hundred dollars ($500) for each day in which the trespass occurs. The Attorney General, upon request of the board, shall petition the superior court to impose assess and recover any sums pursuant to this subdivision. In determining the appropriate amount, the court shall take into consideration all relevant circumstances, including but not limited to, the

> extent o har cause by th violation th nature and persistence of th violation th length of time over which th violatio occurs an th corrective action i any, taken by th violator.
>
> (e Al fund recovered pursuan to thi sectio shal b deposited i th Water Rights Fund established pursuant to Section 1550.
>
> (f) Th remedies prescribed i thi sectio are cumulative an no alternative.
>
> ...
>
> 1825. It i the intent o the Legislature that *th stat should tak vigorou actio* to enforce the terms an condition o permit licenses certifications, an registrations to appropriate water, to enforce state board orders and decisions, and *to preven th unlawful diversio o water.*
>
> ...
>
> 2501 Th board may determine, in th proceedings provided for i this chapter, al rights to water o a stream system whether base upo appropriation, riparian right, o other basi of right.

Nothin in thes section o th Water Code prevents th Board from investigating pre-1914 water rights an eliminatin illegal diversions shoul they b found. Water Code Sectio 275, appear to extend thi authorit o th Board to determining whether any water us i wasteful or unreasonable, o any metho of use o metho o diversion is wasteful o unreasonable.

Thes section provided authorit for th Board to investigate pre-1914 an riparia water rights in the Delta recently. I these investigations, the Board has issued water rights orders that in a least on instance adjusted the rights o a riparian water right holder. (Wilson 2012 Mr. O'Laughlin is surely aware o thi authority. O behal o th Sa Joaqui River Group Authority, his comment on the Board's 2008-201 strategic work pla helpe initiate th Delt water rights investigations in 2008 H cited California Water Code Section 182 to support the San Joaquin River Group Authority's recommendation tha th Board investigate Delt riparia an pre-1914 water rights. (San Joaquin River Group Authority 2008 64)

Whe the Board moves to adjus diversion amounts i th Delta's majo tributaries. Th Board should apply a diversion cap during the regulated period applicable to each tributary (including the Uppe Sa Joaqui River; se Appendix B an the allocate diversions according to water rights priority. C-WIN analyzes operation o th water rights priority system i the following river profiles.

Our testimony analyzes water availability usin water rights prioritie a way of identifyin the legal metho for allocatin responsibility for Delt inflows tha are fully protective o publi trust resources in the Delta.

Th Board announced i two notice (dated February 13 2009 an Apri 1, 2011, th latter containing revisions to the earlier Notice) its intent to revise the Bay Delta Water Quality Control Plan of 2006. This plan traces its lineage to the 199 Bay Delta Water Quality Control Plan an the Bay-Delta Accord. The Sa Joaqui River flow an Sout Delta salinit objective process i likely to b step i th right direction away from thes failed plans Th well-documented failures o this misguide loyalty include:

- Anadromous fishery decline throughout th Central Valley watershed o th Delt estuary.
- Declines o pelagi (open water) aquati ecosystem regimes throughout th Delta
- Continued listin o endangered species includin salmon steelhead, Delt smelt, longfi smelt, Sacramento splittail an green sturgeon.
- Chronic violation from 200 through 200 o sout Delta salinit objectives i bot the Bay-Delta Water Qualit Control Pla an Water Rights Decision 164 tha are intended to protect agricultural beneficial uses i this part of th Delta.

- Historic record Delta pumped exports between 200 and 2006 peaking at nearly 6. million acre-feet. (More recently, 2011 exports reached 6. million acre-feet.)

From the two NOPs, it appears the Board prepares to incorporate flow objectives for major tributaries of the San Joaquin River: the Stanislaus, the Tuolumne, and the Merced rivers. It appears to us the Board intends to require fair share flow contributions from each of these important rivers to flows of the mainstem San Joaquin as inflow to the Delta as measured at Vernalis. Our organizations welcome this prospect in concept, and support the Board's efforts toward this goal despite legal, ecological, and engineering challenges ahead.

The 198 Delta Water Cases decision (also named as the "Racanelli decision" for its author, presiding Justice John Racanelli of the Third District Court of Appeals in California) bears review because it defines the Board's water quality planning duties for the Delta and its watershed. (California Appeals Court, Third District 1986 When it comes to the Board's role in undertaking its duty to fulfill its water quality planning function, the Racanelli court stated:

> In its *water quality* role of setting the level of water quality protection, the Board's task is not to protect water rights, but to protect 'beneficial uses.' The Board is obligated to adopt a water quality control plan consistent with the overall statewide interest in water quality [citation to California Water Code §13240] which will ensure 'the reasonable protection of *beneficial uses*' (§13241 emphasis added) Its legislated mission is to protect the 'quality of all the waters of the state...for use and enjoyment by the people of the state.' (13000 1st para., emphasis added. (California Appeals Court, Third District 1986: 178)

Thus protection of beneficial uses must be the Board's paramount goal in this process. Beneficial uses make up "all competing demands for water" which must receive Board attention during public trust balancing and analysis. Water rights are among the Board's implementation tools for achieving the protection of beneficial uses in California's Central Valley watershed and Delta estuary, not strictly ends in themselves in this context.

Justice Racanelli wrote that the State Water Resources Control Board has a dual role of regulating both water quality and adjudicating water rights. The Racanelli court stated:

> In performing its dual role, including development of water quality objectives, the Board is directed to consider not only the availability of unappropriated water...but also *all* competing demands for water in determining what is a reasonable level of water quality protection. (California Appeals Court, Third District 1986: 179-180)

The Delta Water Cases came about because the Board construed its scope for water quality planning too narrowly, focusing on the major stakeholders in the Delta the Bureau, the Department of Water Resources, and their respective contractors. The Board erred in doing so, the Racanelli court stated.

> ...the Board must consider 'past, present, and probable future beneficial uses of water'...as well as 'water quality conditions that could reasonably be achieved through the coordinated control of *all* factors which affect water quality in the area' Unfortunately, the Board neglected to do so. (California Appeals Court, Third District 1986: 180)

That was 2 years ago As we will indicate below, C-WIN is deeply concerned that the Board may still neglect significant, realistic alternatives that will be essential to fulfilling its water quality planning role for solving problems in the Bay-Delta estuary and the larger Central Valley watershed.

Fortunately, the Board can avoid such neglect. Justice Racanelli wrote that the Board "need only take *the large view of the water resources* in arriving at a reasonable estimate of all water uses and activity well within its water rights function to determine the availability of unappropriated water." And he added "We think a similar *global perspective* is essential to fulfill the Board's water quality planning obligations." (California Appeals Court, Third District 1986, emphasis added) Justice Racanelli stated later that the Board compromised its role in previous water quality control plan when it defined its scope for action too narrowly "in terms of enforceable water rights. In fact," the judge wrote, "the Board's water quality obligations are not so limited."

> ...in order to fulfill adequately its water quality planning obligations, we believe the Board cannot ignore other actions which could be taken to achieve Delta water quality, such as remedial actions to curtail excess diversions and pollution by other water users. (California Appeals Court, Third District 1986, 182)

The Board's "paramount duty" remains to "provide 'reasonable protection' to beneficial uses considering all the demands made upon the water." Finally, Justice Racanelli concludes about the Board's water quality planning powers:

> Thus, we do not believe that difficulty in enforcement justifies a bypass of the legislative imperative to establish water quality objectives which in the judgment of the Board will ensure reasonable protection of beneficial uses. (California Appeals Court, Third District 1986, 182)

C-WIN believes that a credible water quality control plan for the Bay Delta estuary must take what Racanelli deemed the "global perspective" in order to redress the ecological collapse and cumulative salinization and pollution resulting from the Board's water quality planning efforts to date. The 1994 Bay-Delta Accord's water quality control planning pendulum swung too far in favor of water right holders and water contractors, and their respective beneficial uses. The Board's duty now is to credibly balance all of the beneficial uses of water in the estuary so that public trust resources are protected, and so that reasonable uses and methods of diversion of water are employed by all water users.

In addition to the water quality planning obligations that Justice Racanelli eloquently addressed, recent state legislation provides additional authority to the State Water Resources Control Board. Using this added authority, the Board can better protect water quality and beneficial uses in the Bay-Delta Estuary and the Central Valley watershed. We point to two new laws enacted in 2009.

The State Water Resources Control Board has already fulfilled its obligation under California Water Code Section 85086(c) and (e) to prepare a public trust assessment of the Bay-Delta flow criteria needed to protect fish and wildlife beneficial uses. While not a "balancing" analysis required under public trust doctrine, the Board's *Delta Flow Criteria Report* provides valuable scientific analysis and findings that must be used to help the Board fulfill its water quality planning responsibilities and achieve protective public trust resource outcomes in the Bay-Delta estuary. The report employed the best available science in arriving at its findings. (State Water Resources Control Board 2010b)

The same legislative package also changed the California Water Code to recognize the need to reduce reliance on the Delta as a source of water for California:

> 85021. The policy of the State of California is to reduce reliance on the Delta in meeting California's future water supply needs through a statewide strategy of investing in improved regional supplies, conservation, and water use efficiency. Each region that depends on water from the Delta watershed shall improve its regional self-reliance for water through investment

> in water use efficiency, water recycling, advanced water technologies, local and regional water supply projects, and improved regional coordination of local and regional water supply efforts.[5]

These new laws provide the Board with additional legal and political tools aiding the protection of all beneficial uses, particularly fish and wildlife beneficial uses whose protection has been neglected for decades.

The Water Code's Fully Appropriated Stream Provision and Term 91. The Board will need to revise its 199 water rights order concerning fully appropriated streams, and revisit its application of Term 9 curtailment of post-197 water rights permittees. Our water availability analysis helps show where key seasonal and priority thresholds may occur under the Board's new Delta inflow objectives.

California's Water Code implicitly acknowledges the potential for over-appropriation to occur and provides a process by which the State Water Resources Control Board may take steps to avoid or prevent excessive water promises. The Board can declare streams to be fully-appropriated on a month by month basis in every watershed of California under Section 120 through 1207. Its statutory language is reproduced in Appendix F to this testimony.

Section 1205(b) provides that a declaration that a stream system is fully appropriated shall contain a finding that the supply of water in the stream system is fully applied to beneficial use where the Board finds that previous water rights decisions have determined that no water remains available for appropriation. According to Section 1206(a), once a stream system is declared fully appropriated by the Board, the Board shall not accept for filing any application for a permit to appropriate water from the stream system described in the declaration, and may cancel any application pending on that date. Section 1206(b) states that the Board may provide for exceptions to application filing under specified conditions, which may limit the purpose of use, the instantaneous rate of diversion, the season of diversion, or the amount of water diverted annually.

Past State Water Resources Control Boards have declared fully-appropriated streams in California. (State Water Resources Control Board 1989, 1991, and 1998.) The Board's most recent 1998 declaration included major reaches of all tributaries to the Sacramento and San Joaquin River Basins as fully appropriated, including the Trinity River. (State Water Resources Control Board 1998, Exhibit A)

The Board has also designated as fully appropriated some rivers and streams that are adjudicated or have reaches designated for protection under state and federal wild and scenic river legislation. Major portions of the Trinity, Middle Fork of the Feather, the Tuolumne, and the Merced are designated as wild and scenic rivers. Wild and scenic rivers are off-limits to appropriations year-round. Other rivers and streams are fully-appropriated primarily during irrigation season. Appendix summarizes selected critical reaches of the Bay-Delta Estuary's Central Valley Watershed that are designated as fully-appropriated by the State Water Resources Control Board.

The Board's Full Appropriation Declaration blurs the distinction between water rights claims and water usage by claimants. Commendably, the Board has identified reaches of streams that are off-limits to new permanent applications to appropriate water. C-WIN identified several streams where it appears that the Board has excluded riparian and pre-1914 water rights in formulating its declaration. This appears to be the case of the Sacramento mainstem, the Tuolumne, the Merced, and the Yuba. On these rivers, substantial periods of the year are still officially open under the

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[5] California Water Code §85021, passed November 2009.

Board's declaration to applications to appropriate. Substantial amounts of pre-1914 water rights do not appear to be considered in the Board's determination that a stream is fully appropriated.

Section 1205(b) does require that the Board's declaration "shall contain a finding that the supply of water in the stream system is being fully applied to *beneficial uses* where the board finds that previous water rights decisions have determined that no water remains available for appropriation." (For a list of all Bay-Delta beneficial uses see sidebar, page 26 above.) Note that the full-appropriation declaration legislation states that the supply of water is "being fully applied to beneficial uses and not merely to the claims of water right holders.

There is no explicit analysis in the 199 declaration by the State Water Resources Control Board of full application of water to beneficial uses as a direct consequence of citing its water rights decisions. This means that the full appropriation declarations are likely incomplete, albeit from a different standpoint. The Board may have construed Water Code Section 1205(b) as requiring the Board to rely on its archive of water rights decision, appropriately enough. But Water Code Section 1205(b) does not expressly limit the Board to use only water rights decisions, adjudications, and other determinative documents to justify these findings, as evidenced by the Board's additional reliance on wild and scenic river designations. Its approved 2010 flow objectives for the Sacramento and San Joaquin River basins (while legislated to be informational and predecisional in Water Code Section 85086(c)(1)) could also be used to support findings of full appropriation for the Sacramento River, the San Joaquin River, and their other major tributaries. Instream flows serve natural beneficial uses as surely as water rights claims serve economic uses. Accounting for these instream flows as part of full appropriation declarations would increase the period of full appropriation to include November through June throughout the Sacramento Basin and February through June in the San Joaquin Basin, given the magnitude of water rights claims we have identified.

Moreover, Board decisions like Water Rights Decision 1594 (D-1594) acknowledge the Board's duty to account for all beneficial uses, such as those protected by the Board's Delta water quality and flow objectives.

C-WIN's planning-level water availability analysis allocates unimpaired flow hydrology, among instream flow objectives first, followed by water rights in order of priority status for the Sacramento and San Joaquin River basins. This planning-level method of water availability analysis demonstrates that the waters of the Sacramento and San Joaquin River Basins, from a planning standpoint, should indeed be declared fully appropriated. The full spectrum of beneficial uses is fully accounted for in allocating the Basins' flows to full protection of instream beneficial uses as well as those of all water rights claimants in California's water rights priority system. Moreover, this water availability analysis uses instream flow determinations that the Board itself endorsed in 2010 as Delta protective of public trust resources. It also indicates which major claimants have either poorly reliable or no water rights once all beneficial uses are accounted for.

A problem with the State Water Resources Control Board's fully-appropriated declaration involves its reliance on Water Right Decision 1594 (D-1594) from 1984. D-1594 authorized the Board to place into permits (whose priority dates come after August 16, 1978) a new permit condition (called Term 91) notifying all permittees of its intent to curtail diversions of water right permittees. Curtailment occurs when flow and water quality conditions in the Delta demand that reservoir releases are needed to enable the California Department of Water Resources and the US Bureau of Reclamation to meet Delta water quality standards established by the Board. August 16, 1978, is significant as the date on which the Board adopted Water Right Decision 1485. This decision made the Bureau and the Department responsible for meeting water quality objectives in the Delta.

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Workshop 3 Testimony, Bay Delta Plan

Submitted by California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance

D-1594 expressly addresses water availability for appropriation (diversion) in the Bay-Delta Estuary's Central Valley watershed by subordinating junior appropriative water rights to adherence to Delta water quality objectives. D-1594 is cited by the State Water Board as the water right decision authority for including the Sacramento-San Joaquin Delta in the 199 fully-appropriated streams water right order. This decision reaffirms the Board's reserved jurisdiction to revisit the season of diversion of water right permittees in the Bay-Delta Estuary watershed, and it establishes with standard permit Term 91 its authority to curtail diversions by post-1978 diverters so that storage releases by the Bureau and the Department can meet Delta water quality objectives.

In this decision, the Board states:

> The availability of water for appropriative water right permittees is affected by the quantity needed to satisfy holders of prior rights and the quantity necessary for protection of other beneficial uses. (State Water Resources Control Board 1983: 2)

In the process leading up to D-1594, the Board initiated a process to conduct a planning-level water availability analysis. Unfortunately, it abandoned that analysis:

> Staff had originally proposed a comprehensive analysis of water supply and demand which attempted to identify and quantify water usage by all diverters below the foothill reservoirs within the Delta watershed. [SWRCB Exhibit. 1, pp. 19-20] This approach was discontinued [apparently in April 1983, according to reporter's transcript dated April 11, 1983, p. 14, lines 16-20] due to the lack of adequate data for factors such as return flow, groundwater accretions, unmeasured tributary inflow, riparian use, appropriative use, and Delta consumptive use. (State Water Resources Control Board 1983: 9-10)

D-1594 states at least twice that application of Term 91 to post-1978 permittees is an "interim solution" or an "interim measure." Nearly 3 years later, the Board still employs Term 91's method of calculating water availability. D-1594 commits the Board to occasionally requiring the post-1978 permittees in the Delta's extensive watershed to curtail deliveries when flows are insufficient to meet Delta water quality objectives and protect the Delta's beneficial uses.

Our planning-level water availability analysis focuses on water rights claims compared to historical hydrology. As we earlier showed, it finds there are far more water right diversion claims than there are flows in the Bay-Delta Estuary's Central Valley watershed (including the Trinity River claims of the Bureau). Our water availability analysis incorporates Board-approved instream flow determinations the Board approved as fully protective of public trust resources in the Bay-Delta Estuary and its watershed. Its results suggest that *making Delta water quality and flow objectives fully protective of public trust resources will require moving the priority date of Term 8 permittees far earlier than 197 for determining when and for whom Term 9 diversion curtailment would occur*. This is necessary because the State Water Resources Control Board (2010) found that current Delta flow objectives on the mainstem and tributaries of the two basins, including the Vernalis Adaptive Management Plan on the San Joaquin River, are insufficiently protective of the Delta's fish and wildlife beneficial uses (State Water Resources Control Board 2010: 9-10). Conversely, this means that Term 91 *currently* applies Delta water quality objectives that are well known to be ineffective at protecting public trust resources in the Delta.

C-WIN believes it will be necessary for the State Water Resources Control Board to revisit Term 91 and D-1594's method of estimating water availability in the Bay-Delta Estuary's Central Valley watershed when implementing new Delta inflow (instream flow) objectives for the Sacramento and San Joaquin River Basins and their major tributaries upstream of the Delta. For the same reason, the Board's 199 water rights order must also be revisited to update and expand the seasons where appropriations would be prohibited as a matter of protecting all beneficial uses in compliance with Water Code Sections 1205 through 1207. The Board should include these actions in the Bay-Delta Plan's implementation program.

In sum: the Board has acknowledged that existing Delta water quality and flow objectives for the Bay-Delta Estuary are inadequate. (State Water Resources Control Board 2000 5 However, the Board *assumes* these water quality and flow objectives when it enforces Term 9 on post-197 water rights permittees. Improving these objectives will mean the Board must curtail diversions by water right permittees (also probably licensees with priority dates *earlier* than August 16, 1978, in order for Board-required Delta water quality and flow objectives to perform their functions protecting Delta watershed public trust resources. As part of its Phase II process to implement the Bay-Delta Plan the Board must take testimony on how to determine this earlier priority date.

In all types of hydrology and using the Sacramento River Basin flow determination of 7 percent of unimpaired flow from November through June C-WIN's water availability analysis suggests that for the Sacramento River Basin above the Feather River confluence and the Feather River basin itself the earliest date for curtailment should be December 19 1914 On the Yuba and the Bear Rivers, the date of curtailment could be somewhat later, ranging from 192 on the Yuba to 194 on the Bear. On the American River, the earliest date should coincide with the priority date of Placer County Water Agency's 1958 water rights.

In all types of hydrology and applying the San Joaquin River Basin flow determination of 6 percent of unimpaired flow from February through June, C-WIN's water availability analysis suggests that for the Stanislaus and Merced Rivers, the Term 9 curtailment date should be December 19 1914. On the Tuolumne River, the Term 91 curtailment date should be 1871. On the upper San Joaquin River, our analysis suggests that Term 9 curtailment dates should be on or before the dates of the Bureau of Reclamation's permits for Friant Dam and Millerton Lake in 1916. (See Appendix D.1 for Water Availability Analysis model results.)

The Board has acknowledged that current Delta water quality and flow objectives do not protect Delta fish and wildlife beneficial uses adequately. The Board must decrease the seasons of diversion for the Delta and its major tributaries of the Sacramento and San Joaquin River Basin watersheds, because the Board is obligated under the Public Trust Doctrine to protect all beneficial uses in the Delta To implement this obligation, the Board must also revisit its Fully-Appropriated Streams Declaration and push back the priority date used to conduct diversion curtailments under Term 91.

Court Adjudication Still another path that may be used is that of adjudication by a court of competing water rights claims in a watershed. It may take years of painstaking testimony and argumentation by attorneys and (usually) engineers But the present situation of extreme uncertainty and unreliability, clouded water titles, trespassing on the public trust, and related boundary disputes of many surface and groundwater water rights throughout the Bay-Delta Estuary's Central Valley watershed argues for its consideration.

In the 1930s and 1940s, staff within the Department of the Interior and the old State Water Rights Board advocated an adjudication of water rights prior to construction of the Central Valley Project. Both Governor Earl Warren and State Water Rights Board Chairman Henry Holsinger testified during the Clair Engle's Congressional hearing in 195 that a complete adjudication of water rights on the Sacramento River should have occurred prior to the completion of the Central Valley Project. In fact, the Engle committee concluded that, "[t]hat for all practical purposes the developed water supplies on the Sacramento River are overcommitted and oversubscribed." This was prior to approval and construction of the State Water Project. That project was predicated on obtaining some 5,000,00 acre- feet of water annually from north coastal streams (Figure 11) With the exception of about million acre-feet of Trinity River flows to the Central Valley Project service area, this "surplus" of surface water to the Delta system never arrived. Adjustments to the State Water Project should have been made earlier, but were not. The logical result is that the Delta's native aquatic ecosystems have collapsed.

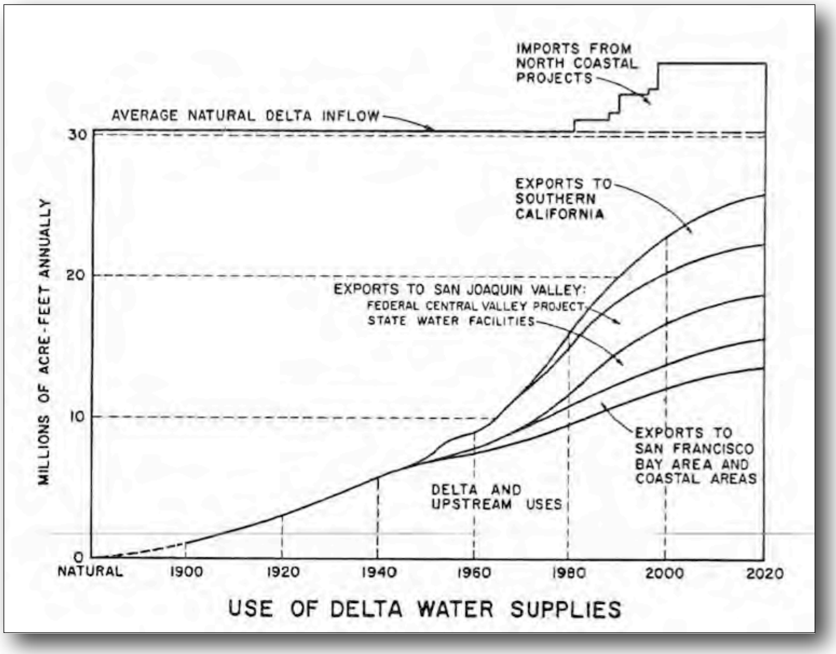

Figure 11
Source: California Department of Water Resources, 1960: 13.

A reliable source of surplus water for the State Water Project and the Central Valley Project eluded the Department and the Bureau, so far. Because surface water imports from north coast watersheds were precluded by wild and scenic river designations the Department and the Bureau have instead tried to establish a "water market" to transfer water from northern California across the Delta as an interim strategy for increasing water supplies in dry years for low-priority water service contractors south of the Delta. C-WIN, CSPA and AquAlliance see this as a grave threat to the regional aquifers of the Sacramento Valley from the Delta to Redding.

This threat is manifest in "groundwater substitution transfers." In such water transfers, surface water rights are transferred by "willing sellers" to the Department or the Bureau. The agencies facilitate the transportation of the water in the deal to the buyer south of the Delta using their export pumps near Tracy. To continue producing their crop however, the seller replaces or substitutes the surface water supply with water pumped from underground. The seller is thus able to achieve a net profit from the gross revenues from selling surface water rights, less the cost of pumping water from below ground, and still can sell a crop after harvest.

Such transactions however assume that groundwater may be treated simply as an individual's property under their land. Such a legal theory runs straight into the reality of groundwater in the Central Valley watershed being a regional commons, a shared resource, particularly among all individual landowners of the Sacramento Valley who overlie its extensive aquifers. One landowner or a set of landowners in one general location may cause a region-wide cone of depression by pumping a lot of groundwater to replace surface water they sold to someone south of the Delta. Such intensive pumping can damage the wells of neighbors near to and far from the scene of the original pumping. Many of the Valley's rivers are well known as "gaining" streams—that is, surface flows are actually enhanced upslope by accretions from groundwater sources. Too much groundwater pumping lower down in the aquifers for the "surplus" benefitting only the State Water Project and the Central Valley Project could drastically lower water tables upslope and reduce river flow permanently if allowed to become "the new normal." Potentially permanent injuries to many beneficial users of water in the Sacramento Valley would result.

glimpse of this prospect occurred in 199 when the Department sponsored a drought water bank program. The program resulted in damage to municipal well and to individual wells in Durham and Cherokee areas of Butte County. More recently, the Department and the Bureau have since 2002 repeatedly sought "willing sellers to offer surface water among the numerous public and private Sacramento Valley water right holders in Sacramento, Yolo, Sutter, Butte, Glenn and Colusa counties The State Water Resources Control Board in 1996 engaged in proceedings to determine the responsibility of Sacramento River Basin diverters to meet water quality standards in the Bay-Delta Estuary. The Board had completed phase through of the proceeding that led in 200 to adoption of Water Rights Decision 164 (D-1641). Phase of that proceeding was to focus on the Sacramento River and its tributaries In Phase 8, the Department of Water Resources and the Bureau of Reclamation, as operators of the state and federal export projects, claimed that certain water right holders in the Sacramento Valley must cease diversions or release water from storage to help meet water quality standards in the Delta. Sacramento Valley water users claimed that their water use had not contributed to any water quality problems in the delta and as senior water right holders and water users within the watershed and counties of origin they are not responsible for meeting these standards. To avoid both litigation and independent regulatory action by the State Water Resources Control Board, water diverters throughout the Sacramento River Basin executed an agreement in April 2001 (Northern California Water Association, 2001 As a result of the Sacramento Valley Water Management Agreement, the Phase process was dismissed by the State Water Resources Control Board. (State Water Resources Control Board 2001)

The Department and the Bureau have encouraged planning approaches to regional water management to facilitate water transfers, such as those in this partial list:

- The Department of Water Resources undertook draft and final Program Environmental Impact Report in 199 of drought water bank but to our knowledge has never certified this document.
- The Sacramento Valley Water Management Agreement, signed in 2002 but which ten years on still lacks a programmatic environmental review document. It expired December 31 2010.
- The 200 Governor's Advisory Drought Planning Panel Report, Critical Water Shortage Contingency Plan, which also promised program environmental document of drought response water transfer program, but was never undertaken.
- The Sacramento Valley Integrated Regional Water Management Plan of 2006 overseen by a joint powers authority of numerous water agencies in the Valley.
- DWR's last Drought Water Bank in 200 sought authorization for over 100,00 acre-feet of temporary transfers of water, though only 16,000 acre-feet were eventually supplied to Southern California buyers.
- The Northern Sacramento Valley Integrated Regional Water Management Plan now in development.
- The Delta Stewardship Council's Delta Plan, whose planning scope includes the entire Sacramento Valley and assumes groundwater surplus is necessary for meeting Delta export water demands The Council has also expressed support for water transfers using groundwater substitution.
- The Bay Delta Conservation Plan which would provide coverage from 50-year habitat conservation plan for Governor Brown's recently announced Peripheral Tunnels Project. This project has no identified water source, other than acknowledgement by the Bureau of Reclamation that it would reroute existing surface flows around the Delta from the Sacramento River Basin (Vlamis et al 2012)

C-WIN, CSPA, AquAlliance, and other knowledgeable experts are concerned that long term impacts of regional use of groundwater to substitute for transferred surface supplies will accelerate the depletion of the Valley's groundwater supplies. There are significant gaps in scientists' grasp of how the aquifer system recharges; how surface flows and groundwater systems interact in the Valley's creeks and rivers; how supplies contained within upper and lower aquifers interact; how the aquifers respond in the long-term to increasingly intense demand on them even during wetter years. And the regional effect of declines in groundwater levels on river and creek flows and riparian corridor species and wetland ecosystems has never been adequately explored. These are beneficial uses upstream along the major tributaries of the Sacramento River Basin that must also be considered part of the public trust responsibilities of the State Water Resources Control Board in its Bay-Delta Plan. (Vlamis et al. 2012)

State and federal water planners assume that surface and groundwater flows will always be there to support this hoped-for surplus. Based on that assumption they continue each winter and spring to plan the next water transfer program that relies on and encourages groundwater substitution transfers. This assumption has been built into the Department and the Bureau's chief water supply and operations planning tool, CalSIM II. When surface water supplies for riparian and appropriative water right holders are exhausted in model runs through CalSIM II the model's automatic response is to add pumped groundwater to make up for any deficit to water demands in the model. (Draper and Bourez 2004, slide 20; Close et al. 2003: 26-27; California Department of Water Resources and U.S. Bureau of Reclamation 2004, Appendix A) Sacramento Valley groundwater activity is explicitly modeled to include "minimum groundwater pumping" for those land uses that rely exclusively on groundwater in the Valley. (California Department of Water Resources and U.S. Bureau of Reclamation et al. 2004: Appendix A) San Joaquin Valley groundwater is not modeled. (Close et al. 2003) This can result in low estimates of salinity reaching the south Delta. (San Joaquin Valley CalSIM II External Review 2006: 45) Upper bounds on potential pumping from aquifers in the Sacramento Valley are undefined. According to Close et al.:

> This does not represent reality, since if CalSIM II is used for statewide planning, it would allow pumping of vast quantities of water for export to southern parts of the state, something which agency staff [i.e. California Bay-Delta Authority Science Program and the Association of Bay Area Governments] claim is unrealistic. Realistic upper bounds to pumping from any of the aquifers represented in the model need to be developed and implemented. (Close et al. 2003: 26-27)

The Department and the Bureau responded that CalSIM II does explicitly model the "impact on groundwater storage of each sub-basin." They state that CalSIM II runs that result in groundwater pumping over and above the natural and artificial recharge and which cause depletion of the basin will cause CalSIM II to no longer run. They also state, however, that CalSIM II "does not include local ground water inventories" but instead relies on a historically-modeled calibration of approximated inventories. They state further that "no groundwater is exported from the overlying watershed (except in the form of surface water return flow or tailwater that results from irrigation using groundwater)." (California Department of Water Resources and U.S. Bureau of Reclamation 2004: A-1) Thus, CalSIM II assumes that groundwater "backstops"surface water rights holders and their needs for supplies when in reality groundwater now backstops river flows (and all associated beneficial uses associated with those flows). It is small comfort that CalSIM II ceases to work when a basin is depleted from the program's operations; more to the point, it fails to assume let alone build in a rational groundwater management strategy of sustained yield.

CalSIM II's reliance on groundwater to meet overall water demand when surface supplies must not be the de facto water supply development strategy for the state of California when supplies run low. When supplies run low—as they are forecasted to as climate change affects the American West—the state and its responsible and lead agencies must increase other means of stretching water supplies. This can be done through water recycling, reuse, conservation, and a range of urban, industrial and agricultural efficiency measures.

Bibliograph (including references in appendices)

Cahill, V., for E.G. Brown. 2008. *Reallocatio of Wate Unde Specifie Conditions*, letter representing the California Attorney General to John J. Kirlin, Executive Director of Delta Vision, July. Accessible online at http://deltavision.ca.gov/BlueRibbonTaskForce/July2008/Handouts/Item_3_Attachment2.pdf.

California Appeal Court, Third District. 1986 *United State of America e al v. Stat Water Resource Contro Boar (an seve othe cases)* 18 Cal.App. 3 82 July.

California Department o Fis an Game. 1992 *Summar and Recommendations fo the Departmen of Fish an Game' Testimon o th Tributarie to th Sacramento-Sa Joaquin Estuary* presented to th State Water Resources Control Board, Interim Water Rights Actions Phase Bay-Delta Estuar Proceedings, WRINT-DFG Exhibi No 29 pages.

California Department o Water Resources an U Bureau o Reclamation. 2004 *Pee Review Response Repor b DWR/Reclamatio in Reply t th Pee Review o th CalSIM-I Model Sponsored by th CalFE Scienc Program in Decembe 2003.* August. 27 pages plus six appendices. Accessible online a http://baydeltaoffice.water.ca.gov/modeling/hydrology/Peer%20Review%20Response%20(August%202004).pdf.

California Department o Water Resources. 1960 *Bulleti 76 Delt Wate Facilities.* December, 61 pages.

California Department o Water Resources. 2007 *Californi Centra Valle Unimpaire Flow Data* 4th edition, Bay Delta Office, May, 50 pages.

California Supreme Court. 1983 *Nationa Audubo Society e al. v Th Superio Cour o Alpine Count an Departmen o Wate an Power o th Cit o Lo Angeles* e al S.F. 24368 Filed February 17, 1983. Cited as 33 Cal.3d 419, 189 Cal.Rptr. 346, cert. denied, 464 U.S. 977. Accessible online at http://www.monobasinresearch.org/images/legal/nassupct.htm.

California Water Project Authority, 1951. *Dat an Informatio o th Central Valle Project* October 29, 66 pages.

Close, A. Hanneman, WM Labadie, JW, Loucks, DP, Lund JR McKinney DC, and Stedinger, JR. 2003. *Strategi Review o CALSI II an it Us fo Wate Planning, Management, an Operation in Centra California* Decembe 4, 12 pages Accessible online a http://sacramentoriverportal.org/modeling/CALSIM-Review.pdf.

Domagalski JL, Knifong DL MacCoy DE Dileani PD, Dawson BJ an Majewski MS 1998 *Water Qualit Assessmen o th Sacrament Rive Basin California—Environmenta Settin an Study Design*. United States Geologica Survey Water Resources Investigations Report 97-4254. Nationa Water Qualit Assessmen Program. Accessible onlin a http://pubs.er.usgs.gov/publication/wri974254.

Draper, A an Bourez, W. 2004 *CalSI I Sacrament River Basi Hydrolog Enhancements*. Powerpoint presentation, February 26. 58 slides. Accessible online at http://www.cwemf.org/Asilomar/Draper.pdf.

Garner, B.A. ed 2010. *Black' Law Dictionary* Abridged Nint Edition.

Gronberg, JM Dubrovsky NM Kratzer CR, Domagalski JL Brown LR, an Burow KR. 1998. *Environmenta Settin o th San Joaquin-Tular Basins, California* United States Geologica Survey Water Resources Investigations Report 97-4205. Nationa Water Qualit Assessment Program. Accessible onlin a http://pubs.er.usgs.gov/publication/wri974205.

Holsinger, H. 1936. *Comment Pertainin t Som Fundamenta Theorie of Californi Wate Law* A address presented before Sacramento Section America Societ o Civil Engineer on February 4, manuscrip i th Water Resources Collections an Archives, University of California, Riverside.

Water Availability Analysis

Workshop 3 Testimony, Bay Delta Plan
Submitted by California Water Impact Network, California Sportfishing Protection Alliance, and AquAlliance

Bibliography (including references in appendices)

Horwitz, M.J. 1977. *The Transformation of American Law, 1780-1860* Cambridge, MA: Harvard University Press, 35 pages.

Hutchins W.A.. 1956. *The California Law of Water Rights* prepared for the U Department of Agriculture, 57 pages.

Kibe P.S. 2011 Instream Flow and the Public Trust: Statutory Innovation in California's 200 Delta Reform Act. 1 Water Resources Committee Newsletter (ABA, January 2011) Accessible online at http://digitalcommons.law.ggu.edu/pubs/444/

Knowles, N. and D.R. Cayan. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco estuary. *Geophysical Research Letters* 29(18) 1891-1894 Accessible online at http://cirrus.ucsd.edu/~pierce/crd/globalwarming/knowles_cayan_2002.pdf.

Littleworth, A.L and E.L Garner, *California Water II* 2nd edition Point Arena, CA: Solano Press Books, 2007, 428 pages.

Northern California Water Association. 2001. *The Sacramento Valley Water Management Agreement* 2 pages including three appendices Accessible online at http://www.norcalwater.org/res/docs/sac_valley_water_mgmt_agrmt.pdf.

O'Laughlin, T. 2011a. *Draft Technical Workshop Need to Disclose Legal Theory Behind Intended Plan of Implementation.* Letter to Charlie Hoppin, Frances Spivy-Weber, Tam Doduc and Dwight Russell, State Water Resources Control Board, February 22, 3 pages. Accessible online at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/022211sjrga2.pdf.

O'Laughlin, T. 2011b. *SWRCB's Jurisdiction in the Bay-Delta Proceedings* Letter to Charlie Hoppin, Frances Spivy-Weber, and Tam Doduc State Water Resources Control Board, June 27 pages Accessible online at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/062711sjrga2.pdf.

Pearsall, J., ed. 1999. *Oxford Concise English Dictionary* Tenth Edition.

Review Panel. 2010. *The Vernalis Adaptive Management Program (VAMP)* prepared for the Delta Science Program, May 11 4 pages. Accessible online at http://www.sjrg.org/peerreview/review_vamp_panel_report_final_051110.pdf.

San Joaquin River Group Authority. 2000 *San Joaquin River Agreement* and Appendix A: Vernalis Adaptive Management Plan Accessible online at http://www.sjrg.org/agreement.htm.

San Joaquin River Group Authority. 2008 *South Delta Hydrology and Water Rights: Comments of the San Joaquin River Group Authority* prepared by O'Laughlin & Paris LLP, Chico, CA, July, 73 pages plus appendices. Accessible online at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/strategic_plan/comments/south_delta_diversion_report.pdf.

San Joaquin River Group Authority. 2011 *2010 Annual Technical Report on Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP)* Prepared for the California Water Resources Control Board in compliance with D-1641 September. 16 pages Accessible online at http://www.sjrg.org/technicalreport/2010/2010_SJRGA_Annual_Technical_Report.pdf.

San Joaquin Valley CalSIM II External Review. 2006. *Review Panel Report San Joaquin River Valley CalSIM II Model Review.* 12 January. 87 pages. Accessible online at http://science.calwater.ca.gov/pdf/calsim/calsim_II_final_report_011206.pdf.

Bibliograph (including references in appendices)

Soulé F. 1901 "Irrigation from th Sa Joaquin River," i Elwood Mead *Repor o Irrigation Investigations*, U Departmen of Agriculture Office o Irrigation Investigations. Accessible at University o California a Riverside, Water Resources an Collections Archives, Call No G4094 C1.

State Water Resources Board. 1951 *Bulleti No 1 Wate Resource o California* State of California, 648 pages.

State Water Resources Control Board. 1983 *Wate Righ Decisio 1594 In th Matte of Water Righ Permit i th Sacramento-Sa Joaqui Delt Watershe i which th Boar Reserved Jurisdictio t Change th Seaso o Diversio (Term 8 Permits)* November 1983, 6 pages plu Appendix A, and Order W 84-2 amendin an affirmin Decisio 159 an Denying Petitions for Reconsideration, February 1984, 29 pages. Accessible online at http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1550_d1599/wrd1594.pdf.

State Water Resources Control Board. 1989 *Order W 89-25 I th Matte o Declaratio o Fully Appropriate Strea System i California Order Adoptin Declaratio o Full Appropriated Strea Systems an Specifiying Conditions fo Acceptanc o Application an Registrations*. November 16 5 page plu Exhibi A Accessible onlin at http://www.swrcb.ca.gov/waterrights/board_decisions/adopted_orders/orders/1989/wro89-25.pdf.

State Water Resources Control Board. 1991 *Order W 91-07 I th Matte o Declaratio o Fully Appropriate Strea System i California Order Revising Declaratio o Full Appropriated Strea Systems* August 22 2 page plu revisions to Exhibi A Accessible onlin a http://www.swrcb.ca.gov/waterrights/board_decisions/adopted_orders/orders/1991/wro91-07.pdf.

State Water Resources Control Board. 1992 *Draf Wate Right Decisio 1630 Sa Francisco Bay/Sacramento-Sa Joaqui Delt Estuary* December, 12 pages.

State Water Resources Control Board. 1994 *Mono Lak Basi Water Righ Decisio 1631 Decision an Orde Amendin Wate Righ License t Establis Fisher Protectio Flows in Streams Tributar t Mon Lake an t Protec Publi Trust Resource a Mon Lak an i the Mono Lake Basin* September 28 21 pages Accessible onlin a http://www.swrcb.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1631.pdf.

State Water Resources Control Board. 1998 *Order W 98-08 I th Matte o Declaratio o Fully Appropriate Strea System i California Order Revising Declaratio o Full Appropriated Strea Systems* November 19 2 page plu Exhibi A Accessible onlin a http://www.swrcb.ca.gov/waterrights/board_decisions/adopted_orders/orders/1998/wro98-08.pdf.

State Water Resources Control Board. 2000 *Revise Wate Righ Decision 1641 In th Matte of Implementatio of Wate Quality Objective fo th Sa Francisc Bay/Sacramento-San Joaquin Delt Estuary Petitio t Chang Point o Diversio of th Centra Valle Project an th State Wate Project in th Souther Delta an Petitio to Chang Place of Use an Purpose of Use o th Centra Valle Project* Decembe 29 1999 revised in accordance with Order WR 2000-02 March 15, 19 pages Accessible online a http://www.waterboards.ca.gov/waterrights/board_decisions/adopted_orders/decisions/d1600_d1649/wrd1641_1999dec29.pdf

State Water Resources Control Board. 2001 *Order W 2001-05* April Accessible onlin a http://www.swrcb.ca.gov/waterrights/board_decisions/adopted_orders/orders/2001/wro2001-05.pdf.

Bibliography (including references in appendices)

State Water Resources Control Board. 2008 *Water Rights Within the Bay-Delta Watershed.* Provided to the Delta Vision Blue Ribbon Task Force for its October 16 and 17 2008 meeting Document dated September 26 2008 pages Accessible online at http://deltavision.ca.gov/BlueRibbonTaskForce/Oct2008/Respnose_from_SWRCB.pdf.

State Water Resources Control Board. 2010 *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem* prepared pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009 17 pages. Accessible online at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/final_rpt.shtml

State Water Resources Control Board. 2011a *Revised Notice of Preparation and Notice of Additional Scoping Meeting (San Joaquin River Flows and South Delta Water Quality Objectives)*, 1 pages Accessible online at http://www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/notice_sjr_flow_southern_delta_scoping_mtg_with_attachments.pdf.

State Water Resources Control Board. 2011b California Code of Regulations, Title 2 Waters, Division State Water Resources Control Board and Regional Water Quality Control Boards (Sections pertaining to water rights), January, 16 pages. Accessible online at http://www.swrcb.ca.gov/laws_regulations/docs/wrregs.pdf.

State Water Resources Control Board. 2011c *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives* October, 17 pages, including appendices Accessible online 6 December 201 at http://www.swrcb.ca.gov/water_issues/programs/peer_review/docs/sanjoaquin_river_flow/technical_report.pdf.

Steinberg, T. 1991 *Nature Incorporated Industrialization and the Waters of New England*, Amherst, MA University of Massachusetts Press, 28 pages.

Stevens, J.S. 2005 *Applying the Public Trust Doctrine to River Protection* presentation given June 9 200 at University of California at Davis, reprinted in California Department of Water Resources, *California Water Plan Update 2005, Volume 4* pp 393-400 Accessible online at http://www.waterplan.water.ca.gov/docs/cwpu2005/vol4/vol4-environment-applyingpublictrustdoctrine.pdf.

US Department of the Interior. 2000 *Record of Decision Trinity River Mainstem Fishery Restoration Final Environmental Impact Statement/Environmental Impact Report.* December. 28 pages plus three appendices. Accessible online at http://odp.trrp.net/Library/Details.aspx?document=227.

Vlamis, B., Krieger, C., and Jennings B 2012 *Letter re: Initial Study and Proposed Negative Declaration for the Butte Water District 201 Water Transfer Program* to Mark Orme, General Manager, Butte Water District, Gridley, CA, March 29, 2012, 2 pages.

Wiel S.C. 1928 The Pending Water Amendment to the California Constitution, and Possible Legislation (Concluded), *California Law Review* 16(4) 257-280 May.

Wilson, C.M. 2011. *The State Water Resources Control Board's Role in Implementing the Delta Plan* Report to the State Water Resources Control Board and the Delta Stewardship Council by the Delta Watermaster. pages Accessible online at http://www.swrcb.ca.gov/board_info/agendas/2011/mar/031511_9att.pdf.

Wilson, C.M. 2012. *Water Right Compliance and Enforcement in the Delta.* Report to the State Water Resources Control Board and the Delta Stewardship Council by the Delta Watermaster. pages. Accessible online at http://www.swrcb.ca.gov/board_info/agendas/2012/feb/020712_9_with%20report.pdf.

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SUPERIOR COURT OF CALIFORNIA

COUNTY OF SACRAMENTO

California Water Impact Network, a non-profit Corporation, California Sportfishing Protection Alliance, a non-profit Corporation, and AquAlliance, a public benefit Corporation, Petitioners, vs. The California State Water Resources Control Board, The California Department of Water Resources, and DOES 1-100, Respondents The United States Bureau of Reclamation, Real Party in Interest	Case No.: 34-2010-80000653 **SECOND AMENDED COMPLAINT FOR DECLARATORY AND INJUNCTIVE RELIEF AND PETITION FOR WRIT OF ADMINISTRATIVE MANDATE (Code of Civ. Proc. §§ 526, 1060, 1094.5)** Judge: Hon. Michael P. Kenny Action Filed: September 3, 2010

INTRODUCTION

1. Petitioners California Water Impact Network (hereinafter "C-WIN"), the California Sportfishing Protection Alliance (hereinafter "CSPA"), and AquAlliance (collectively "Petitioners"), by and through their counsel, hereby allege on information and belief that the California Department of Water Resources (hereinafter "DWR"), is operating in violation of the Public Trust; Article X, Section Two of the California Constitution; the 1995 Water Quality Control Plan narrative standard for salmon; and State Water Resources Control Board Decision 1641 (hereinafter "D-1641"), all of which have led to the continuing and ongoing degradation of fish and wildlife.

2. Petitioners further allege that the State Water Resources Control Board (hereinafter "Board" or "SWRCB"), has failed to enforce permit and licensing conditions of the Porter-Cologne Act and D-1641 against DWR, thereby allowing DWR to cause extensive damage to the Bay-Delta estuary and the fish and wildlife that live therein.

3. Petitioners request a writ of administrative mandate challenging the approval by Respondent SWRCB of WR Order 2010-0002, which modified the Cease and Desist Order of WR Order 2006-0006 on January 5, 2010, and request that the Court set aside Board WR Order 2010-0002 and reinstate the Cease and Desist Order in WR Order 2006-0006 that required Respondent DWR to comply with interior Delta salinity standards by July of 2009.

4. Petitioners seek declaratory relief against DWR for violations of the Public Trust; Article X, Section Two of the California Constitution; the 1995 Water Quality Control Plan narrative standard for salmon; and D-1641 and seek an injunction to further pumping by DWR at the Banks Pumping Facility until DWR can comply with the law.

PARTIES

5. Petitioner C-WIN is a California non-profit public benefit organization with its principal place of business in Santa Barbara, California. C-WIN's organizational purpose is the protection and restoration of fish and wildlife resources, scenery, water quality, recreational opportunities, agricultural uses, and other natural environmental resources and uses of the rivers and streams of California, including the Bay-Delta, its watershed and its underlying groundwater

resources. Members of C-WIN reside in, use, and enjoy the Bay-Delta and inhabit and use its watershed. They use the rivers of the Central Valley and the Bay-Delta for nature study, recreation, and aesthetic enjoyment. Harm to the pelagic and anadromous fishery in the Bay-Delta and its watershed harms the California Water Impact Network and its members by threatening impairment of their use and enjoyment of these species and their habitat.

6. Petitioner CSPA is a California non-profit public benefit organization with its principal place of business in Stockton, California. CSPA's organization purpose is the protection, preservation, and enhancement of fisheries and associated aquatic and riparian ecosystems of California's waterways, including Central Valley rivers leading into the Bay-Delta. This mission is implemented through active participation in water rights and water quality processes, education and organization of the fishing community, restoration efforts, and vigorous enforcement of environmental laws enacted to protect fisheries, habitat and water quality. Members of CSPA reside along the Central Valley watershed and in the Bay-Delta where they view, enjoy, and routinely use the Delta ecosystem for boating, fishing, and wildlife viewing. Petitioner's members derive significant and ongoing use and enjoyment from the aesthetic, recreational, and conservation benefits of the Bay-Delta ecosystem. Harm to the Bay-Delta fisheries has had, and continues to have, a substantial negative impact on Petitioners' organizational members use and enjoyment of the Bay-Delta.

7. Petitioner AquAlliance is a California public benefit corporation organized to protect Northern California's waters to sustain family farms, recreation opportunities, vernal pools, creeks, rivers, and the Bay-Delta estuary. Currently, AquAlliance is a fiscally sponsored project of the Rose Foundation. Members and officers of AquAlliance are being affected by the over-pumping of the Bay-Delta and by the over-appropriation of water for excess water delivery south of the Bay-Delta. Mismanagement of water resources in the Bay-Delta deplete local lakes, and harm salmonids that travel through the lakes and streams used and enjoyed by AquAlliance members.

8. Respondent DWR is a state agency responsible for the State of California's management and regulation of water usage. DWR operates the State Water Project ("SWP"), a

water storage and delivery system of reservoirs, aqueducts, power plants and pumping plants, including the Oroville Reservoir and dam, the Clifton Court Forebay, the John E. Skinner Delta Fish Protective Facility, and the Harvey O. Banks Pumping Plant.

9. Respondent SWRCB the governing board that performs both adjudicatory and regulatory functions of the state in allocating water rights and ensuring water quality pursuant to the California Water Code. The Board has broad authority to carry out these functions, including the authority to hold hearings and conduct investigations in any part of the state necessary to carry out the powers vested in it. It also may require a state or local agency to investigate or report on technical factors, or comply with waste discharge requirements involved in water quality control. The Board may subject water rights to terms and conditions the board finds necessary to carry out a water quality control plan, and a water quality control plan may require changes to water rights, and it may reserve its jurisdiction to enforce these terms and conditions over time. The Board may hold an adjudicative proceeding to consider any changes to water rights to implement the plan.

10. Real Party in Interest the United States Bureau of Reclamation (hereinafter "Bureau" or "USBR"), is a federal agency required to comply with state laws relating to the control, appropriation, use, or distribution of water by the Reclamation Act of 1902. The Bureau operates the Central Valley Project (hereinafter "CVP" of "Project"), which reaches from the Cascade Mountains near Redding in the north some 500 miles to the Tehachapi Mountains near Bakersfield in the south. The Project is one of the world's largest water storage and transport systemscomprised of 20 dams and reservoirs, 11 power plants, and 500 miles of major canal as well as conduits, tunnels, and related facilities.

11. The true names and capacities of Respondents sued in the Petition under the fictitious names of DOES 1 through 100, inclusive, are unknown to Petitioners who therefore sue such Respondents by such fictitious names.

12. Whenever reference is made in this complaint to any act of Respondents, such allegation shall mean that each Respondent acted individually and jointly with the other Respondents named in that cause of action.

13. At all relevant times, each of the Respondents has acted as an agent, representative, or employee of each of the other Respondents and has acted within the course and scope of said agency or representation or employment with respect to the causes of action in this complaint.

14. At all relevant times, each Respondent has committed the acts, caused others to commit the acts, or permitted others to commit the acts referred to in this complaint and has made, caused, or permitted others to ignore the legal obligations referred to in this complaint.

JURISDICTION AND VENUE

15. Pursuant to Public Resources Code §§ 21168 and 21168.5, and Code of Civil Procedure section 1094.5, this Court has jurisdiction to hear this matter.

16. Venue is appropriate in this judicial district in accordance with Code of Civil Procedure §§ 401 and 393 because the respondents SWRCB and DWR are both located in Sacramento.

PROCEDURAL BACKGROUND

17. Violations of state permit and license requirements by DWR, and the Board's failure to enforce permit conditions, water quality standards, and its own decisions and order are causing, and continue to cause, extensive and irreparable damage to the Bay-Delta estuary and the public trust resources therein.

18. In 2000, the SWRCB adopted Decision D-1641, which established water quality objectives for the interior southern delta and conditioned DWR's pumping and export activities on meeting those standards.

19. On February 15, 2006, after DWR had repeatedly failed to meet the D-1641 standards, the SWRCB adopted WR Order 2006-0006, holding DWR responsible for meeting the water quality objectives described in D-1641 and imposing a time schedule requiring DWR to obviate the threat of non-compliance by no later than July 1, 2009. The order specifically rejected the possibility of any time extensions for compliance, stating "considering that the objectives were first adopted in the Water quality control plan in 1978… the State Water Board

will not extend the date for removing the threat of non-compliance beyond July 1, 2009."[1] WR Order 2006-0006 included a cease and desist order ("CDO") mandating DWR to cease and desist pumping and export activities if it failed to obviate the threat of non-compliance by July 1, 2009. DWR chose, as their preferred method of compliance, to build gates, known as permanent operable barriers.

20. In May of 2007, DWR informed the SWRCB that it would be unable to construct the permanent operable barriers that it planned to use to meet the D-1641 standards by the July 1, 2009 deadline, and requested an extension until July 1, 2011. No evidentiary hearing on the request to extend the compliance deadline was set by the Board at that time.

21. By June of 2009, one month before the CDO deadline, DWR had not begun construction on the proposed operable barriers to comply with the requirements of WR Order 2006-0006. That same month, a biological opinion from the National Marine Fisheries Service (NOAA Fisheries) was published that specifically prohibited construction of the proposed operable gates as a part of the South Delta Improvements Program (SDIP).

22. Therefore, on June 5, 2009 the Board issued public notice of an evidentiary hearing on whether the CDO in WR Order 2006-0006 should be extended. The Board asserted that the evidentiary hearing was noticed in response to DWR's May 2007 request to extend the compliance deadline. In late June of 2009 the SWRCB held an evidentiary hearing on potential modifications to the CDO in WR Order 2006-0006. The Board later adopted WR Order 2010-0002 on January 5, 2010, which modified the CDO and extended DWR's compliance deadline for complying with D-1641 standards to an uncertain future date, thereby allowing DWR to continue operating its pumps despite the continuing and ongoing degradation of fish and wildlife in the Delta.

23. In February of 2011, the Board officially denied Petitioner's Petition for Reconsideration of WR Order 2010-0002. Petitioners have therefore exhausted all available administrative remedies.

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[1] WR Order 2006-0006, p. 27, ¶ 5

STATEMENT OF FACTS

24. The Bay-Delta is the largest estuary on the west coast of the Americas, and serves as one of California's most environmentally important and economically valuable ecosystems. Millions of Californians depend upon the Bay-Delta Estuary as one of the sources of their drinking water. Still more use the Bay-Delta as a recreational resource, making it a major recreation and tourist destination. Of the Delta's approximate 738,000 acres, roughly two-thirds support agriculture. More than 500,000 acres of the Delta currently are in agricultural production.

25. In addition to supplying drinking water and serving agricultural interests, the Bay-Delta but is home to approximately 750 plant and animal species, including 130 species of fish. The Delta serves as a critical fishery habitat as it supports an estimated twenty-five percent (25%) of all warm water and anadromous sport-fishing species, and eighty percent (80%) of California's entire commercial fishery habitat.

26. An extraordinary variety of wildlife, including several species which cannot be found anywhere else, live in the Bay-Delta. Many other species depend upon the Bay-Delta for migratory corridor habitat, and numerous commercial and sport fisheries depend upon the Bay-Delta for their continued existence.

27. The Bay-Delta provides critical habitat for a number of species that are protected by the Endangered Species Act ("ESA"), including the Sacramento winter-run Chinook salmon, Central Valley spring-run Chinook salmon (*Onchorhynchus tschawytscha*), Central Valley steelhead (*Onchorhynchus mykiss*), and Delta smelt (*Hypomesus transpacificus*, collectively, the "Listed-Species").

28. Since 1993, the National Marine Fisheries Service ("NMFS") has listed the several fish in the Bay-Delta as "threatened" or "endangered," including the Sacramento River winter-run Chinook salmon and the Central Valley spring-run Chinook salmon.

29. In September of 1999 the National Marine Fisheries Service listed the Central Valley spring-run Chinook salmon as a threatened species, with a population of only 500.

30. The NMFS has also officially listed the Bay-Delta as critical habitat for the aforementioned threatened and endangered fish. As such, the Bay-Delta Estuary is one of California's most threatened ecosystems. The SWRCB designated the Delta's channels, the Sacramento and San Joaquin Rivers, and areas throughout the Bay as water-quality-limited water bodies, yet violations of water quality standards in the Delta are chronic.

31. Many of the Bay-Delta's fish are threatened with extinction. In the last three (3) years several populations of previously healthy species have also suffered catastrophic declines. Still others, including plankton and other food organisms that underpin the Bay-Delta's entire food chain, are in similarly poor health.

32. The collapse of the California salmon run has triggered severe fishing restrictions that have resulted in the near-complete closure of commercial and recreational salmon fishing in California for the 2008, 2009, and 2010 fishing seasons. The number of Chinook or King salmon returning from the Pacific Ocean to spawn in the Sacramento River and its tributaries dropped 67 percent from a poor year earlier. Restoration of California's anadromous fish populations is mandated by the Salmon, Steelhead, and Anadromous Fisheries Program Act of 1988 which states that it is the policy of the State to significantly increase the natural production of salmon and steelhead by the end of the 20th century.

33. Pursuant to the California Water Code, the SWRCB has a duty to protect the waterways of California by the imposition and enforcement of certain requirements to permits and licenses that regulate water quality in the State.[2]

34. Under California law, the SWRCB has an affirmative duty to take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible.[3]

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[2] See, Wat. Code § 100: "…The right to water or to the use or flow of water in or from any natural stream or watercourse in this State is and shall be limited to such water as *__shall__* be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water" (*__emphasis added__*); and Wat. Code § 275: "The department and board *__shall__* take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in this state" (*__emphasis added__*).

35. The SWRCB is also charged with complying with California Constitution Article X, Section 2, which requires that any right to the use or divert water from any natural stream or water in the State shall be reasonable.

36. The SWRCB has adopted several orders that, if enforced, would be protective of fish and wildlife in the Bay-Delta estuary. For example, the Porter Cologne Act required the Board to adopt the 1995 Water Quality Control Plan which includes a Narrative Standard for Fish and Wildlife (hereinafter “the narrative standard”). This narrative standard requires that water flow, water quality, and appropriate temperature conditions are sufficient to achieve a doubling of natural production of Chinook salmon from the average production of 1967-1991.

37. Consistent with the Clean Water Act, the Porter-Cologne Act requires the SWRCB to create and enforce a water quality control plan that includes water quality standards and objectives, which resulted in the SWRCB adopting D-1641.

38. Decision 1641, adopted by the SWRCB on December 29, 1999, establishes water quality objectives for the Bay-Delta Estuary as a part of the Board’s implementation of the 1995 Bay-Delta Water Quality Control Plan. D-1641 also imposes a series of restrictions on the use of export pumps to protect fish and wildlife and assigned responsibilities to the persons or entities holding water rights permits to meet specific flow objectives to protect fish and wildlife. One such restriction requires that water quality objectives must be met at four different monitoring stations in the Bay-Delta before DWR pumping activities can continue. D-1641 holds DWR specifically responsible for meeting these flow objectives.

39. The Board has consistently assigned DWR responsibility for meeting salinity objectives in the Bay-Delta, including those objectives described in D-1641.

40. The SWRCB found that export pumping under the conditions imposed by D-1641 would not unreasonably affect or substantially injure any legal user of water, and would not unreasonably affect fish, wildlife, or other in-stream beneficial uses of water.

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[3] See *National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419.

41. Contrary to the findings and conditions of D-1641, the SWRCB continuously fails to enforce its own Basin Plan standards, allowing DWR to continue pumping activities leading to the dramatic decline in the health and viability of the Bay-Delta estuary and the public trust recourses therein.

42. In spite of D-1641 Respondent DWR, with the tacit approval of the SWRCB, has increased its water exports by 53% percent since 2000. This increase exceeds the average of 2.1 million acre-feet that was exported during the 1990s, resulting in the dramatic decline of Delta fisheries. Meanwhile, Delta fish populations of salmon, striped bass, Delta smelt, and other listed and unlisted species collapsed.

43. DWR exports water that it claims is excess or surplus under Article 21 of the amended State Water Project contracts. The exported water is used largely to further development, water banking, and water transfers. Despite the recent and dramatic further decline in the health of the Bay-Delta estuary, DWR has continued to export increasing amounts of water in violation of D-1641, causing some substantial fish declines between the years of 2000 and 2010 with the approval of the SWRCB.

44. In 2008, 2009, and 2010 the populations of various California salmon runs have dramatically declined, resulting in the complete closure of commercial and sport-fishing salmon fishing in California for the 2008 and 2009 fishing seasons, and a substantial reduction in fishing in 2010. The number of Chinook or King salmon returning from the Pacific Ocean to spawn in the Sacramento River and its tributaries this fall dropped 67 percent from a year earlier.

45. Every scientific study done in the last decade (CalFed ROD, IEP Science Reviews, OCAP Biological Opinions on Delta smelt and listed salmonids) has found that exports from the Bay-Delta are largely to blame for the current fish and wildlife declines in the Delta.

46. The fish protection conditions of D-1641, when they are not enforced and allow increased export pumping, are not protective of the Bay-Delta fisheries. The lack of protection has resulted in a serious decline in the health of those fisheries and in their habitat. Increased SWP pumping necessarily decreases in-stream flow and Delta outflow, thereby increasing the concentration of pesticides, herbicides, and other toxins in the Bay-Delta waterways. Increased

export pumping by the SWP since 2000 has had a significant, negative impact on the survival of juvenile Chinook salmon emigrating through the Delta, particularly in the November through June period.

47. Numerous scientific studies, including the SWRCB's recent report to the State Legislature, indicate that increasing flows from the SWP to the Delta in the spring would protect marine wildlife habitat and the threatened water ecosystem. Increased flows in the San Joaquin River correlate to increased numbers of adult fall-run Chinook salmon, and spring flow coincides with the spawning season of a number of estuarine species, such as delta smelt, Sacramento split-tail, Green sturgeon, and striped bass.

48. The SWRCB has a duty of continuing supervision over the taking and use of appropriated water, and must allocate water resources in light of current knowledge and current needs. In the face of mounting evidence that water exports are harming fish and wildlife since 2000, the Board has refused to reduce DWR's water rights and export permits and has failed to evaluate permit conditions that would protect fish and wildlife and would reflect changed environmental circumstances in the Bay-Delta.

49. The SWRCB has continuously refused to act on public trust complaints against DWR and its activities at the Banks pumping plant, and has rejected Petitioners' attempts to address the allegations contained herein through administrative proceedings.

50. On January 5, 2010 the SWRCB modified WR Order 2006-0006 and the related Cease and Desist Order (CDO) against DWR for threatened violation of their permit/license requirements to meet the 0.7 EC standard in the interior southern Delta. Petitioners had strongly opposed the modification of the CDO, which had required complete compliance with the permit and license requirements by July of 2009. In its decision to modify the CDO in WR Order 2006-0006, the Board largely dismissed fish and wildlife concerns under the public trust, and failed to enforce Article X, Section 2 of the California Constitution.

51. By approving WR Order 2010-0002, the SWRCB has allowed Respondent DWR to violate the conditions of their permits, the agricultural water quality standards in the Bay-

Delta, D-641, and the CDO (WR Order 2006-0006), and has failed to exercise its duty to protect the public trust and guard against waste and unreasonable use.

FIRST CAUSE OF ACTION
Violation of the California Public Trust Doctrine

52. Petitioners restate and re-allege and incorporate all of the preceding paragraphs as if fully set forth herein.

53. Respondent DWR has increasing annual pumping in violation of the Public Trust Doctrine since 2000, despite the increasingly perilous collapse of Delta fish populations of salmon, striped bass, Delta smelt, and other listed and unlisted species.

54. Respondent DWR's decision to continue pumping despite the obvious damage to public trust resources has caused there to be a substantial decline in the food web, in fish numbers, in water quality, and in hydrologic changes which have caused injury to the ecosystem and to members of the public, including Petitioners. Present ecological conditions in the Bay-Delta have contributed to the closure of the commercial and sport-fishing fishing seasons off the California Coast, resulting in the near complete loss of recreational fishing opportunities for anglers.

55. On information and belief, unless the DWR is enjoined by this court, it will continue to violate the Public Trust, as described above, and Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

56. An actual controversy exists between Petitioners and Respondent DWR. Specifically, Petitioners contend and Respondent DWR denies that its pumping methods constitute a violation of the California Public Trust doctrine or that its failure to abide by salinity standards set by their water rights permits violates the Public Trust and injures Petitioners. As an actual controversy exists, Petitioners are entitled to and hereby seek a declaration that Respondent DWR has violated the Public Trust.

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SECOND CAUSE OF ACTION
Violation of Article 10, Section 2 of the California Constitution: Unreasonable Method of Diversion

57. Petitioners restate and re-allege and incorporate all of the preceding paragraphs as if fully set forth herein.

58. Article X, Section Two of the California Constitution states that "the right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water."

59. Water levels in several Delta channels are reduced to unacceptably low levels by Respondent DWR's operation of the State Water Project pumps, harming fish and riparian diverters in the process. At present export levels, DWR's Method of Diversion from the Bay-Delta at the export pumps is unreasonable and has overwhelmingly contributed to the pelagic fish decline and the listing of several species as threatened or endangered.

60. Over the years and continuing to the present time, Respondent DWR's methods of diversion caused there to be insufficient in-stream flow and Delta outflow to support the environmental needs of the estuary which has caused injury to the ecosystem and to members of the public, including Petitioners.

61. Over the years and continuing to the present time, Respondent DWR has used an unreasonable method of diversion of water from their facilities in the Bay-Delta in violation of Article 10, Section Two of the California Constitution by continuing to increase volumes of water drawn from the Bay-Delta ecosystem, and limiting and ignoring research and information that indicated this method of diversion is causing a collapse in the Pelagic fisheries in the Bay-Delta and harm to the listed salmonids and other fish and wildlife.

62. On information and belief, unless enjoined Respondent DWR will continue to violate the California Constitution, as described above.

63. In light of the Respondent DWR's failure to comply with the California Constitution, and the significant likelihood of repeated violations in the future, Respondent DWR

must be permanently enjoined from continuing to divert water from the Bay-Delta until they comply with Article X, Section Two of the California Constitution. If Respondent DWR is not so enjoined, Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

64. An actual controversy exists between Petitioners on the one hand and Respondent DWR on the other. Specifically, Petitioners contend and Respondent DWR denies that its pumping methods constitute a violation of Article 10, Section Two of the California Constitution for unreasonable use methods of diversion, causing injury to Petitioners. As an actual controversy exists, Petitioners are entitled to, and hereby seek, a ruling that Respondent DWR has violated Article X, Section 2 of the California Constitution for unreasonable method of diversions.

THIRD CAUSE OF ACTION

Violation of Article X, Section 2 of the California Constitution: Unreasonable Use

65. Petitioners restate and re-allege and incorporate all of the preceding paragraphs as if fully set forth herein.

66. Article X, Section Two of the California Constitution states that, due to the conditions prevailing in the State "the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare."

67. Further, Article X, Section Two specifically states that "the right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water."

68. SWP export pumping from the Delta for water banking and resale by Respondent DWR at the current levels is an unreasonable use of the water resources of this State. Export pumping adversely effects fish and wildlife resources in the Delta, including spring-run Chinook

salmon (listed as threatened under the CESA and ESA) and winter-run Chinook salmon (listed as endangered under the CESA and ESA). The adverse impacts to fish include decreases in salmon smolt survival during outmigration from changes in hydrologic patterns in the Delta (increases in net reverse flows), entrainment at the export pumps, and increased predation at the pumps. On information and belief, unless enjoined Respondent DWR will continue to violate the California Constitution, as described above.

69. In light of the Respondent DWR's failure to comply with the California Constitution, and the significant likelihood of repeated violations in the future, Respondent DWR must be permanently enjoined from continuing to divert water from the Bay-Delta until they can comply with all applicable water quality standards and fish protection mechanisms, including appropriate screening of diversions. If Respondent DWR is not so enjoined, Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

70. An actual controversy exists between Petitioners on the one hand and Respondent DWR on the other. Specifically, Petitioners contend and Respondent DWR denies that its operation of the SWP violates Article X, Section Two of the California Constitution and injures Petitioners. As an actual controversy exists, Petitioners are entitled to, and hereby seek, a ruling that Respondent DWR has violated Article X, Section 2 of the California Constitution by failing to use water reasonably.

FOURTH CAUSE OF ACTION
Violation of the 1995 Water Quality Control Plan Narrative Standard for Fish and Wildlife

71. Petitioners restate and re-allege and incorporate herein the foregoing paragraphs of this Complaint.

72. In accordance with the SWRCB 1995 Water Quality Control Plan, the Board adopted a narrative standard for fish and wildlife to double the natural production of salmon from the average number of fish in the Bay-Delta between the years 1967-1991. Due to the dramatic decline in salmon populations, Respondent DWR has failed to comply with the narrative salmon doubling standard as required by law.

73. In light of Respondent DWR's violation of the standard, and considering the significant likelihood of repeated violations in the future, Respondent DWR must be enjoined from export pumping at the Banks pumping facility in the Delta until such a time as DWR can operate in compliance with the narrative standard for fish and wildlife. If Respondent DWR is not so enjoined, Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

74. An actual controversy exists between Petitioners on the one hand and Respondent DWR on the other. Specifically, Petitioners contend and Respondent DWR denies that it is violation of the 1995 Narrative standard. As an actual controversy exists, Petitioners are entitled to, and hereby seek, a ruling that Respondent DWR has violated the 1995 Water Quality Control Plan Narrative Standard for Fish and Wildlife.

FIFTH CAUSE OF ACTION
Violation of and Failure to Enforce State Board Decision 1641

75. Petitioners restate and re-allege and incorporate herein the foregoing paragraphs of this Complaint.

76. Board decision 1641 implemented flow objectives for the Bay-Delta Estuary that Respondent DWR was specifically charged with meeting. Respondent DWR has repeatedly failed to meet the flow objectives in the Bay-Delta.

77. Respondent Board has a statutory duty to comply with its own water quality control plan, and has failed to enforce the flow objectives against Respondent DWR as set out in D-1641.

78. DWR has an affirmative duty to meet the interior southern Delta salinity objectives established pursuant to D-1641, yet the Board's approval of WR Order 2010-0002 obviates DWR's mandatory compliance with those standards until an undisclosed, future date.

79. In light of the Respondents DWR's failure to comply with Decision 1641, Respondent Board's failure to enforce D-1641 as required by law, and the significant likelihood of repeated violations in the future, Respondent DWR must be permanently enjoined from continuing to export water from the Bay-Delta until such a time as they fully comply with the

requirements of D-1641. If Respondent is not so enjoined, Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

80. An actual controversy exists between Petitioners on the one hand and Respondent DWR on the other regarding the extent to which their export pumping violates the conditions of D-1641, and Respondent Board's duty to enforce D-1641 as against DWR. Specifically, Petitioners contend and Respondent DWR denies that they are in violation of D-1641 by their export pumping in the Bay-Delta. Petitioners further contend and Respondent Board denies that they decided WR Order 2010-0002 without substantial evidence on the record and that their decision was arbitrary and capricious. As an actual controversy exists, Petitioners are entitled to, and hereby seek, a ruling that Respondent DWR is in violation of D-1641 and that Respondent Board decided WR Order 2010-0002 without substantial evidence in the record thereby rendering their decision arbitrary and capricious.

SIXTH CAUSE OF ACTION

Failure to Enforce Requirements of the Porter-Cologne Act

81. Petitioners restate and re-allege and incorporate herein the foregoing paragraphs of this Complaint.

82. Respondent SWRCB's actions in WR Order 2010-0002 constituted a prejudicial abuse of discretion, in that Respondent SWRCB did not proceed in the manner required by the Porter-Cologne Act, and substantial evidence does not support their Findings, as set forth below.

83. WR Order 2010-0002 fails to adequately analyze the reasonably foreseeable adverse effects of continued exceedence of the interior southern Delta salinity standards would have on fish and wildlife, water quality, and Delta agriculture in the Bay-Delta.

84. Respondent DWR has violated, and continues to violate, the interior southern Delta salinity standards required by D-1641. The SWRCB refuses to hold DWR to the water quality standards required by D-1641 and the Porter-Cologne Act, and the significant likelihood that DWR will continue to violate these standards in the future, demands that Respondent SWRCB must be required to set aside WR Order 2010-0002 and hold DWR to the requirements of Order WR 2006-0006. If Respondent DWR is allowed to continue pumping at the Banks

pumping facility in violation of the water quality standards, Petitioners will suffer irreparable injury for which there is no adequate remedy at law.

85. An actual controversy exists between Petitioners and SWRCB. Specifically, SWRCB denies Petitioners' contention that the Board is in violation of the Porter-Cologne Act. Petitioners allege that the SWRCB's method of "enforcing" DWR's permit conditions is not enforcement at all, and the adoption WR Order 2010-0002 is not based on substantial evidence. As an actual controversy exists, Petitioners are entitled to seek, and hereby do seek, a declaratory ruling that Respondent DWR is pumping in violation of the water quality standards of D-1641 with the SWRCB's permission in violation of the Porter-Cologne Act. Petitioner's further request a writ of administrative mandate requiring Respondent SWRCB to enforce the Porter-Cologne Act as required by law.

PRAYER FOR RELIEF

WHEREFORE, Petitioners respectfully request that the Court enter judgment as follows:

1. For a declaration that Respondent DWR's operations have violated the California Public Trust in the Bay-Delta;

2. For a declaration that Respondent DWR's operations are an unreasonable method of diversion in violation of Article X, Section 2 of the California Constitution;

3. For a declaration that Respondent DWR's operations are an unreasonable method of use in violation of Article X, Section 2 of the California Constitution;

4. For a declaration that Respondent DWR's operations have violated the 1995 Water Quality Control Plan narrative standard for salmon in that Respondent DWR has failed to meet the required doubling of the salmon population under the 1995 Water Quality Control Plan;

5. For a declaration that Respondent SWRCB has failed to enforce, and Respondent DWR's operations have violated, Decision 1641 in that Respondent DWR has failed to meet flow objectives necessary to protect beneficial uses in the Bay-Delta;

6. For a declaration that Respondent SWRCB has failed to enforce DWR's permit and license conditions under the Bay-Delta Water Quality Control Plan in accordance with the Porter-Cologne Act;

7. That the Court enjoin Respondent DWR from diverting water from the Bay-Delta until such a time as Respondent DWR's operations conform with the law;

8. That the Court enjoin Respondent SWRCB from allowing operation of state water export projects until such a time that Respondent DWR come into compliance with the law;

9. That the Court direct Respondents to remedy their violations of the California Public Trust, Article X, Section 2 of the California Constitution, the Porter-Cologne Act, the 1995 Water Quality Control Plan, and Decision 1641 within a reasonable time;

10. That the Court issue a writ of administrative mandate vacating and setting aside WR Order 2010-0002;

11. That the Court retain jurisdiction over this matter until such time as Respondents have fully complied with the law;

12. That the Court award Petitioners their costs of litigation pursuant to California Code of Civil Procedure § 1021.5; and

13. That the Court grant Petitioners such other further relief, including injunctive relief, as the Court may deem just and proper.

Dated: April 21, 2011

____
Michael B. Jackson
Attorney for Petitioners
C-WIN, CSPA, and AquAlliance

VERIFICATION

I, Michael B. Jackson, am the attorney for Petitioners herein and am authorized to execute this on their behalf. I have read the foregoing Petition for Writ of Mandate and Complaint for Injunctive and Declaratory Relief and am informed and believe, and thereon allege, that the matters stated therein are true and correct. I sign this verification on behalf of Petitioners pursuant to Code of Civil Procedure § 446, as Petitioners are located outside the county in which my office is located.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct and that this verification was executed on April 21, 2011 in Quincy, California.

____

Michael B. Jackson

Critique of Long-Term Water Transfers Environmental Impact Statement/Environmental Impact Report Public Draft

Economic Issues

December 1, 2014

Prepared for:

AquAlliance

ECONorthwest
ECONOMICS • FINANCE • PLANNING

Contact Information

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ECONorthwest specializes in economics, planning, and finance. Established in 1974, ECONorthwest has over three decades of experience helping clients make sound decisions based on rigorous economic, planning and financial analysis.

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Executive Summary

The US Bureau of Reclamations and San Luis & Delta-Mendota Water Authority released the Public Draft of the *Long-Term Water Transfers Draft Environmental Impact Statement/Environmental Impact Report* (LTWT) in September 2014. The purpose of the LTWT, as we understand, is to evaluate the potential impacts of three proposed water-transfer alternatives, as well as a no action alternative. AquAlliance asked ECONorthwest to critique and provide written comments on the LTWT.

In general, the analysis described in the LTWT suffers from significant omissions and errors. These omissions and errors matter. As written the report provides stakeholders and decisions makers with a biased and incomplete description of the environmental and economic consequences of water transfers. In the following sections of this report we describe our critiques in detail. Our major critiques include the following.

The LTWT ignores relevant background information about the affected environment that would have helped inform the analysis. The LTWT provides a cursory description of the relevant affected environment that paints an incomplete picture of the context within which water transfers would happen. A more complete, accurate and up-to-date description would have included, for example: information from the many recent reports on California's climate and groundwater conditions; current data on water transfers; and, a market analysis of water prices, prices for agricultural commodities and how price changes influence the number and volumes of water transfers. As such, the deficient description is the shaky foundation upon which a lacking analysis rests. The resulting effort yields questionable results regarding the likely future frequency and amounts of water transfers and their environmental and economic consequences.

The LTWT relies on outdated and incomplete data. The analysis described in the LTWT relies on obsolete data for certain key variables and ignored other relevant data and information. For example, the analysis assumes a price for water that bears no resemblance to the current reality. It also ignored relevant research results on the impacts of groundwater pumping on stream flow depletion and the current status of groundwater levels as provided by monitoring wells. The water transfers at issue in the LTWT would not happen in an economic vacuum. Growers and water sellers and buyers react to changing prices and market conditions. The analysis described in the LTWT, however, is silent on these forces and how they would influence water transfers.

The LTWT underestimates negative impacts on the regional economy in the sellers area. The LTWT acknowledges that negative economic impacts would be worse if water transfers happen over consecutive years. The analysis, however, estimates impacts for single-year transfers, ignoring the data on the frequency of recent consecutive-year transfers. The analysis also fails to address the extent to which water transfers cause economic harm to water-based recreational activities.

The LTWT finds significant negative effects but the vague and incomplete proposed monitoring and mitigation plans would not address these effects. The LTWT proposed both a monitoring and mitigation program for significant negative impacts. Implementing these programs would take planning, effort and financial resources on the part of sellers, injured third parties, and regulatory agencies. The LTWT does not include these costs. The monitoring program is vague and depends on potential sellers implementing the program. This conflict of interest pits financial gain from water sales against complete and impartial monitoring efforts. This opens the door to lax, biased, or incomplete monitoring, which could lead to negative environmental and economic consequences for third parties. The monitoring program includes monitoring subsidence, however, the program is vague on requirements and what amount of subsidence would trigger a halt in water transfers. Injured third parties would bear the costs of bringing to the sellers' attention harm caused by groundwater pumping. The analysis described in the LTWT assumes that disagreements regarding third-party damages would be settled cooperatively between third parties and sellers, without presenting evidence substantiating such an optimistic assumption. The LTWT is silent on the economic consequences of sellers and injured third parties not cooperatively agreeing on harm and compensation.

The LTWT ignores the environmental externalities and economic subsidies that water transfers support. The LTWT lists Westlands Water District as one of the CVP contractors expressing interest in purchasing transfer water. The environmental externalities caused by agricultural production on Westlands are well documented, as are the economic subsidies that support this production. To the extent that the water transfers at issue in the LTWT facilitate agricultural production on Westlands, they also contribute to the environmental externalities and economic subsidies of that production. The LTWT is silent on these environmental and economic consequences of the water transfers.

The LTWT underestimates the cumulative effects of water transfers. Cumulative effects analyses under NEPA and CEQA are intended to identify impacts that materialize or are compounded when the proposed action is implemented at the same time as or in conjunction with other actions. The LTWT addresses cumulative effects for each resource area and provides a global description of the methods and actions considered for analysis in each resource area. The analysis, however, provides cursory discussion of potential cumulative effects for the regional economy, and ignores the full range of possible cumulative outcomes associated with the proposed transfer

1 Introduction and Context

The US Bureau of Reclamations (BOR) and San Luis & Delta-Mendota Water Authority (SLDMWA) released the public draft of the *Long-Term Water Transfers Draft Environmental Impact Statement/Environmental Impact Report* (LTWT) in September 2014. The LTWT covers water transfers that would happen between 2015 through 2024. Because the transfers would use federal and state infrastructure, the LTWT must comply with NEPA and CEQA guidelines. BOR is the lead agency regarding NEPA requirements, and SLDMWA is the lead agency for CEQA requirements.[1]

The premise underlying the proposed water transfers is that sellers, mostly in the Sacramento Valley, would idle cropland, switch to less water-intensive crops, and/or substitute groundwater for surface water, and send the surface water they would other wise have used through the Bay Delta to buyers in the south.

The proposed transfers would happen within a context of environmental conditions that both highlight the increasing demand for water throughout California and raise concerns regarding the environmental and economic effects of the water transfers at issue in the LTWT. These conditions include:

- Current drought conditions of historic proportion coming on the heals of consecutive dry years.
- Increasing concerns over the demands on groundwater and groundwater conditions throughout the state, including in the Sacramento Valley.
- Increasing competition for water from all user groups including agricultural, municipal and industrial users, and environmental requirements that help protect habitats and water quality.

Within this context, regulatory agencies face increasing demands from stakeholders for transparent decisions that rely on the best available science and information when balancing competing demands. For example, the relevant NEPA requirements for the LTWT analysis include:

> "Rigorous exploration and objective evaluation of all reasonable alternatives, …"[2]

AquAlliance asked ECONorthwest to review the LTWT and provide comments on the extent to which the analysis described in the report fulfills the NEPA requirement. We describe the results of our initial review and critique of the document in this report. The relatively short

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[1] LTWT, page 1-1, 2-1.

[2] LTWT page 2-1.

public comment period limited the extent of our review. Should the comment period be extended or reopened, we may expand and revise our comments.

The remainder of our report is as follows. In the next section, Section 2, we comment on the LTWT's incomplete description of the affected environment within which the water transfers would happen. We cite sources with relevant information that if included would yield a more complete and comprehensive description of the affected environment.

In Section 3 we highlight deficiencies in the data and analysis described in the LTWT. For example, we note that the model relies on outdated prices for water and agricultural commodities—two central components of the analysis. The analysis also estimates that water transfers would happen in a static environment where water prices and commodity prices remain fixed. These conditions do not reflect the dynamic reality of water demands and use.

In Section 4 we note instances in which the analysis described in the LTWT underestimates the impacts of water transfers on the regional economy in the source-water areas.

In Section 5 we draw attention to some of the deficiencies of the proposed monitoring and mitigation programs that the LTWT's authors claim will adequately address any negative effects of the transfers. These deficiencies include the inherent conflicts of interests in the programs, excluding the costs of the programs, and vague and ill-defined critical components of the programs.

In Section 6 we describe some of the environmental and economic externalities associated with the use of the transferred water.

In Section 7, we list some of the deficiencies in the analysis of cumulative effects. For example, the analysis ignores the impacts of transfers that would happen in addition to those at issue in the LTWT.

2 The LTWT ignores relevant background information about the affected environment that would have helped inform the analysis

The LTWT provides a cursory description of the relevant affected environment that paints an incomplete picture of the context within which water transfers would happen. A more complete, accurate and up-to-date description would have included, for example: information from the many recent reports on California's climate and groundwater conditions; current data on water transfers; and, a market analysis of water prices, prices for agricultural commodities and how price changes influence the number and volumes of water transfers. As such, the deficient description is the shaky foundation upon which a lacking analysis rests. The resulting effort yields questionable results regarding the likely future frequency and amounts of water transfers and their environmental and economic consequences.

Specific concerns regarding the LTWT's incomplete description of the affected environment in the Sacramento Valley include the following.

Incomplete description of current climate conditions

According to the California Department of Water Resources (DWR), 2013 was the driest year on record for many parts of the state.[3] Such drought conditions are one reason given for why growers and municipal and industrial (M&I) users in the south would purchase water from other parts of California. The analysis described in the LTWT fails to acknowledge, however, that other parts of the state, including the Sacramento Valley, also feel the effects of drought. How agricultural and M&I water users in the north respond to recent drought conditions would affect water transfers. The authors of the LTWT exclude these factors from their analysis.

For example, in a recent letter to the BOR, the Glenn-Colusa Irrigation District (GCID) indicated they were developing a groundwater supplemental supply program and that developing this program takes priority over participating in water transfers as described in the LTWT.

> "GCID's position is that it will pursue, as a priority, the proposed Groundwater Supplemental Supply Program over any proposed transfer program within the region, including Reclamation's Long-Term Water Transfer Program (LTWTP)."

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[3] California Department of Water Resources (DWR). 2014a. *Public Update for Drought Response Groundwater Basins with Potential Water Shortages and Gaps in Groundwater Monitoring*. April 30. Page ii.

> "… It is important to underscore that GCID would prioritize pumping during dry and critically dry water years for use in the Groundwater Supplemental Supply Program, and thus wells used under that program would not otherwise be available for USBR's LTWTP."[4]

GCID's focus on its own groundwater program over BOR water transfers is notable because the LTWT lists GCID as a potential seller with the largest volume of water for sale, 91,000 af.[5] GCID's reasons for pursuing its groundwater supply program include concerns over water availability during dry years.

> "The primary objective is to develop a reliable supplemental water source for GCID during dry and critically dry years. The proposed goals are as follows:
>
> - Increase system reliability and flexibility
> - Offset reductions in Sacramento River diversions by GCIS during drought years to replace supplies for crops and habitat
> - Periodically reduce Sacramento River diversions to accommodate fishery and restoration flows
> - Protect agricultural production"[6]

A related point is that the LTWT fails to discuss the possibility that current climate and water conditions may represent a new benchmark rather than a deviation from past trends. The increasing number of years with water transfers (described below), and reports on climate change and its impacts on water conditions, are two arguments in support of exploring this point. For example, according to a report commissioned by the Northern California Water Association (NCWA),

> "This year [2014] we face unprecedented drought conditions, following a decade of relatively dry years and increased demands on our groundwater resources. These increased demands have two principal causes. The reduced availability of surface water during dry years brings a predictable shift towards greater use of groundwater. The second is expanding and intensifying agricultural land use within the Sacramento Valley, together with increasing urban water demands, leading to increased reliance on groundwater even in 'normal' years."[7]

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[4] Bettner, T. 2014. *Letter to Brad Hubbard, Bureau of Reclamation* re Draft EIS/EIR on Proposed Long-Term Water Transfer Program. Glenn-Colusa Irrigation District. October 14. Pages 1 and 3.

[5] LTWT, Table 2-4, page 2-14.

[6] Bettner, 2014, page 2.

[7] Davids Engineering, Macaulay Water Resources, and West Yost Associates (DMW). 2014. *Sacramento Valley Groundwater Assessment Active Management – Call to Action.* Prepared for Northern California Water Association. June. Page 2.

Fails to consider concerns regarding the oversubscription of water resources

The analysis described in the LTWT fails to acknowledge the problem of supporting water transfers using "paper water," or oversubscribed water in the Sacramento Valley. A report on water transfer issues in California describes one aspect of this problem.

> "The inability of interested parties to agree on the volume of transferable water associated with the short-term fallowing of agricultural lands has caused substantial controversy and delays in approving certain water transfer proposals. The primary issue for interested parties is whether a fallowing-based transfer proposal would actually increase the burden on the CVP and SWP to maintain water quality and flow conditions in downstream portions of the Sacramento River and Delta because upstream transfer proponents were allowed to transfer what might prove to be 'paper' water."[8]

Stakeholders in the Sacramento Valley concerned about this problem researched the extent of paper water and found that rights to water significantly exceed available supply. Testimony by the California Water Impact Network submitted to the State Water Resources Control Board concluded that, "The ratio of total consumptive use claims to average unimpaired flow in the Sacramento River Basin is about 5.6 acre-feet of claims per acre-foot of unimpaired flow."[9] Thus, claims on water in the Sacramento Valley significantly exceed the available supply.

Incomplete description of current groundwater conditions

The LTWT excluded current information on groundwater conditions in the Sacramento Valley. This information includes concerns regarding historically low groundwater levels in certain areas of the Sacramento Valley, related concerns over subsidence caused by depleted groundwater, and a lack of groundwater monitoring information.

According to the DWR, groundwater levels are decreasing through out California, including in the Sacramento Valley. Groundwater levels decreased since the spring of 2013, and "notably" since the spring of 2010.[10] A related point, according to the DWR, is that there are "significant" gaps in groundwater monitoring data for areas throughout the state, including the Sacramento Valley.[11] There's also a lack of understanding

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[8] The Water Transfer Workgroup. 2002. Water transfer issues in California. Final Report to the California State Water Resources Control Board. June, page 20.

[9] Stroshane, T. 2012. *Testimony on water availability analysis for Trinity, Sacramento, and San Joaquin River basins tributary to the Bay-Delta Estuary*. October 26. California Water Impact Network. For Workshop #3 Analytical Tools for Evaluating the water Supply, Hydrodynamic, and Hydropower Effects of the Bay-Delta Plan November 13 and 14, 2012. Page 11.

[10] DWR, 2014a, page ii.

[11] DWR, 2014a, page ii.

regarding groundwater recharge and interactions between surface and groundwater in the Sacramento Valley. According to the NCWA report,

> "[G]roundwater changes can take many years to become apparent, and we have not yet been able to measure with certainty the long-term impacts of the current level of groundwater use as it affects our measures of sustainability."
>
> "Persistently declining groundwater levels in many areas of the Sacramento Valley over the past decade reveal that groundwater discharge exceeds recharge. Simply put: if the objective is to stem or reverse the trend, the groundwater balance must be adjusted either by putting more water into the ground or taking less out."[12]

According to the DWR, the Sacramento River hydrologic region has 23 groundwater basins ranked "high" or "medium" as described by the CASGEM groundwater basin prioritization study. These rankings describe a groundwater basin's importance in meeting demands for urban and agricultural water use. The San Joaquin River hydrologic region has nine "high," or "medium" ranked basins.[13]

A recent report from Glenn County indicates that current groundwater levels in the county are at the lowest levels recorded going back to the start of record keeping in the 1920s.

> "Data in reference to groundwater levels has been collected from both private and dedicated monitoring wells located within Glenn County, in some cases dating as far back as the 1920's. The lowest levels in these wells were most frequently associated with measurements from the 1976-77 monitoring period, which coincided with one of the more severe droughts in California's history. In the years following the 76-77 drought, groundwater levels often approached these historic lows but rarely fell below them. However, recent (2012-13) data indicate levels in many wells have declined below those historic thresholds and are now at the lowest levels observed since monitoring began."[14]
>
> "Readily available monitoring data obtained through DWR's California Statewide Groundwater Elevation Monitoring (CASGEM) is available for 100 wells, and of those 100, 21 still show their lowest levels as occurring in 1977, while 21 had an all-time low water surface elevation level in 2013, and an

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[12] DMW, 2014, page 10.

[13] DWR, 2014b. *California Groundwater Elevation Monitoring Basin Prioritization Process*. June. Page 5.

[14] Glenn County Water Advisory Committee, Ad-hoc Committee. 2014. *Report on Groundwater Level Declines in Western Glenn County*. May 6. Page 5.

> additional 15 wells reached their lowest point in 2009-2012. Therefore, one out of every five monitored wells in the area was at its lowest-ever recorded level in 2013, and one out of every three wells monitored in the area was at its lowest-ever recorded level between 2009 and 2013."[15]

Regarding the limited groundwater modeling described in the LTWT, consulting hydrologist Kit Custis comments,

> "Because the groundwater modeling effort [described in the LTWT] didn't include the most recent 11 years record, it appears to have missed simulating the most recent periods of groundwater substitution transfer pumping and other groundwater impacting events, such as recent changes in groundwater elevations and groundwater storage [citation omitted], and the reduced recharge due to the recent periods of drought. Without taking the hydrologic conditions during the recent 11 years into account, the results of the SACFEM2013 model simulation may not accurately depict current conditions or predict the effects from the proposed groundwater substitution transfer pumping during the next 10 years."[16]

The DWR reports that areas of the Sacramento Valley are at risk for subsidence from depleted groundwater. Most of the groundwater basins susceptible to future subsidence are also ranked "high" and "medium" priority by the CASGEM groundwater basin prioritization analysis. According to the DWR and based on data from 2008 through 2014, approximately 36 percent of long-term wells surveyed in the Sacramento Valley are at or below the historical spring low levels. Another measure indicates that 50 percent of groundwater levels in 18 groundwater basins in the Sacramento Valley are at or below historical spring low levels.[17] A white paper by a consulting engineer on groundwater use and subsidence in the Sacramento Valley noted that subsidence may happen years after groundwater pumping and that real-time monitoring of groundwater pumping "will generally tend to underestimate the long-term settlement of the ground surface."[18]

Subsidence can cause substantial economic harm. According to a report by consulting engineers studying subsidence in California,

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[15] Glenn County Water Advisory Committee, Ad-hoc Committee. 2014. *Report on Groundwater Level Declines in Western Glenn County*. May 6. Page 6.

[16] Custis, K. 2014. *Letter to Barbara Vlamis*, November 10. RE: Comments and recommendations on U.S. Bureau of Reclamation and San Luis & Delta-Mendota Water Authority Draft Long-Term Water Transfer DRAFT EIS/EIR, dated September 2014. Page 5.

[17] DWR, 2014c. *Summary of Recent, Historical, and Estimated Potential for Future Land Subsidence in California*. Pages 9, 11.

[18] Mish, D. 2008. *Commentary on Ken Loy GCID Memorandum*. Page 4.

> "Land subsidence has been discovered in many areas of the state, causing billions of dollars of damage. Impacts from subsidence fall into the following categories:
>
> - Loss of conveyance capacity in canals, streams and rivers, and flood bypass channels;
> - Diminished effectiveness of levees;
> - Damage to roads, bridges, building foundations, pipelines, and other surface and subsurface infrastructure; and
> - Development of earth fissures, which can damage surface and subsurface structures and allow for contamination at the land surface to enter shallow aquifers."[19]

Subsidence in Colusa, Yolo and Solano counties in the Sacramento Valley during the 1976-77 drought caused widespread well casing damages, which made some wells unusable.[20] A recent series of reports by the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West at the Water in the West center at Stanford University describe the subsidence concerns regarding groundwater pumping in California, including the Sacramento Valley.[21] Custis notes the types of infrastructure in the Sacramento Valley susceptible to damage from subsidence,

> "There are a number of critical structures in the Sacramento Valley that may be susceptible to settlement and lateral movement. These include natural gas pipelines, gas transfer and storage facilities, gas wells, railroads bridges, water and sewer pipelines, water wells, canals, levees, other industrial facilities."[22]

In response to concerns over groundwater use and related issues, the California legislature recently passed, and Governor Brown signed into law, the Sustainable Groundwater Management Act (Act).[23] The Act will affect groundwater users including those supplying water transfers. The LTWT makes no mention of how the Act could affect the context within which water transfers would happen, or the transfers themselves. This is a significant omission.

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[19] Borchers, J. and M. Carpenter. 2014. *Land Subsidence from Groundwater Use in California*. Luhdorff & Scalmanini Consulting Engineers. Support provided by the California Water Foundation. April. Page ES-2.

[20] Borchers, J. and M. Carpenter. 2014. *Land Subsidence from Groundwater Use in California*. Luhdorff & Scalmanini Consulting Engineers. Support provided by the California Water Foundation. April. Page ES-3.

[21] Water in the West. 2014. *Understanding California's Groundwater*. waterinthewest.stanford.edu.

[22] Custis 2014, page 28.

[23] opr.ca.gov/s_groundwater.php.

Carriage Water Costs

The LTWT assumes that required carriage water component of water transfers from the Sacramento River will account for 20 percent of transferred water.

> "Transfers from the Sacramento Rive assume a 20 percent carriage water adjustment to maintain Delta salinity."[24]

Recent data on the percentage of required carriage water are higher than the 20-percent assumption in the LTWT. For example, the DWR describes a recent carriage water percentage of 30.

> "Another cost related to transferring water is carriage water. … For the Sacramento River, this has generally been about 20 percent of the transfer water … It is worth noting, however, that in 2012 and 2013 carriage water losses for the Sacramento River were as high as 30 percent of transfer water."[25]

To the extent that carriage water requirements exceed 20 percent, the LTWT overestimates the amount of water delivered south through the Bay Delta to water purchasers, and thus the economic benefits of these transfers.

Data and modeling ignore recent trends in water transfers

Using water data from 1970 through 2003, the LTWT estimates that future water transfers will happen on average 12 out of 33 years.[26] Twelve of 33 years is a transfer probability of approximately 36 percent. By ignoring water data for years after 2003, the analysis excludes relevant information on the more recent dry trend and current historical drought. For example, Table 1-3 on page 1-17 of the LTWT lists years and amounts of water transfers from 2000 through 2014. This data shows that water transfers happened in 9 of the previous 15 years, or a transfer probability of 60 percent, almost double that used in the LTWT. For years after 2003, transfers happened in eight out of 11 years, for a transfer percent of approximately 73.

Other sources of data on the frequency of water transfers do not support the LTWT's water-transfer results. For example, a report by the Western Canal Water District (WCWD) includes a table showing water transfers from the Sacramento Valley through the Bay Delta from 2001 through projected 2010. The information in this table shows transfers happening in eight out of ten years.[27] A similar report by WCWD in 2014

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[24] LTWT page B-18.

[25] California Department of Water Resources. 2013. California Water Plan 2013 Update. Bulletin 160-13. Volume 3 Resource Management Strategies. Pages 8-9.

[26] LTWT, page 3.3-60 and -61.

[27] Western Canal Water District (WCWD). 2009. *Initial Study and Proposed Negative Declaration for Western Canal Water District 2010 Water Transfer Program*. Western Canal Water District, Richvale, California. January. Page 25.

included a table of water transfers for years 2006 through projected 2014. The data in that table shows transfers happening during seven of nine years.[28] Taken together, these two reports show water transfers from the Sacramento Valley south through the Bay Delta in 11 out of 14 years between 2001 through 2014. This works out to a transfer probability of approximately 79 percent.

These results demonstrate two important points. First, using a transfer probability of 36 percent greatly underestimates the actual years that transfers happened post-2003, the last year of data in the LTWT analysis. Underestimating transfers leads to underestimating the environmental and economic effects of the transfers.

Second, the data upon which conclusions in the LTWT rest do not depict actual conditions post-2003. That is, by relying on flawed or incomplete data, models that use this data produce flawed or biased results. The estimated transfer frequency (36 percent of years), does not match the recent actual transfer frequency (60, 73, or 79 percent, depending on the source and years included).

At an October 21st, 2014 public hearing in Chico, California on the LTWT, a consultant working with BOR on the LTWT commented on the water model and the 1970 through 2003 data upon which the model relies. In response to questions about why the model did not include data from the previous ten years, or why the period of analysis was not extended out to the current drought situation, the consultant replied that the modeling tools "are not up-to-date."[29]

According to resource agencies in California, variable, even extreme climate and rainfall conditions are the norm. Climate change is projected to make these trends worse and increase prediction uncertainties. The recent Bay Delta Conservation Plan describes this uncertainty,

> "Variability and uncertainty are the dominant characteristics of California's water resources."[30]
>
> "Precipitation is the source of 97% of California's water supply. It varies greatly from year to year, by season, and by where it falls geographically in the state.

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[28] WCWD. 2014. *Initial Study and Proposed Negative Declaration for Western Canal Water District 2014 Water Transfer Program*. Western Canal Water District, Richvale, California. February. Page 25.

[29] Transcript of October 21, 2014 public hearing in Chico, California on the LTWT EIS/EIR; Hacking, H. 2014. "Sacramento Valley water transfer idea leaves locals fuming. ChicoER News, October 22, 2014, http://www.chicoer.com.

[30] California Department of Water Resources (DWR). 2013. Bay Delta Conservation Plan. Public Draft. November Sacramento, CA. Prepared by ICF International (ICF 00343.12). Sacramento, CA. Page 5-1.

> With climate change, the state’s precipitation is expected to become even more unpredictable.”[31]
>
> “However, the total volume of water the state receives can vary dramatically between dry and wet years. California may receive less than 100 MAF of water during a dry year and more than 300 MAF in a wet year (Western Regional Climate Center 2011).”[32]
>
> “The geographic variation and the unpredictability in precipitation that California receives make it challenging to manage the available runoff that can be diverted or captured in storage to meet urban and agricultural water needs.”[33]
>
> “Historically, precipitation in most of California has been dominated by extreme variability seasonally, annually, and over decade time scales; in the context of climate change, projections of future precipitation are even more uncertain than projections for temperature. Uncertainty regarding precipitation projections is greatest in the northern part of the state, and a stronger tendency toward drying is indicated in the southern part of the state.”[34]

Consultants working for the BOR admit that the water model and data upon which the LTWT analysis and conclusions rest are not up to date. We note above the model’s unreliability and poor projection capabilities regarding water transfers post-2003. The DWR concludes that variability and extremes characterize the state’s weather and rainfall conditions, and that climate change is increasing this variability and uncertainty. Taken together, these facts raise questions regarding the veracity of the projected water transfers described in the LTWT, and the estimated environmental and economic consequences of those transfers.

The analysis does not adequately take into account recent trends in agricultural production

Not included in the LTWT’s description of current conditions are recent trends in agricultural production that affect groundwater use and conditions in the Sacramento Valley. For example, according to a recent report, approximately half the increase in irrigated acres in the Sacramento Valley since 2008 (approximately 200,000 acres), happened on lands not served by surface water suppliers. Irrigating these lands takes approximately 300,000 acre-feet (af) of groundwater per year. [35]

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[31] DWR, 2013. Page 5-2.

[32] DWR, 2013, page 5-2.

[33] DWR, 2013, page 5-2.

[34] DWR, 2013, page 5-2.

[35] DMW, 2014, page 7.

A related point is the lack of discussion or analysis in the LTWT of trends in prices for agricultural goods produced with surface and groundwater, trends in prices for water, and how these factors affect grower decisions. For example, the analysis fails to address the extent to which historically high prices for water (discussed below) increase groundwater mining and sale in the Sacramento Valley, and how this affects water transfers and their environmental and economic consequences.

Another agricultural trend not discussed in the LTWT, but which has implications for water transfers and their consequences, is the increasing use of pressurized irrigation methods in the Sacramento Valley. Pressurized irrigation reduces groundwater recharge by limiting water percolation. Some growers supply their pressurized irrigation systems using groundwater, even when they have access to surface water. According to the report commissioned by the NCWA,

> "The increasing use of pressurized irrigation systems using groundwater is likely to be an increasingly important factor in the overall management of groundwater and surface water in the Sacramento Valley as a whole, particularly as such system displace the use of available surface water."[36]

In response to the recent trend in high prices for almonds, olives, walnuts and other tree crops, growers in the San Joaquin *and* Sacramento Valleys planted more acres of these tress and other permanent-type crops, and less acres of lower valued annual crops. Such a change increases and "hardens" demand for water in both valleys because growers no longer have the flexibility of idling these acres in response to drought.[37] Thus, one of the arguments in support of water transfers—that growers south of the Bay Delta planted increased acres of tree crops that have higher water demands—also affects growers and water use and demands north of the Bay Delta.

The LTWT is silent on these trends or how they would influence future water transfers from the Sacramento Valley.

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[36] DMW, 2014, page 8.

[37] DMW, 2014, page 7.

3 The LTWT relies on outdated and incomplete data

In addition to the deficiencies described in previous sections, the analysis described in the LTWT relies on obsolete data for certain key variables. The analysis also ignored other relevant data and information. These shortcomings include the following.

The LTWT assumes a price for water that bears no resemblance to the current reality

The analysis described in the LTWT assumes a price of water of $225 per af of water.[38] This amount drastically underestimates the current price for water. Dollar amounts for water trades are not readily available to the public. However, information on the current price of water from news articles and other sources reveals a range of current prices that exceed $225 by a significant amount.

A report by Bloomberg News on the impacts of drought on water prices reports water prices of $1,000 to $2,000 per af. The article also quotes a spokesman for the BOR,

> "The rising prices are 'a function of supply and demand in a very dry year and the fact that there are a lot of competing uses for water in California,' said Mat Maucieri, a spokesman for the Bureau of Reclamation."[39]

An article in the Sacramento Bee on water transfers noted that one buyer was paying "in the neighborhood of $500 to $600 an acre-foot."[40] The Glenn-Colusa Irrigation District commenting on the LTWT noted that the $225 per af price used in the analysis was the price paid for water over eight years ago.[41]

Water users, sellers and buyers would surely respond differently to a market price of water of $1,000 to $2,000 per af, than they would to a price of $225. As such, the extent to which growers idle cropland, switch to less water intensive crops, and substitute groundwater for surface water in the LTWT likely does not reflect this difference. As we note below, missing from the LTWT analysis is an assessment of the economics of water markets, how sellers and buyers respond to changing water prices, and how this affects the type and amount of water transfers.

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[38] LTWT, page 3.10-27.

[39] Vekshin, A. 2014. "California Water Prices Soar for Farmers as Drought Grows," Bloomberg. July 24. http://www.bloomberg.com.

[40] Garza, M. 2014. "The Conversation: A controversial water transfer worth millions." The Sacramento Bee. May 25. http://www.sacbee.com/opinion/the-conversation/article99570.html.

[41] Glenn-Colusa Irrigation District. 2014. *Board of Directors Meeting of November 6, 2014, Item 6*.

Ignored impacts on tax revenues to local governments from IMPLAN results

The LTWT describes estimating impacts of water transfers on employment, labor income and total value of output using IMPLAN.[42] IMPLAN is a commonly used software and data package that helps analysts estimate economic impacts of policy changes or compare economic impacts of allocation alternatives, e.g., alternative logging proposals or alternative water-transfer amounts. According to the IMPLAN website, IMPLAN "… allows an analyst to trace spending through an economy and measure the cumulative effects of that spending."[43] IMPLAN traces the economic benefits of increased spending as it works its way through an economy, or, when spending decreases, the negative economic impacts of decreased spending. From our own experience using IMPLAN, and from information on the IMPLAN website, in addition to the employment, labor income and total value of output reported in the LTWT, IMPLAN also quantifies the impacts of alternatives on *government finances and tax revenues*.[44] For example, the IMPLAN website describes how the software can estimate state, local, and federal tax amounts collected (or lost) as a result of a change in an economy, such as reduced agricultural activity.[45]

Even though IMPLAN calculates impacts of alternatives on local government finances and tax revenues, the analysis described in the LTWT does not report these results. That is, the authors apparently choose not to report the output from IMPLAN on how the transfer alternatives would affect the dollar amounts of tax revenues to local governments as a result of the reduced agricultural activity and spending. Instead, the report notes that impacts "to local government finances, including tax revenues and costs, are described *qualitatively*." [emphasis added][46] The report does not explain why the analysts chose to address impacts on local tax revenues of the water-transfer alternatives qualitatively, rather than rely on the estimates of tax impacts produced by IMPLAN.

Ignored own research results on stream flow depletion factors

The LTWT makes no mention of the results from studies of the impacts of groundwater pumping in support of water transfers on stream flow depletion. A technical memo on the impacts of groundwater pumping on stream flow depletion describes the analysis and concludes that,

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[42] LTWT, page 3.10-21.

[43] IMPLAN web site, implan.com/index.php?option=com_glossary&id=236&letter=E.

[44] IMPLAN. https://implan.com/index.php?option=com_content&view=article&id=532:532&catid=233:KB16.

[45] IMPLAN. https://implan.com/index.php?option=com_content&view=article&id=532:532&catid=233:KB16.

[46] LTWT, page 3.10-24.

> "The effect of groundwater substitution transfer pumping on stream flow, when considered as a percent of the groundwater pumped for the program, is significant."[47]

> "The three scenarios presented here estimated effects of transfer pumping on stream flow when dry, normal, and wet conditions followed transfer pumping. Estimated stream flow losses in the five-year period following each scenario were 44, 39, and 19 percent of the amount of groundwater pumped during the four-month transfer period."[48]

In spite of these results, information distributed by the DWR and BOR to those interested in making water transfers in 2014, cites a stream flow depletion factor of 12 percent.[49] It's not clear how BOR justifies using a 12-percent depletion factor when analyses conducted by their contractors found depletion factors of 44, 39 and 19 percent.

We understand that the same SACFEM model that produced other results in the LTWT also produced the stream flow depletion factors.[50] Yet, while the LTWT reports other results from SACFEM, it makes no mention of these results. It also ignores the assumed 12-percent depletion factor cited by DWR and BOR. Instead, it states that stream flow depletion will be studied at a later date.[51] This approach ignores their own modeling results on stream flow depletion.

Incomplete and selective use of information from groundwater monitoring wells

The LTWT omits a significant concluding passage when describing results from a groundwater monitoring well in the Sacramento Valley.

For well 21N03W33A004M, the LTWT states,

> "Water levels at well 21N03W33A004M generally declined during the 1970s and prior to import of surface water conveyed by the Tehama-Colusa Canal. During the 1980s, groundwater levels recovered due to import and use of surface water supply and because of the 1982 to 1984 wet water years [citation omitted]."[52]

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[47] Lawson, P. 2010. Technical Memorandum. Groundwater Substitution Transfer Impact Analysis, Sacramento Valley. CH2MHill. March 29. Page 8.

[48] Lawson, 2010, Page 8.

[49] DWR and BOR, 2014. Addendum to DRAFT Technical Information for Preparing Water Transfer Proposals. Information to Parties Interested in making Water Available for water Transfers in 2014. January. Page 33.

[50] LTWT, page 3.3-60.

[51] LTWT, page 3.1-21.

[52] LTWT, page 3.3-22.

The document cites a DWR report from 2014 on drought response and gaps in groundwater monitoring.[53] The description in the DWR report, however, includes this additional concluding passage that the LTWT authors excluded,

> "Water levels declined again in the 2008 drought period, followed by a brief recovery during 2010 to 2011, and *then returning to 2008 levels (which are notably lower than the 1977-79 drought levels)."*[54] [emphasis added]

The omission matters as it completely changes the conclusion regarding current groundwater conditions as reported by the well.

The description in the LTWT of results from well 15N03W01N001M match those from the DWR source document. That description concludes,

> "… After the 2008-2009 drought, water levels declined to historical lows. Water levels recovered quickly during 2010 and 2011, *then after returned to the trend of long-term decline*."[55] [emphasis added]

Taken together these results indicate a long-term trend in declining groundwater levels in areas around the wells. The LTWT discounts or ignores these results instead favoring results from other wells. On this point, consulting hydrologist Custis describes other relevant data on groundwater monitoring,

> "The Draft EIS/EIR doesn't provide maps showing groundwater elevations, or depth to groundwater, for groundwater substitution transfer seller areas in Sutter, Yolo, Yuba, and Sacramento counties.
>
> The DWR provides on a web site a number of additional groundwater level and depth to groundwater maps at: [website omitted]."[56]

Custis notes other deficiencies of the groundwater monitoring as described in the LTWT.

> "…[T]he Draft EIS/EIR provides only limited information on the wells to be used in the groundwater substitution transfers [citation omitted], and no information on the non-participating wells that may be impacted."[57]

Custis goes on to list other recommended groundwater monitoring information that the LTWT does not include.[58]

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[53] LTWT, page 3.3-22.

[54] DWR, 2014a, page 24.

[55] LTWT, page 3.3-22.

[56] Custis 2014, pages 9-10.

[57] Custis 2014, page 2.

A related point is the available monitoring data from past water transfers. DWR and BOR apparently already collect information on the impacts of groundwater pumping in support of water transfers on groundwater levels.[59] The LTWT makes no mention of this data or how it could help inform the analysis of impacts of water transfers at issue in the LTWT on groundwater levels and related concerns. It would seem that BOR has available data relevant to its analysis described in the LTWT but makes no use of this data. On this point Custis notes,

> "The BoR should already have monitoring and mitigation plans and evaluation reports based on the requirements of the DTIPWTP for past groundwater substitution transfers, which likely were undertaken by some of the same sellers as the proposed 10-year transfer project."[60]

The analysis relies on outdated prices for agricultural commodities

The analysis described in the LTWT uses outdated prices for agricultural commodities to estimate the volume and value of water transfers. The analysis relies on prices for rice, processing tomatoes, corn and alfalfa from 2006 through 2010.[61] The analysis compares the price of water, which as we note above bears no resemblance to current prices, with prices for agricultural commodities to estimate cases in which selling water is more profitable than producing crops. Using outdated commodity prices compounds the error of using water prices that greatly underestimate actual prices. The combined effect is misleading results and conclusions regarding the degree of participation by growers in the water transfer program.

No mention of how prices for water and agricultural commodities could impact the affected environment, water transfers and their environmental and economic consequences

The water transfers at issue in the LTWT would not happen in an economic vacuum. Growers and water sellers and buyers react to changing price and market conditions. The LTWT, however, is silent on these forces and how they would influence water transfers.

The analysis depicted in the LTWT assumes a static water price of $225 per af and prices for agricultural commodities as they existed in 2006 through 2010.[62] Such a static analysis

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[58] Custis 2014, page 2.

[59] See for example, DWR and BOR, 2014. *DRAFT Technical Information for Preparing Water Transfer Proposals. Information to Parties Interested in making Water Available for water Transfers in 2014*. January; DWR and BOR. 2013. *DRAFT Technical Information for Preparing Water Transfer Proposals. Information to Parties Interested in Making Water Available for Water Transfers in 2014*. October.

[60] Custis 2014, page 24.

[61] LTWT, page 3.10-27, -28.

[62] LTWT, page 3.10-27.

provides a single estimate, or a snapshot view, of estimated water transfers. A more informative and useful analysis would have described how changing water and commodity prices influence the conclusions re the number and volumes of water transfers. Such a sensitivity analysis would allow readers to better compare current or expected future prices with prices in the analysis to see how these conditions affect results.

The LTWT is also silent on likely transaction costs and how they influence water transfers. Water transactions, particularly out-of-basin and cross-Delta, would require a diverse and substantial set of transaction costs that are not quantitatively included in the analysis. Omitting these transaction costs either overestimates the benefit potential to buyers and sellers of these transactions, or implies that these transaction costs will be borne by the public. Communication, information, and contracting costs have long inhibited water markets in California, and while mechanisms for overcoming these challenges have improved, they do have real costs, particularly across diverse regions and incorporating farmers using differing operations.[63] Transaction costs are hurdles to transactions, functionally a third party that must be satisfied before the buyer and seller can find opportunities to both be made better off by the transaction. For example, if a seller is willing to sell water at $250 per af, and a buyer is willing to pay $300 per af, if there are $60 per af in transaction costs, the transaction cannot efficiently take place.

Cross-Delta transaction would also impose a number of costs on the Delta conveyance system. Pumping costs at Banks and Jones Pumping Plants should be incorporated into transaction costs. Transactions could also affect congestion and overall capacity for these plants and the SWP and CVP systems overall. Energy, management, staffing, delays, and other costs and impositions could arise that would either require compensation by the buyers and sellers, or externalities on other parties.

Permitting, liability, and long-term protection of water rights all contribute to additional concerns for buyers and sellers that functionally generate additional forms of transaction costs. If these are incorporated into willingness-to-pay for buyers and willingness-to-accept for sellers, the transactions become less desirable. Alternatively, if these costs are borne by public agencies, as with the variety of other transaction costs mentioned above and referenced qualitatively throughout the LTWT, the burden for taxpayers could be substantial. These public contributions require demonstration of benefits to the public as a whole. The LTWT does not demonstrate benefits to portions of the public that are not party to transactions. On this point Custis notes,

> "Because the spatial limits of groundwater substitution pumping impacts are controlled by hydrogeology, hydrology, and rates, durations and seasons of pumping, the impacts may not be limited to the boundaries of each seller's service area, GMPs [groundwater

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[63] Haddad, B. M. 2000. *Rivers of Gold: Designing Markets to Allocate Water in California*. Island Press.

> management plan], or County. There is a possibility that a seller's groundwater substitution area of impact will occur in multiple local jurisdictions, which should results [sic] in project requirements coming from multiple local as well as state and federal agencies. The Draft EIS/EIR doesn't discuss which of the multiple local agencies would be the lead agency, how an agreement between agencies would be reached, or how the requirements of the other agencies will be enforced."[64]

Overall, the estimates of benefits and costs of transactions, as well as identification of efficient transactions, do not include the diverse and substantial set of transaction costs that cross-Delta transfers would require. Therefore the analysis either overestimates the benefits of the LTWT, or hides public costs to manage and overcome these transaction costs.

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[64] Custis 2014, page 9.

4 The LTWT underestimates negative impacts on the regional economy in the sellers area

In this section we describe our comments on the analysis of regional economic effects in the LTWT.

Underestimates economic effects on regional economy in sellers area

In the sections above, we describe omissions and errors regarding the estimated number and volumes of water transfers. Some of these errors could lead to underestimating the number and volume of water transfers, some could have the opposite effect. In this subsection we focus on additional examples of how the LTWT likely underestimates the number and volume of water transfers that will happen in the future. By underestimating the water transfers the LTWT also underestimates the negative impacts of the transfers on the regional economy in the sellers area.

The negative economic effects listed in the LTWT include:

- Approximately 500 lost jobs in Glenn, Colusa, Yolo, Sutter, Butte and Solano counties.
- Over $20 million in lost labor income and over $61 million in lost economic output in these same counties.
- Unquantified but increased pumping costs for water users in areas where groundwater levels decline.
- Unquantified but negative affects on other local economic effects.
- Unquantified but negative affects on tenant farmers.[65]

The LTWT analysis of some regional economic effects assumes non-consecutive years of water transfers. If water transfers happen in consecutive years, impacts would be greater than reported in the LTWT.

> "Local effects would be more adverse if cropland idling transfers occurred in consecutive years. Business owners would likely be able to recover from reduced sales in a single year, but it would be more difficult if sales remained low for multiple years."[66]

As shown in LTWT Table 1-3 on page 1-17, from 2004 through 2014, there have been eight water-transfer years out of 11, and 5 cases of consecutive transfer years. Given these recent

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[65] LTWT, page 3.10-45 and -46.

[66] LTWT, page 3.10-33.

conditions, it is likely that consecutive years of water transfers will happen more frequently than assumed in the LTWT.

Incomplete description of impacts on pumping costs

The LTWT reports that farmers in the Sacramento and San Joaquin Valleys pay water-pumping costs of approximately $0.32 per af.[67] The LTWT analysis estimates that as a result of groundwater-substitution transfers, pumping costs for "many growers" would increase by $0.32 to $1.60 per af.[68] This represents a non-trivial increase of 100 to 500 percent. In some cases, cost increases could be $6.40 to $8.00 per af.[69] Expressed on a percentage basis these amounts are increases of 2,000 to 2,500 percent. The LTWT describes these increases in pumping costs as "adverse." The analysis, however, does not report a total estimated increase in pumping costs or describe the increase as a percentage of current costs, either of which would have helped the reader better understand the significance of the increase.[70] A related point is that the analysis of pumping costs in the LTWT relies on results from the water modeling, the deficiencies of which we describe above and elsewhere in this report.

It's also not clear from the description of the analysis if the "adverse" effects on pumping costs apply only to those participating in water transfers, or also affect third parties that will not benefit from the transfers.

No mention of costs of deepening or installing new wells

The LTWT makes no mention of increased costs of deepening or installing new wells as a result of the impacts of groundwater pumping on groundwater levels. As we note above in section 2 under the description of current groundwater conditions, the CASGEM groundwater basin prioritization study lists 23 basins in the Sacramento Valley ranked "high" or "medium" dependent on groundwater. These basins support private residential wells, public water supply wells, and irrigation wells.[71] Recent news reports describe the intensity of well drilling operations in California's Central Valley.[72] To the extent that groundwater pumping in support of water transfers lowers groundwater levels, some

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[67] LTWT, page 3.10-24.

[68] LTWT, page 3.10-36.

[69] LTWT, page 3.10-36.

[70] A related point is that Figures 3.10-5 and 3.10-6 are confusing in that the captions include "September 1990" and "September 1976," respectively. The discussion on page 3.10-36, which introduces the figures, makes no mention of these dates or their significance.

[71] DWR, 2014b, pages 2-5.

[72] Howard, B.C. 2014. California drought spurs groundwater drilling boom in Central Valley. National Geographic. August 15. http://news.nationalgeographic.com/news.2014/08/140815-central-valley-california-drilling-boom-groundwater-drought-wells/; Khokha, S. 2014. Drought has drillers running after shrinking California water supply. National Public Radio. June 30. http://www.npr.org/2014/06/30/325494399/drought-has-drillers-running-after-shrinking-california-water-supply.

current water users depending on groundwater may face increased costs of deepening or installing new wells. The analysis described in the LTWT does not address these costs.

Underestimates the significance of impacts on unemployment rates

Any negative impacts of water transfers on agricultural production and related unemployment effects, would take place against a backdrop of already hurting economies. As Figure 3.10-7 illustrates, current unemployment rates in the seller counties runs between approximately 8 and 18 percent. The LTWT analysis estimates that water transfers will idle approximately 500 workers in the Sacramento Valley. The analysis assumes that impacts of transfers on unemployment would be temporary.

> "Reductions in employment associated with cropland idling transfers would contribute to unemployment in the region. However, cropland idling effects are temporary and under the Proposed Action, cropland idling transfers would not occur each year over the 10-year period."[73]

As we note above, however, data on the frequency of recent water transfers do not support the LTWT assumptions regarding infrequent future water-transfer years. Thus, the LTWT analysis likely underestimated the negative impacts of the plan on unemployment in the Sacramento Valley.

No mention of economic harm to local economies from lost water-based recreational activities

The analysis of regional economic effects in the LTWT focuses on impacts of water transfers on agricultural production and related businesses. The LTWT ignores other negative impacts on the regional economy. For example, the LTWT is silent on the impacts of water transfers on reservoirs such as Lake Oroville and others in the sellers area, and the related impacts on the region's water-based recreational economy. In their letter commenting on the LTWT, the Butte County Board of Supervisors noted their concerns that the LTWT "… failed to take into account the reduction in stream flows and the lowering of Lake Oroville that will harm the local economy."[74] In an earlier letter to Governor Brown commenting on the BDCP, the Butte County Board of Supervisors noted the importance of the lake to the region's economy, and the fact that the State of California has not fulfilled commitments made regarding developments at Lake Oroville.[75] Ignoring the potential impacts of water transfers on Lake Oroville and the associated economic impacts compounds the negative effects of the State's failure to fulfill past commitments at the lake.

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[73] LTWT, page 3.10-49.

[74] Teeter, D. 2014. *Letter to Brad Hubbard, BOR, and Frances Mizuno, SLDMWA*, November 25. Re: Long-Term Water transfers Program Draft Environmental Impact Statement/Environmental Impact Report (EIS/EIR). Page 2.

[75] Lambert, S. 2012. *Letter to The Honorable Edmund G. Brrown, Jr*. August 14. Re: Butte County's Opposition to the Bay Delta Conservation Plan (BDCP). August 14. Page 2.

Arbitrary limits on crop idling

The analysis in the LTWT relies on arbitrary limits on crop idling as a means of avoiding negative economic impacts. The DWR and BOR document that provides technical guidance for those interested in making water transfers describes the possibility of negative economic effects of crop idling, however, the guidelines for the amount of idling that would cause economic harm appear arbitrary. The relevant passage from the document states,

> "Cropland idling/crop shifting transfers have the potential to affect the local economy. Parties that depend on farming-related activities can experience decreases in business if land idling becomes extensive. Limiting cropland idling to 20 percent of the total irrigable land in a county *should* limit economic effects."[76] [emphasis added]

While the statement may be true, it lacks the analytical rigor that would satisfy NEPA requirements for, "Rigorous exploration and objective evaluation of all reasonable alternatives, …"[77] As such, the guidelines on crop idling seem arbitrary rather than the result of rigorous and objective analysis.

Table 3.10-22 lists the total number of acres affected by cropland idling in the analysis described in the LTWT. As shown in this table, approximately 60,000 acres could be idled in Glenn, Colusa, Yolo, Sutter, and Butte counties.[78] In the table below, we show the total number of acres of irrigable land in each county, and 20 percent of these acres. According to the guidelines noted above, up to 257,000 acres could be idled in these counties without significant economic effects. This seems doubtful. Rather than relying on arbitrary rules of thumb and assumed limited economic effects of idling, a more complete and transparent assessment of the economic effects of water transfers would take an analytical and quantified approach.

Table 1: Acres of Cropland, by County, 2011.

County	Acres of Cropland	20 Percent of Acres
Butte	224,592	47,969
Colusa	291,435	56,246
Glenn	250,493	50,099
Sutter	239,846	58,287
Yolo	281,228	44,918
Total	1,287,594	257,519

Source: US Department of Agriculture. 2011. California Cropland Data Layer. National Agricultural Statistics Service. Research and Development Division, Geospatial Information Branch, Spatial Analysis Research Section.

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[76] DWR and BOR, 2013. *DRAFT Technical Information for Preparing Water Transfer Proposals. Information to Parties Interested in Making Water Available for Water Transfers in 2014*. October. Page 22.

[77] LTWT page 2-1.

[78] LTWT, page 3.10-26.

5 The LTWT finds significant negative effects but the vague and incomplete proposed monitoring and mitigation plans would not address these effects

The LTWT concludes that water transfers will have some significantly negative impacts on groundwater resources. As we note in earlier sections of this report, the analysis described in the LTWT likely underestimates the negative effects of water transfers. For example, the analysis likely underestimates the frequency of water-transfer years, and so the negative effects of the transfers. The analysis also ignores negative impacts on water-based recreational activities and the associated negative economic consequences. The monitoring and mitigation plans focus only on the negative effects listed in the LTWT. Thus, they would address only a subset of the likely total negative economic consequences of the water transfers. In addition, the vague and incomplete proposed monitoring and mitigation plans would not adequately address those negative effects listed in the LTWT. Concerns regarding these plans include the following.

The LTWT ignored the costs of monitoring and mitigation

The LTWT proposes both a monitoring and mitigation program for significant negative impacts of water transfers on groundwater resources. Implementing these programs would take planning, effort and financial resources. The LTWT, however, does not include these costs in their analysis of alternatives. For example, water sellers would be required to monitor and record groundwater conditions and coordinate with regulators regarding the impacts of their groundwater pumping on groundwater levels. Water seller will incur costs monitoring, measuring, recording, and reporting the necessary information. The LTWT excludes these and related costs from the analysis.

Likewise, the mitigation of negative groundwater consequences would also require time, effort, and costs to water sellers, third parties negatively affected by groundwater pumping, and regulators. LTWT excludes these costs as well.

The monitoring and mitigation programs include inherent conflicts of interests

The monitoring program as described in the LTWT is vague and depends on sellers implementing the program. This conflict of interest pits financial gain from water sales against complete and impartial monitoring efforts. This opens the door to lax, biased, or incomplete monitoring, which could lead to negative environmental and economic consequences for third parties not part of the water transfers.

The monitoring program includes provisions for a coordination plan that would share information among "well operators and other decision makers."[79] Such confidential results would keep other stakeholders in the dark regarding the impacts of water transfers. Given the fact that multiple wells belonging to multiple property owners can access the same groundwater aquifer, and that groundwater pumping can affect flows of surface water, such a confidential program seems counter to the wellbeing of the regional economy in the sellers area. An open monitoring program with public results would better communicate the potential environmental and economic risks of groundwater pumping in support of water transfers.

If the seller's monitoring program finds that water sales are causing "substantial adverse impacts"[80] the seller will be responsible for implementing a mitigation program. The conflict of interest is obvious.

One method of avoiding the obvious conflicts of interests is requiring monitoring by independent third parties not involved with or affected by groundwater pumping in support of water transfers. Such monitoring could be detailed, transparent and public, which would alleviate concerns over the risks and consequences of negative environmental and economic effects of groundwater pumping. Mitigation decisions and requirements should likewise be detailed, transparent and public for the same reasons.

Insufficient monitoring period

As described in the LTWT, groundwater levels would be monitored through March of the year following a transfer. It's not clear that this limited monitoring period is sufficiently long enough to track potential impacts on groundwater of water transfers. For example, the report cited above for the NCWA states,

> "…[G]roundwater changes can take many years to become apparent, and we have not yet been able to measure with certainty the long-term impacts of the current level of groundwater use as it affects our measures of sustainability."[81]

An insufficient monitoring period could underestimate the impacts of groundwater pumping on groundwater levels and impacts on stream flow depletions. Lowering groundwater level and increasing stream flow depletions would generate negative environmental and economic impacts. The monitoring period in the LTWT may cause analysts to underestimate the environmental and economic effects of the water-transfers alternatives.

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[79] LTWT, page 3.3-89.

[80] LTWT, page 3.3-90.

[81] DMW, 2014, page 10.

Insufficient monitoring for land subsidence

The monitoring program includes monitoring subsidence, however, the program is vague on monitoring requirements and what amount of subsidence would trigger a halt in water transfers. Custis describes a number of technical deficiencies in the proposed mitigation plan.

> "The Draft EIS/EIR should be able to provide the specific thresholds of subsidence that will trigger the need for additional extensometer monitoring, continuous GPS monitoring, or extensive land-elevation benchmark surveys by a licensed surveyor as required by GW-1. The Draft EIS/EIR should also specify in mitigation measure GW-1, the frequency and methods of collecting and reporting subsidence measurements, and discuss how the non-participating landowners and the public can obtain this information in a timely manner. In addition, the Draft EIS/EIR should provide a discussion of the thresholds that will trigger implementation of the reimbursement mitigation measure required by GW-1 for repair or modifications to infrastructure damaged by non-reversible subsidence, and the procedures for seeking monetary recovery from subsidence damage [citation omitted]."
>
> "Specific 'strategic' subsidence monitoring locations should be given in mitigation measure GW-1 based on analysis of the susceptible infrastructure locations and the potential subsidence areas."[82]

Implementing the Custis recommendations will take time and financial resources for water sellers, local jurisdictions and third parties negatively affected by groundwater pumping. The LTWT does not include the costs of these measures in the analysis. Thus, the costs of the water transfers described in the LTWT underestimate the true costs of the program.

Vague significance criteria

The mitigation program includes a number of vague descriptions of critical components. Relevant missing descriptions include details on:

- How regulators and stakeholders would define "substantial adverse impacts" from groundwater pumping.
- What constitutes a "significant" increase in pumping costs suffered by injured third parties.
- Required modifications to damaged third-party infrastructure or the installation of new infrastructure.

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[82] Custis 2014, page 28.

- The procedure that injured third parties would use when making claims against a seller.
- The procedure that regulators and stakeholders would use when investigating third-party claims.
- What constitutes "legitimate significant effects" on third parties.[83]

A vague and ill-defined mitigation program increases risks of environmental and economic harm, and shifts the costs of such harm from water sellers to third parties and society in general. The analysis described in the LWTW does not identify, describe or quantify these risks, costs and consequences. A related point is that the LTWT makes no mention of BOR addressing these or similar issues as part of reviewing past annual water transfers. Including such information from past water transfers—if BOR considered these effects—in the LWTW could help illustrate or describe the uncertainties listed above.

The mitigation plan puts costs on to injured third parties

Injured third parties bear the costs of bringing to the sellers' attention harm caused by groundwater pumping. Also, the LTWT states that proposed mitigation options would be developed "in cooperation"[84] with injured third parties. This approach places costs on injured third parties rather than on sellers. That is, those who would not benefit financially from the program bear the costs of bringing negative impacts to the sellers' attention. They also would incur costs of documenting and presenting their damages in the context of an ill-defined mitigation program. This raises equity concerns that those suffering costs of the program bear the additional costs of identifying, describing and calling attention to their costs. The analysis described in the LTWT further assumes that disagreements regarding third-party damages would be settled cooperatively, without presenting evidence substantiating such an optimistic assumption. The LTWT is silent on the economic consequences of sellers and injured third parties not cooperatively agreeing on harm and compensation.

As we note above, information the BOR collected from past water transfers may help inform the types and amounts of costs that injured third parties could incur as a result of the water transfers at issue in the LTWT.

BOR's role in monitoring and mitigation

The LTWT describes a substantive role for BOR in the monitoring and mitigation program, without specifics of how BOR would implement its responsibilities. Topic not addressed include:

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[83] LTWT, page 3.3-88 through -91.

[84] LTWT, page 3.3-91.

- The costs to BOR of monitoring and mitigation.
- The details of interactions between sellers, injured third parties, and BOR staff regarding the details of monitoring and mitigation.
- The details of collecting, organizing and publishing relevant details of monitoring and mitigation.
- The details of decision making processes that affect monitoring and mitigation.
- The details of interactions between BOR and other federal or state agencies, and BOR and local jurisdictions.

Lead CEQA agency

SLDMWA is the lead state agency regarding CEQA compliance. It is also one of three potential buyers for the transferred water.[85] This arrangement creates a conflict of interest in that the lead CEQA agency also has a self interest in facilitating the water transfers. As described on their website, SLDMWA delivers approximately 3 million af of water to member agencies.[86] SLDMWA has a financial and operational interest in delivering water to its members. Thus, SLDMWA is not an impartial agent.

The LTWT provides no information on why SLDMWA is the lead state agency and not the California Department of Water Resources.

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[85] LTWT EIS/EIR, Table 1-2, page 1-5. The other two buyers are Contra Costa Water District and the East Bay Municipal Utility District.

[86] SLDMWA web site, www.sldmwa.org/learn-more/about-us/.

6 The LTWT ignores the economic costs of environmental externalities and subsidies that water transfers support

The LTWT lists Westlands Water District as one of the CVP contractors expressing interest in purchasing transfer water.[87] The environmental externalities caused by agricultural production in Westlands are well documented, as are the economic subsidies that support this production. To the extent that the water transfers at issue in the LTWT facilitate agricultural production in Westlands, they also contribute to the environmental externalities and economic subsidies of that production. The LTWT is silent on these environmental and economic consequences of the water transfers.

In this section we summarize recent information on the environmental externalities and economic subsidies of agricultural production on Westlands that water transfers would support.

The environmental and economic externalities of Westlands have a long history

For decades, high levels of selenium have posed a serious environmental threat to drinking water, soil quality, and agriculture in the Westlands Water District.[88] This naturally occurring element leaches into soil and drinking water when irrigation water is applied and when significant levels accumulate, has been known to cause deformities and death in wildlife and human beings.[89] The most extreme example of this type of degradation occurred from 1981-1986 during the Kesterson Disaster, when the federally operated San Luis Unit diverted selenium-rich wastewater into the Kesterson National Wildlife Refuge, killing over one thousand birds and causing severe birth defects.[90]

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[87] LTWT, page 1-5.

[88] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land

[89] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land

[90] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. Environmental Working Group. Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land; Environmental Working Group. 2010b, September 28. U.S. Taxpayers Paid nearly $60 million to Farmers on Westlands Toxic Lands. Environmental Working Group. Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land; Luoma, Samuel N. and Teresa S. Presser. (2000). Forecasting Selenium Discharges to the San Francisco Bay-Delta Estuary: Ecological Effects of a Proposed San Luis Drain Extension. U.S. Geological Survey. (Open-File Report 00-416). Menlo Park, California.

Current environmental concerns

Since the Kesterson Disaster, the Westlands has followed a "no-discharge policy" where irrigated wastewater is reused on agricultural land or stored in groundwater aquifers.[91] In spite of the well-documented concerns regarding selenium contaminated runoff from Westlands, as yet there is no official monitoring of selenium levels in the district.[92] The San Luis Act (1960) gives the BOR, not the Westlands Water District, responsibility for disposing of Westland Water,[93] but as of yet neither entity has implemented any meaningful solution. This failure prompted the Westlands District to bring a lawsuit against the BOR in 1995, which was finally brought to the Ninth Circuit Court of Appeals in 2000.[94] The court upheld a lower court's decision to force the BOR to provide drainage to the district but allowed that solutions other than a drain might be considered.[95]

At first, it seemed that large-scale retirement of farmland was the solution favored by both the Westlands and the federal government.[96] In 2001, the District released a fact sheet entitled "Why Land Retirement Makes Sense for the Westlands Water District" advocating for a possible deal with the federal government that would retire up to 200,000 acres of agricultural land. According to the federal government's National Economic Development analysis, this option would result in an economic gain of $3.6 million per year excluding any additional savings as a result of reduced crop subsidies.[97] Instead, after more than a decade of negotiations, the federal

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[91] State of California. Centerl Valley Regional Water Quality Control Board. Irrigated Lands Program – Development of the Long-term Program. http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/new_waste_discharge_requirements/western_tulare_lake_basin_area_wdrs/index.shtml#octdec2013

[92] State of California. Centerl Valley Regional Water Quality Control Board. Irrigated Lands Program – Development of the Long-term Program. http://www.waterboards.ca.gov/centralvalley/water_issues/irrigated_lands/new_waste_discharge_requirements/western_tulare_lake_basin_area_wdrs/index.shtml#octdec2013

[93] US Bureau of Reclamation. 2012a, August 7. *CVP Ratebooks - Irrigation, 2012*. Retrieved from http://www.usbr.gov/mp/cvpwaterrates/ratebooks/irrigation/2012/index.html; U.S. Bureau of Reclamation. 2012b, September. San Luis Unit Drainage, Central Valley Project. ***Reclamation: Managing Water in the West.*** Retrieved from http://www.usbr.gov/mp/PA/docs/fact_sheets/San_Luis_Drainage.pdf.

[94] US Bureau of Reclamation. 2012a, August 7. *CVP Ratebooks - Irrigation, 2012*. Retrieved from http://www.usbr.gov/mp/cvpwaterrates/ratebooks/irrigation/2012/index.html; U.S. Bureau of Reclamation. 2012b, September. San Luis Unit Drainage, Central Valley Project. ***Reclamation: Managing Water in the West.*** Retrieved from http://www.usbr.gov/mp/PA/docs/fact_sheets/San_Luis_Drainage.pdf.

[95] US Bureau of Reclamation. 2012a, August 7. *CVP Ratebooks - Irrigation, 2012*. Retrieved from http://www.usbr.gov/mp/cvpwaterrates/ratebooks/irrigation/2012/index.html; U.S. Bureau of Reclamation. 2012b, September. San Luis Unit Drainage, Central Valley Project. ***Reclamation: Managing Water in the West.*** Retrieved from http://www.usbr.gov/mp/PA/docs/fact_sheets/San_Luis_Drainage.pdf.

[96] Westlands Water District. 2001, October 16. Why Land Retirement Makes Sense for Westlands Water District. *Westlands Water District*.

[97] Westlands Water District. 2001, October 16. Why Land Retirement Makes Sense for Westlands Water District. *Westlands Water District*; Sharp, Renée. 2010, September 28. Throwing Good Money at Bad Land. *Environmental Working Group*. Retrieved from http://www.ewg.org/agmag/2010/10/throwing-good-money-after-bad-lands.

government and the Westlands Water District finally signed an agreement in 2014 which lifts the federal government's obligation to provide drainage to the district, forgives the nearly $400 million the district owes to the federal government for its part in the construction of the Central Valley Project (CVP), assures the district almost 900,000 acre-feet of water per year from the CVP, and requires only 100,000 acres of land be retired.[98] This leaves over 100,000 more acres of selenium-degraded land that the Westlands Water District will now need to decide how to drain in the years to come.[99] In addition, while the BOR's Environmental Assessment found that there would be no significant environmental impact as a result of the interim renewal contracts with the Westlands and other CVP districts, several environmental groups have criticized the study as violating federal environmental requirements, including the National Environmental Policy Act of 1969.[100]

Economic subsides to the Westlands water district

As the largest water district in California and the largest recipient of water under the Central Valley Project, the Westlands Water District receives significant crop, water, and power subsidies to supplement its agricultural activities. According to a report by the Environmental Working Group, between 2005 and 2009, the federal government issued almost $55 million of counter cyclical and direct crop subsidies to 356 individuals in the district.[101] The district's 350 farms networks are entitled to over 1.1 million acre-feet of water per year, more than twice the allocation of the City of Los Angeles.[102] In 2002, the group estimated that the federal

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[98] California Water Impact Network. 2014, October 16. Obama Selling Out California to Westlands Water District. *California Water Impact Network.* Retrieved from http://www.c-win.org/content/media-release-obama-selling-out-california-westlands-water-district-secret-deal-forgives-gov; US Department of the Interior. 2013, December 6. *PRINCIPLES OF AGREEMENT FOR A PROPOSED SETTLEMENT BETWEEN THE UNITED STATES AND WESTLANDS WATER DISTRICT REGARDING DRAINAGE.* Retrieved from www.c-win.org/webfm_send/453; Boxall, Bettina. 2014, October 21. Amid California's drought, a bruising battle for cheap water. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-westlands-20141021-story.html#page=2.

[99] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land.

[100] US Bureau of Reclamation. 2013, December 7. *Central Valley Interim Renewal Contracts for Westlands Water District, Santa Clara Valley Water District, and Pajaro Valley Water Management Agency 2014-2016.* (FONSI-13-023). Sacramento, CA; Minton, Jonas, Kathryn Phillips, et al. 2014, January 14. The Environmental Assessment [EA] for Westlands Water District et. al. Central Valley Project Interim 6 Contract Renewals for Approximately 1.2 MAF of water [Letter to Rain Emerson, Bureau of Reclamation].

[101] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land; Environmental Working Group. 2010b, September 28. U.S. Taxpayers Paid nearly $60 million to Farmers on Westlands Toxic Lands. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land.

[102] Boxall, Bettina. 2014, October 21. Amid California's drought, a bruising battle for cheap water. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-westlands-20141021-story.html#page=2; Environmental Working Group. 2005, September 14. Soaking Uncle Sam: Why Westlands Water District's New Contract is All Wet. *Environmental Working Group.* Retrieved from http://www.ewg.org/research/soaking-uncle-sam.

government paid $110 million per year in water subsidies, making its water drastically less expensive than that allocated to urban households.[103]

In 2002, the Westlands Water District received more than $70 million in power subsidies Although the Westlands receives 25% of all water from the CVP, it consumes 60% of the electricity required to deliver water to all districts and 60% of all government granted power subsidies to the CVP.[104]

As mentioned above, the federal government has subsidized the Central Valley Project since its construction. While farmers were meant to pay $1 billion of the $3.6 billion project cost fifty years after its completion, it's estimated that by 2008, only 20% of that debt had been repaid.[105]

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[103] Boxall, Bettina. 2014, October 21. Amid California's drought, a bruising battle for cheap water. *Los Angeles Times.* Retrieved from http://www.latimes.com/local/california/la-me-westlands-20141021-story.html#page=2; Environmental Working Group. 2005, September 14. Soaking Uncle Sam: Why Westlands Water District's New Contract is All Wet. *Environmental Working Group.* Retrieved from http://www.ewg.org/research/soaking-uncle-sam; Environmental Working Group. 2007, May 30. Power Drain: The Biggest Winner: Westlands. *Environmental Working Group.* Retrieved from http://www.ewg.org/research/power-drain/biggest-winner-westlands.

[104] Environmental Working Group. 2007, May 30. Power Drain: The Biggest Winner: Westlands. *Environmental Working Group.* Retrieved from http://www.ewg.org/research/power-drain/biggest-winner-westlands.

[105] Environmental Working Group. 2010a, September 28. Throwing Good Money at Bad Land. *Environmental Working Group.* Retrieved from http://www.ewg.org/Throwing-Good-Money-at-Bad-Land.

7 The LTWT underestimates the cumulative effects of water transfers

Cumulative effects analyses under NEPA and CEQA are intended to identify impacts that materialize or are compounded when the proposed action is implemented at the same time as or in conjunction with other actions. In Chapters 3 and 4, the LTWT addresses cumulative effects for each resource area and provides a global description of the methods and actions considered for analysis in each resource area. Section 3.10 provides a cursory discussion of potential cumulative effects for the regional economy, but ignores the full range of possible cumulative outcomes associated with the proposed action.

According to NEPA and CEQA requirements, cumulative effects analysis must examine the possibility of effects occurring across several dimensions. When multiple projects produce effects within the same geographic and temporal range, they may:

- Expand or contract the set of possible impacts.
- Increase or decrease the likelihood of specific potential impacts.
- Accelerate or decelerate the timing of specific potential impacts.
- Change the trajectory of potential impacts.
- Increase or decrease the economic importance of specific potential impacts.
- Shift the distribution of uncertainty or risk borne by different groups.

Cumulative effects may arise as multiple projects interact in a linear fashion, resulting in impacts that are additive. Interactions might also be non-linear, either offsetting each other to be less than additive, or exacerbating each other to be greater than additive.

The LTWT does not adequately consider cumulative effects within this framework, so misses important interactions that could result in significant impacts beyond those identified for the project alone.

One of the greatest potential sources of cumulative impacts is non-CVP water transfers. Although transfers under the SWP were considered, the possibility of other transfers occurring was not. Additional transfers would have similar impacts in the sellers' region, and may also lead to net effects that exceed sustainable thresholds and have a larger impact than each would individually. For example, the analysis

- Ignores cumulative effects of additional water transfers on water prices, and fails to examine the effects of price on the decisions and behaviors of farmers in the context of other water transfers.
- Ignores effects resulting from additional water transfers that have the potential to influence agricultural prices, and how those agricultural prices influence decisions about water transfers.

- Treats effects as “temporary” and thus not significant, and thereby fails to adequately account for potential thresholds in the local agricultural economy where short-term effects would become long-term effects.
- Assumes mitigation for groundwater effects of the proposed action would make farmers whole, so fails to properly account for potential threshold effects in groundwater resources, and associated costs to farmers.
- Ignores the possibility that increased uncertainty related to groundwater levels, agricultural market conditions, etc. from the proposed action, in conjunction with other actions, would adversely affect farmers.
- Ignores the cumulative effects of additional water transfers on environmental resources and conditions including aquatic, riparian, terrestrial and avian species and habitats.

9/26/08

WATER RIGHTS WITHIN THE BAY/DELTA WATERSHED
STATE WATER RESOURCES CONTROL BOARD

The water right permit system administered by the State Water Resources Control Board (State Water Board) applies to surface water bodies and to a narrow classification of groundwater, “subterranean streams flowing in known and definite channels.” (Wat. Code, § 1200.) Aquifers that are not part of a subterranean stream are classified as “percolating groundwater.” There are two basic categories of surface water rights: post-1914 appropriative; and pre-1914 appropriative and riparian. The State Water Board has very limited information on water use for either of these classes of water rights, and the little information it does have has not been synthesized and is not maintained electronically. The State Water Board has no information on groundwater use in the Delta watershed.

Post-1914 Appropriative Water Rights

The State Water Board has permitting and licensing authority over surface water diversions associated with post-1914 appropriative water rights within the legal Delta and within the Delta watershed. December 19, 1914 is the effective date of the Water Commission Act that established the modern procedures to regulate surface water appropriation. Surface water appropriations established prior to this date are not bound by these procedures. The State Water Board maintains paper and electronic files for post-1914 permitted and licensed water rights, pending water right applications, and also state filings, which are state filed water right applications reserved for future use by individuals and entities in the areas where water originates. The information in its files includes the holder of the water right, point of water diversion, limitations on the rate, amount, and season of diversion, the place and purpose of use of the water, and any other terms or conditions placed on the water right. These limitations on rate, amount, and season of use are used to determine the “face value” of the water right, defined as the total annual amount of diversion authorized for direct diversion or storage by a permit or license. The term is primarily used in the calculation of water right fees and does not take into account water availability, bypass requirements, or other conditions that may have a practical effect of limiting diversions. Further, the State Water Board has continuing authority to change existing water rights, following formal notice and opportunity for hearing, in order to protect the public trust and water quality and to prevent the waste, unreasonable use, and unreasonable method of use or diversion of water.

Water right permit and license holders are required to file progress reports with the State Water Board, and to report their water diversion and use amounts (Cal. Code of Regs, tit. 23, § 847). These reports are to be completed annually for water right permit holders and triennially for water right license holders. Approximately 68 percent of permit and license holders submit completed water use reports to the State Water Board. The Water Code does not contain specific enforcement provisions that would allow the State Water Board to enforce against the lack of reporting. Use information reported to the State Water Board is stored in paper files and there has been no verification of the quality of this information except as part of limited enforcement actions. Summary information is therefore not available to compare face value of water rights to actual use. Some water users who hold multiple rights report the same use information for all of their rights. For instance, a right holder may use 2500 acre-feet per year of water under three different water rights. If that user reports a use of 2500 acre-feet for each of the three rights, a cursory review might lead the reviewer to conclude that 7500 acre-feet of water is being used, although this is not the case.

Pre-1914 Appropriative and Riparian Water Rights

The State Water Board does not have permitting and licensing authority over Pre-1914 appropriative or riparian water rights. The State Water Board does however collect Statements of Water Diversion and Use (Statements) from water diverters claiming riparian and pre-1914 water rights. (Wat. Code, § 5100 et seq.) The State Water Board has approximately 5,500 Statements of Water Diversion and Use on file for pre-1914 and riparian rights in waters tributary to the Delta. These Statements, however, do not provide complete information about riparian and pre-1914 water diversions in California. Of particular significance in the Delta, certain diverters are statutorily exempt from filing Statements; Water Code section 5101 exempts diversions that are reported by the Department of Water Resources (Department) in its hydrologic data bulletins or that are included in the consumptive use data for the Delta lowlands published by the Department in its bulletins. (*Id.*, § 5101, subds. (e)-(f).) The State Water Board estimates that there are approximately 1,600 unreported Pre-1914 and riparian diversions in the Delta. Additionally, even if a water diverter is statutorily required to file a Statement, there is no penalty for failure to file a report. (*Id*., § 5108.)

Groundwater

Percolating groundwater is not subject to the State Water Board's permitting system and, in most of the state, is not regulated by any other public agency. When considering a proposed appropriation of groundwater, or determining whether an unpermitted diversion in close proximity to a stream is an unauthorized diversion, the State Water Board must evaluate the legal classification of the groundwater from which the water is being appropriated to determine whether it is a subterranean stream, which is under the jurisdiction of the State Water Board, or percolating groundwater, which is not. (See *North Gualala Water Co. v. State Water Resources Control Board* (2006) 139 Cal.App.4th 1577 [43 Cal.Rptr.3d 821] [upholding State Water Board's use of four-part test in determining legal classification of groundwater].) To the extent groundwater is classified as a subterranean stream, it is managed as surface water. (See also Wat. Code, § 2500 [statutory adjudication procedures, under which all rights in a stream system are determined, apply to surface waters and subterranean streams, not percolating groundwater]. The State Water Board has no legal authority to require users of percolating groundwater to report their uses of water, other than in four southern California counties. The State Water Board does not therefore maintain information on extraction of percolating groundwater within the Delta watershed.

Water Use versus Water Rights

The mean annual unimpaired or full natural flow in the Delta Watershed between 1921 and 2003 was 29 million acre-feet per annum (AFA), with a maximum of 73 million AFA in 1983.[1] Unimpaired flow is flow that would be expected in the Delta watershed in the absence of storage and other human developments. In contrast, the total face value of the approximately 6,300 active water right permits and licenses within the Delta managed by the State Water Board, including the already assigned portion of state filings, is approximately 245 million AFA. There are 100 rights with a face value of 500,000 AFA, or more that account for 84% of the total face value of the water rights within the Delta watershed. The Central Valley Project and State Water Project hold 75 permits and licenses within the Delta watershed that account for 53% of the total face value of the water rights within the watershed. The total face value of the unassigned portion of state filings for consumptive use (excluding state filings for the beneficial use of power) within the Delta watershed is approximately 60 million AFA. This does not mean that this 60 million AFA is hydrologically available for appropriation. Prior to assignment of a state filing, the State Water Board will require that an applicant provide evidence that water is available to support the assignment. Clearly, actual use must be only a small fraction of the face value of these water rights, particularly since face value does not include pre-1914 and riparian water rights. There are three primary reasons why the face value of water rights is greater than actual diversions:

1. When approving a water right application, the State Water Board has to find that water is available for appropriation for the project being proposed. In making that determination, the State Water Board looks at both the demand characteristics associated with the proposed use and the likelihood that supply will be adequate to supply that demand. The State Water Board is required to maximize the beneficial use of water. Historically, the State Water Board has approved permits for agricultural projects if water is available in 50 percent of years, under the condition that water cannot be diverted in years in which there is insufficient supply to satisfy prior vested rights.
2. Water rights are issued based on the maximum rate of diversion (for direct diversion projects) and the maximum annual diversion to storage (for reservoirs and other impoundments). For large storage projects, the maximum annual diversion to storage generally only occurs in the year in which the project initially fills. Most modern water rights include a bypass condition which can limit diversion amounts below the "face value" amount in many years. Some water rights include a condition that limits the amount of water that can be diverted in combination with other water rights. This information is difficult to capture in a database format.
3. Some projects are covered by multiple rights for the same molecules of water. The State Water Board's regulations require that separate water rights be obtained for non-consumptive and consumptive uses of water. Large multi-use reservoirs will have at least two permits as a result, one that allows non-consumptive uses like recreation at and below the reservoir and one that allows consumptive uses such as municipal and irrigation uses. Similarly, the same molecule of water may be diverted several times by several different water right holders as it works its way down a river. If the water is not consumptively used,

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[1] DWR, Bay Delta Office, California Central Valley Unimpaired Flow Data, Fourth Edition Draft, May 2007

or lost to deep groundwater recharge, it likely returns to a river and is rediverted downstream.

Actual use under existing water rights is clearly a better metric to compare with unimpaired flows than is face value but the State Water Board has limited information on actual use. Comprehensive review and synthesis of the State Water Board's paper files would however provide only a crude estimate of actual historic and current use because of gaps in reporting and unreliability of the data already collected. Finally, there is a linkage between water availability in many surface waters and groundwater pumping but the State Water Board has no information on percolating groundwater pumping in the Delta watershed.

1.D.2.2 Attachments to Comments of California Water Impact Network and California Sportfishing Protection Alliance

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21 July 2015

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Executive Director
Ms. Barbara L. Evoy
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VIA: Electronic Submission
Hardcopy if Requested

RE: COMPLAINT: Against SWRCB, USBR and DWR for Violations of Bay-Delta Plan, D-1641 Bay-Delta Plan Requirements, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution

Dear Mr. Howard and Ms. Evoy:

The California Sportfishing Protection Alliance (CSPA) hereby submits a complaint against the State Water Resources Control Board (SWRCB), United States Bureau of Reclamation (USBR) and California Department of Water Resources (DWR) for violations of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Delta Estuary (Bay-Delta Plan) and violations of D-1641 implementing requirements of water quality standards, Clean Water Act (CWA), Endangered Species Act (ESA), Public Trust Doctrine and the California Constitution.

Specifically, CSPA alleges that the SWRCB's sequential weakening of D-1641 requirements violates the federal CWA and represents a de facto change in the standards themselves, that the SWRCB has failed to enforce Bay-Delta water quality standards and has failed to enforce its 2010 Cease & Desist Order against USBR and DWR for violations of southern Delta salinity standards, that USBR and DWR are presently violating water quality standards protecting fish & wildlife and agricultural beneficial uses, and that USBR and DWR have failed to comply with the SWRCB 2010 Cease & Desist Order. CSPA additionally alleges that the SWRCB, USBR and DWR have failed to comply with their respective responsibilities and obligations under the ESA, Public Trust Doctrine and Article X of the California Constitution.

We incorporate by reference the protests, objections, exhibits and workshop comments and presentations that CSPA et al., the Bay Institute, Restore the Delta and Sequoia Forestkeeper et al. have previously made during the 2014 and 2015 SWRCB proceedings regarding USBR and DWR's Temporary Urgency Change Petitions (TUCPs) for the operation of the State Water Project and Central Valley Project.

Given the impending extinction of Delta smelt and possibly several other species, we ask the SWRCB to act expeditiously in responding and requiring USBR and DWR to respond to the allegations herein and to immediately reestablish D-1641's critical year requirements for the protection of fish and wildlife.

Dr. Peter Moyle has been publicly quoted as predicting the imminent demise of Delta smelt. Agency biologists have privately told us "they're gone." Should Delta smelt perish, it will not be the drought that sent them into extinction: it will be the failure of the SWRCB to comply with and enforce minimal standards for drought sequences that it adopted to prevent such catastrophe. Fallowed fields will be replanted when the drought is over; extinct species are forever lost. It would be tragic if the SWRCB's legacy were that its failure to comply with the law sent species that evolved and prospered over millennia into extinction. And longfin smelt are next in line.

Violations of Bay-Delta Standards & D-1641 Requirements

The federal CWA requires the adoption of water quality standards consisting of the designated uses of navigable waters and the water quality criteria or objectives necessary to protect those designated uses. Antidegradation requirements are an integral part of water quality standards.

The current water quality objectives in the 2006 Bay-Delta Plan for the San Francisco Bay/Sacramento-San Delta Estuary are the same as those in the 1995 Water Quality Control Plan. Many of those objectives were also in the 1978 Bay-Delta Plan.

The SWRCB's Decision 1641, issued in 2000, is the current implementation plan for Bay-Delta water quality standards. Implementation plans that do not protect the designated use of the waters do not comply with applicable water quality standards. D-1641 contains objectives to protect fish and wildlife, agricultural, municipal and recreational designated beneficial uses of the Bay-Delta estuary. Those objectives are expressed as narrative, concentration and or flow.

There is continuing disagreement between the SWRCB and U.S. Environmental Protection Agency (USEPA) concerning whether the CWA regulates the quantity of water or flow. However, flow and constituent concentration are flip sides of the same coin. Reductions in flow increase the concentration of pollutants. The U.S. Supreme Court observed that a lowering of quantity or flow could destroy all of the beneficial uses of a river, and specifically that "… there is recognition in the Clean Water Act itself that reduced stream flow, *i.e.*, diminishment of water quantity, can constitute water pollution." *PUD No. 1 of Jefferson County v. Washington Department of Ecology,* (1994), 511 U.S. 700, 17.

This complaint addresses violations of agricultural objectives, expressed as concentration, and fish and wildlife objectives, expressed as both flow and concentration. For example, fish and wildlife objectives are expressed as both minimum Delta outflow and salinity concentration. However, the preferred habitat of estuarine species like Delta and longfin smelt is predicated on the concentration of salinity. A key to Delta smelt abundance, X2, is determined by the concentration of salinity and not by flow.

In an effort to avoid having to secure USEPA approval, the SWRCB suggests that it only modified the implementation of water quality objectives and not the objectives themselves. However, the sequential or serial weakening of standards and refusal to enforce violations of standards constitutes a de facto change in the standards themselves, especially when the serial weakening of and failure to enforce standards is replicated over decades in similar situations.

In 2013, the SWRCB Executive Director allowed USBR and DWR to operate to critical year criteria, without being subject to enforcement, instead of to the prevailing dry year criteria. In 2014, the Executive Director issued a series of TUCP Orders substantially weakening and extending the modifications of water quality objectives and requirements on 31 January, 7 February, 14 February, 28 February, 18 March, 9 April, 11 April, 18 April, 2 May and 7 October. The SWRCB denied multiple objections and petitions for reconsideration of the TUCP Orders on 24 September 2014. So far in 2015, the Executive Director has issued a series of TUCP Orders modifying and weakening water quality objectives and requirements on 3 February, 5 March, 6 April and 3 July.

Beyond the SWRCB's de facto weakening of Bay-Delta water quality objectives, the USBR and DWR have failed to comply with even the modified objectives. Violations of salinity standards at Threemile Slough and Jersey Point have occurred in 2015 and are continuing. Additionally, the sequential Cease & Desist Order compliance schedules adopted by the SWRCB in WR Orders 2006-0006 and 2010-0002 that allowed USBR and DWR to avoid actual compliance with southern Delta salinity objectives have expired and USBR and DWR are now in violation of WR Order 2010-0002 and the southern Delta salinity objectives at Old River Near Tracy, Old River near Middle River and San Joaquin River at Brandt Bridge. Further, the Vernalis salinity objective was violated on 5 days in July 2015.

This pattern and practice has replicated itself over decades. For example, during the 1987-1992 drought, D-1485 Bay-Delta standards were violated 246 times in the period from 1988 through 1991, and the SWRCB declined to take enforcement action. In 1992, the SWRCB, citing an effort to preserve sufficient cold water in Shasta Reservoir to meet temperature requirements for spawning salmon, weakened Suisun Marsh salinity and Rock Creek chloride requirements in WR Order 92-02. Of particular note, the SWRCB, referencing WR Order 90-05, stated in WR 92-02 at page 9:

> The State Water Board also has advised the USBR that decisions on water deliveries are subject to the availability of water, and that water should not be considered available for delivery if it is needed as carryover to maintain an adequate cold water pool for the fishery.

However, the USBR and DWR have ignored that advice and have continued to maximize water deliveries in the initial years of drought sequences and failed to maintain sufficient carryover storage to protect fisheries and public trust resources. The pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards has been extensively discussed and documented in previous protests, objections and SWRCB TUCP workshops and is incorporated by reference and need not be repeated here.

Violations of Bay-Delta Agricultural Salinity Objectives

Water quality objectives contained in the Bay-Delta Plan include salinity standards to protect agricultural beneficial uses. Table 2 objectives include electrical conductivity (EC) requirements of 2.78 mmhos/cm in the Sacramento River at Emmaton between 1 April and 15 August of critical dry years; EC requirements of 2.20 mmhos/cm in the San Joaquin River at Jersey Point between 1 April and 15 August of critical dry years and EC requirements of 0.7 mmhos/cm (April-August) and 1.0 mmhos/cm (September-March) at four locations in the South Delta (Vernalis, Brandt Bridge, Old River near Middle River and Old River at Tracy Road) in all years.

On 6 April 2015, the SWRCB Executive Director approved a Temporary Urgency Change Petition submitted by USBR and DWR to move the Emmaton EC compliance location to Threemile Slough from April through June. On 30 June 2015, the Executive Director provided interim approval of a subsequent TUCP, and, on 3 July he issued an order approving an extension of the relocated Emmaton objective to Threemile Slough until 15 August 2015. This action was similar to an action in the 2014 TUCP Order by the Executive Officer that moved the compliance point to Threemile Slough.

Had the SWRCB Executive Director not relocated the Emmaton compliance point, EC would have violated objectives on or about 1 May 2015, when the 14-day running average EC was 2.81 mmhos/cm, and would be ongoing in the present. As of 16 July 2015, 14-day running average EC at Emmaton was 5.26 mmhos/cm. During 2014, the Emmaton objective was exceeded on or about 26 May, and exceedances continued through 23 July.

Beginning on 7 July 2015, the EC objective of 2.78 mmhos/cm at the relocated Threemile Slough compliance point has been violated. The 14-day running average EC concentrations stated respectively for each day were 2.85, 2.94, 3.03, 3.09, 3.11, 3.15, 3.18, 3.20, 3.21, 3.21, 3.18, 3.14, 3.01, 2.91 and 2.84 mmhos/cm from 7 through 21 July. The 15-minute EC data from the DWR gage at Threemile Slough is included in Attachment A. As of this writing, violations are continuing.

Beginning on 8 July 2015, the EC objective of 2.20 mmhos/cm at Jersey Point has been violated. The 14-day running average EC concentrations stated respectively for each day were 2.204, 2.234, 2.242, 2.233, 2.250, 2.239 and 2.238 and 2.231, 2.219 and 2.207 mmhos/cm from 8 through 17 July. The 15-minute EC data from the USBR gage at Jersey Point is included in Attachment A.

USBR and DWR have not requested changes regarding salinity objectives at compliance stations in the South Delta in any of their 2014 and 2015 TUCPs and no changes or variances have been granted. D-1641 included a 5-year time schedule to meet the southern Delta 0.7 mmhos/cm EC objective. The objective became effective on 1 April 2005. Violations occurred. The SWRCB, in Order 2006-0006, issued a Cease & Desist Order that required USBR and DWR to take corrective actions in accordance with another time schedule in order to obviate violations of water quality objectives for EC by 1 July 2009. Violations continued. The SWRCB extended the compliance deadline yet again in Order 2010-0002. CSPA and South Delta Water Agency petitioned for reconsideration of Order 2010-0002 but the SWRCB denied both petitions.

Order 2010-0002 required USBR and DWR to implement measures to obviate the threat of non-compliance with South Delta EC objectives and to submit a detailed plan and completion dates for actions that would ensure compliance. Order 2010-0002 extended the timeline for compliance to allow the SWRCB time to consider the possibility of modifying the responsibilities of USBR and DWR for meeting the objective, as part of its 2006 review of the 2006 Bay-Delta Plan. However, Order 2010-0002 explicitly states that *"the pending proceeding to consider changes to the interior southern Delta salinity objectives and associated program of implementation and any subsequent water right proceeding shall be deemed to have been completed if the State Water Board has not issued a final order in the water right proceeding by January 1, 2013, unless the Deputy Director for Water Rights determines that the water right proceeding has been initiated, is proceeding as expeditiously as reasonably possible, and will be completed no later than October 1, 2014."* Emphasis added.

After three consecutive compliance deadlines have expired, violations of southern Delta EC objectives continue. Pursuant to the 2010-0002 Cease & Desist Order, the "compliance schedule" concluded on 1 January 2013 because a 2006 Bay-Delta Plan water rights proceeding was not underway and could not be successfully concluded by October 2014. The USBR and DWR have failed to provide a detailed plan and completion date for coming into compliance with salinity objectives and are presently violating those objectives. We have documented more than 1,400 days of violations of the 1.0 or 0.7 mmhos/cm EC objective at the Old River at Tracy Road compliance site alone since April of 2007, including every day this year. In fact, between 10 June and 15 July 2015, all three southern Delta locations have violated the 30-day running average EC objective everyday and the EC objective at Vernalis was violated 7-9 July.

In summary, from 1 January through the end of 14 July 2015, legally promulgated water quality criteria in Table 2 of the Bay-Delta Plan to protect agricultural beneficial uses was exceeded numerous times: specifically, Emmaton salinity criterion was exceeded at least 79 days; Old River Near Tracy salinity criterion was exceeded at least 199 days; San Joaquin River at Brandt Bridge salinity criterion was exceeded at least 96; days and Old River near Middle River salinity criterion was exceeded at least 40 days. In July 2015, the modified 14-day running average salinity criterion at Threemile Slough was exceeded 7 July and continues to be exceeded, the 14-day salinity criterion at Jersey Point was exceeded 8 July through 17 July and the 30-day salinity criterion at Vernalis on the San Joaquin River was exceeded 7 - 11 July. The USBR and DWR have failed to provide a plan and date for achieving compliance with southern Delta salinity criteria and, consequently, have been violating the SWRCB's Cease & Desist Order since 1 January 2013 (566 days, as of 20 July 2015).

Violations of Bay-Delta Fish and Wildlife Salinity Objectives

Table 3 of the Bay-Delta Plan contains Delta outflow requirements, several of which are also expressed as salinity concentration. For critically dry years, the requirements mandate a minimum monthly average Net Delta Outflow Index (NDOI) of 7,100 cubic feet per second (cfs) or a daily average or 14-day running average of EC less or equal to 2.64 mmhos/cm at

Collinsville. For July, August, September and October of critically dry years, the requirements are an NDOI of 4,000, 3,000, 4,000 and 3,000 cfs, respectively. During dry years, the July, August, September and October requirements are 5,000, 3,500, 4,000 and 4,500 cfs, respectively.

As noted above, so far in 2015, the Executive Director has issued a series of TUCP Orders modifying and weakening water quality objectives and requirements on 3 February, 5 March, 6 April and 3 July. The 2 February TUCP Order reduced NDOI requirements and salinity objectives from 7,100 cfs/2.64 mmhos/cm requirements to 4,000 cfs, increased allowable exports when the 7,100 cfs objective wasn't being met, allowed the Delta Cross Channel Gates to be opened under certain circumstances and reduce San Joaquin River flow requirements from 710/1,140 to 500 cfs.

The 5 March TUCP Order exempted water transfers from export provisions and increased exports when outflow was between 5,500 and 7,100 cfs. The 6 April extended outflow/salinity and export requirements through June, shifted the time period and reduced the volume of the San Joaquin pulse flow from 3,110 to 710 cfs, reduced minimum San Joaquin River outflow requirements to 300 cfs in May and 200 cfs in June and moved the Western Delta salinity compliance point on the Sacramento River at Emmaton to Threemile Slough.

The 3 July TUCP Order reduced Delta outflow requirements in July from 4,000 to 3,000 cfs, with a 7-day running average of no less than 2,000 cfs, reduced the minimum Sacramento River flow requirements at Rio Vista from 3,000 cfs (September, October) and 3,500 cfs in November to a monthly average of no less than 2,500 cfs, with a 7-day average of no less than 2,000 cfs and extended the change in the salinity compliance point from Emmaton to Threemile Slough on the Sacramento River through 15 August.

From 1 January through the end of June 2015, legally promulgated water quality criteria in Table 3 of the Bay-Delta Plan to protect fish and wildlife beneficial uses were exceeded numerous times. Specifically, Delta outflow criterion was exceeded approximately 124 days, Collinsville salinity criterion was exceeded at least 146 days and San Joaquin River flow criterion was exceeded approximately 112 days.

Violations of the Public Trust and Article X of the California Constitution

Article X, Section 2 of the California Constitution provides that:

> The right to water or to the use of the flow of water in or from any natural stream or water course in this state is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water.

Because of this Constitutional requirement, the SWRCB must consider the reasonableness of a particular method of diversion of water when evaluating (or reevaluating) all permitted uses of water and the requirements controlling those uses. "The limitations of Art. X, Section 2 … apply to all water users of the state and serve as a limitation on every water right and method of diversion." See *Yuba River D-1644* at p. 29. Both USBR and DWR are water users subject to Article X, Section 2 in the operation of their respective projects in the Central Valley.

Considering the conditions of drought which are described in the "drought emergency" declared by Governor Brown - the curtailments of water rights, the waiver of D-1641 standards to protect fish and wildlife and water quality in the Delta watershed - it is time for the SWRCB to declare flood irrigation by agriculture during the drought emergency a waste and unreasonable use until the emergency is over.

If the SWRCB can require urban conservation, it can also require conservation in agriculture. Flood irrigation in the Sacramento Valley in particular is unreasonable when the endangered salmon are facing extirpation. Increased evaporation from spreading water on the ground alone likely uses more stored water than that needed to save the fishery.

Alfalfa and irrigated pasture alone consumes 8.6 MAF of water in California and provides low net revenue and few jobs. The SWRCB can and must reduce the quantity of water allocated to irrigated pasture and low-value crops like alfalfa that use prodigious amounts of water during the drought emergency. To continue this use is unreasonable and a waste of water and must be stopped or reduced until the drought emergency is declared over.

The continued killing of threatened and endangered species by obsolete and non-protective export pumping facilities simply because the state and federal water contractors refuse to pay for new state-of-the-art fish screens is an unreasonable method of diversion. This is especially true when water diverted through those facilities deprives listed species of water and primary production necessary for survival. The SWRCB can and must curtail south Delta exports during the drought emergency until D-1641 water quality standards are met.

The SWRCB must also consider public trust issues in proceedings that concern water rights and water quality based on reserved jurisdiction or under the doctrine of reasonable use. The SWRCB may also modify permits of "the projects" that require the appropriator to reduce the quantity of exports. *United States v. SWRCB* (1986) 182 Cal.App. 3d 82, 124-131. The SWRCB has a complaint procedure that can exercise authority over both federal and state water projects by virtue of having state water rights permits issued by the Board.

The State's management responsibilities include broad discretion to promote trust uses, such as the continued survival of the Bay/Delta estuary and dependent endangered species, provided the discretion is exercised consistent with constitutional and statutory constraints. *People v. California Fish Co.* (1913) 166 Cal. 576, 597. While the State has discretion to promote trust issues, the SWRCB has "an affirmative duty" to protect trust resources. See *Illinois Central Railroad v. Illinois,* 146 U.S. 387; and *National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419 (The state may not abdicate its supervisory role any more than the state may abdicate its police power); see also Stevens, The Public Trust: *A Sovereign's Ancient Prerogative Becomes the People's Environmental Right*, 14 U.C. Davis Law Review 195, 223.

Fish and wildlife are natural resources unequivocally protected by state sovereignty, whereby ownership of the resource is reserved to the states. *Geer v. Connecticut*, (1896) 161 U.S. 519.

The court in *Audubon v. Superior Court*, (1983) 33 Cal.3d. 419 held that "no one may obtain a vested right to undertake an act that is harmful to the trust." See also *SWRCB D-1644* (Yuba River) at page 29. The supremacy of the public trust over private individuals is reflected in a "judicial presumption against state or legislative alienation of trust resources." *People v. California Fish*; see also *Illinois Central v. Illinois* (1892) 146 U.S. 387; *Montana v. U.S.*, (1981) 450 U.S.544. Historically, state sovereign ownership was limited to "the traditional triad of uses" – commerce, navigation, and fishing.

However, in 1971 the California Supreme Court expanded the protected uses to cover the environment generally. *Marks v. Whitney* (1971) 6 Cal 3d. 251, 259-260. State sovereign ownership imposes restraints on the state's discretion regarding the use of navigable waters. The use of trust resources must be consistent with the general trust purposes or it is invalid. *State of California v. Superior Court* (Lyon) (1981) 29 Cal 3d. 210, 220-230; *Marks v. Whitney*, supra; *City of Long Beach v. Mansell*, (1970) 3 Cal 3d. 462, 482-485. Preservation of a public trust resource such as the San Francisco Bay/Delta estuary is a legitimate disposition of the public trust resource, and is consistent with general trust purposes. Thus, tidelands and water may be burdened with a negative easement against any active use or disposition of the trust reserve. Id; *National Audubon*, supra; *State of California v. Superior Court* (Fogerty), (1981) 29 Cal 3d. 240, 249-250.

Consequently, the SWRCB has both the authority and responsibility under its reserved jurisdiction in the permits and licenses of the USBR and DWR, and under its continuing authority and responsibilities pursuant to the public trust and reasonableness doctrine to protect fisheries, public trust resources and beneficial uses. To protect those resources and uses, it established minimum water quality objectives and requirements for critical dry years in the Bay-Delta Plan and D-1641.

USBR and DWR's pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards established to protect public trust resources as successive dry years occur has been amply documented in multiple documents and TUCP proceedings over the last several years. The SWRCB has failed to establish minimum reservoir storage levels that ensure compliance with water quality standards protective of public trust resources. When successive dry years occur, it then routinely weakens those standards, with little regard to its public trust and constitutional obligations.

To weaken those water quality objectives and requirements simply because USBR and DWR recklessly delivered water that was otherwise necessary to maintain sufficient carryover storage to comply with water quality objectives and to protect public trust resources and agricultural beneficial uses in the Delta is a violation of Public Trust Doctrine and the California Constitution. To send fisheries into extinction while continuing to supply water for low value crops like pasture and alfalfa is an unreasonable use of water.

It is not the SWRCB's responsibility or legal right to sacrifice public trust resources and Delta beneficial uses in order to absolve USBR and DWR of the consequences of their egregious mismanagement. If customers of water contractors are now suffering because USBR and DWR failed to exercise prudence and due diligence in water management and rashly delivered near normal water supplies in initial drought years with little thought that another dry year might occur, it is USBR and DWR and not the SWRCB that have the responsibility to alleviate the suffering they caused.

The SWRCB has failed to balance the public trust. The California Legislature, in the Sacramento-San Joaquin Delta Reform Act of 2009, mandated the SWRCB to develop new flow criteria for the Delta ecosystem that are necessary to protect public trust resources. Following an extensive public proceeding, the SWRCB prepared a report titled "*Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem.*" The SWRCB's 2010 Report stated: "Recent Delta flows are insufficient to support native Delta fishes for today's habitats" and recommended 75% of unimpaired Delta outflow from January through June, 75% of unimpaired Sacramento River inflow from November through June and 60% of unimpaired San Joaquin River inflow from February through June as necessary to protect public trust resources. While the flow report did not balance the public trust against other beneficial uses or consider economics, it did conclusively establish that present flows are seriously insufficient to protect public trust resources.

The Legislature also mandated the California Department of Fish and Wildlife (DFW) to develop *Quantifiable Biological Objectives and Flow Criteria for Aquatic and Terrestrial Species of Concern Dependent on the Delta.* Following an extensive public proceedings throughout 2010, the DFW's report mirrored the conclusions and recommendations contained in the SWRCB flow report.

Five years after those reports were issued, the SWRCB has not begun to balance the public trust. It has, however, significantly weakened water quality standards and Delta flows. Fisheries have continued to decline and we are now faced with the imminent likelihood that one or more native species will become extinct.

An example of the SWRCB's egregious failure to even attempt to balance the public trust is demonstrated in the paucity of flows allocated to protect water quality and fisheries in July 2015. Releases from upstream-of-Delta rim reservoirs (Keswick, Whiskey Town, Oroville, Bullards Bar, Folsom, Camanche, New Hogan, New Melones, Don Pedro, New Exchequer and Friant) averaged 22,039 cfs or 43,703 AF daily 1 July through 19 July. Delta outflow for the same period averaged 2,990 cfs or 5,928 AF, most of which was necessary to allow operation of the state and federal project export pumps. In other words, under the most favorable light, only 13.6% of reservoir releases were allocated to protect fish and wildlife and Delta agricultural beneficial uses. The situation is even more bizarre on the San Joaquin River. Between 1 and 19 July, only 2.9% of flows released from New Melones, Don Pedro, New Exchequer and Friant reached the Delta. Whatever represents a reasonable public trust balancing, it is not 2.9% or 13.6% of flow, as water quality standards are violated and listed fish species plunge toward extinction.

Another example of the disregard for the public trust was provided in SWRCB staff's presentation on Sacramento-San Joaquin Watershed Use at the SWRCB 20 May 2015 Workshop on the TUCP, Emergency Drought Barrier, and Water Right Curtailments. Staff revealed that the 2015 TUCP Orders had reduced regulatory outflow by 78% to allow export pumping to increase by 46%. Increasing water exports is apparently a higher priority to the SWRCB than protecting water quality, critical habitat for listed species and public trust resources.

Violations Are Likely to Cause or Contribute to Extinction of Species

Since DWR's State Water Project began exporting water from the Delta, the DFW Fall Midwater Trawl indices for striped bass, Delta smelt, longfin smelt, American shad, splittail and threadfin shad have declined by 99.7, 97.8, 99.9, 91.9, 98.5 and 97.8 percent, respectively. The U.S. Fish & Wildlife Service's (USFWS) Anadromous Fisheries Restoration Program (AFRP) documents that, since 1967, in-river natural production of Sacramento winter-run Chinook salmon and spring-run Chinook salmon have decline by 98.2 and 99.3 percent, respectively, and are only at 5.5 and 1.2 percent, respectively, of doubling levels mandated by the Central Valley Project Improvement Act, California Water Code and California Fish & Game Code. Numerous species have been listed pursuant to state and federal endangered species acts.[1]

Populations of Bay-Delta fisheries plummeted during the 1987-1992 period and have never recovered from the impacts resulting from the serial violations of water quality objectives. Winter-run Chinook salmon were listed as threatened under the federal ESA emergency interim rule and endangered under the California Endangered Species Act (CESA) in 1989. Delta smelt were listed as threatened under both state and federal endangered species in 1993. Many of the noxious invasive species that have been identified as adversely impacting native fisheries became established and/or entrenched during that period.

The estuary's pelagic and anadromous fisheries have continued to decline since the 1987-1992 period. And now, the further weakening of water quality standards in 2013-2015 threatens to catapult several species into extinction.

For example, the 2014 Fall Midwater Trawl, 2015 Spring Kodiak Trawl and Summer Townet Delta smelt indices were the lowest in history. The Summer Townet index for Delta smelt was 0.0. Trawl #8 of the 20-mm Survey, conducted in late June, found only a single Delta smelt in Sacramento River at Threemile Slough, no longfin smelt and few striped bass. Compared to 2012, the 2015 trawl #8 of the 20-mm Survey catch-per-unit-effort of Delta smelt, striped bass and longfin smelt were down 98.9, 98.0 and 100 percent, respectively. Perhaps most alarmingly, the Survey identified no Delta smelt in Cache Slough and the Sacramento Deep-Water Ship

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[1] Southern DPS green sturgeon (*Acipenser medirostris*), federal threatened, candidate for federal endangered; Delta smelt (*Hypomesus transpacificus*), state endangered, federal threatened, Longfin smelt (*Spirinchus thaleichthys*), state threatened; Central Valley steelhead (Oncorhynchus mykiss), federal threatened; Sacramento winter-run Chinook salmon (Oncorhynchus tshawytscha), state endangered, federal endangered; Central Valley spring-run Chinook salmon (Oncorhynchus tshawytscha), state threatened, federal threatened; Central Valley fall/late-fall-run Chinook salmon (*Oncorhynchus tshawytscha*), federal species of concern, state species of special concern; Sacramento splittail (*Pogonichthys macrolepedotus*), state species of special concern; Pacific lamprey (*Entosphenus tridentate*), federal species of concern and river lamprey (*Lampetra ayresi*), state species of special concern. The state and federal Project also have the potential to adversely affect Killer whales or Orcas (Southern Resident DPS) (*Orcinus orca*), federally listed as endangered because they are dependent upon Chinook salmon for 70% of diet and reduced quantity and quality of diet is one of the major identified causes of their decline.

Channel and trawl #9 found only one. The northern population of Delta smelt seems to have, as expected, succumbed to excessive temperature.

Delta smelt are at extreme risk of imminent extinction. There are multiple threats to the Delta Smelt population that contribute to its vulnerability and risk of extinction. Chief among these threats are reductions in freshwater inflow to the estuary; loss of larval, juvenile and adult fish at the state and federal Delta export facilities and urban and agricultural water diversions; direct and indirect impacts of the Delta Smelt's planktonic food supply and habitat; and lethal and sub-lethal effects of warm water and toxic chemicals in Delta open-water habitats.

Weakened water quality objectives and failure to enforce objectives have significantly reduced Delta outflow, increased Delta salinity and moved the Low Salinity Zone further upstream (eastward) into the Delta, thereby increasing the degree of each of these threats. Presently, remnants of the population are confined to a small area of the Low Salinity Zone where water temperatures have been significantly above levels identified in the literature as highly stressful and barely below the lethal endpoint.

The continued violations of Bay-Delta Plan and D-1641 objectives and requirements are an obvious and direct threat to the remnants of Delta smelt living in the Low Salinity Zone. Allowing these "weakened standards" to be violated is a direct disregard for the remaining population, placing them under extraordinary risk by bringing them further into the zone of water diversions, degrading their habitat into the lethal range of water temperature, further degrading their already depleted food supply, and increasing the concentrations of toxic chemicals being discharged into the Delta.

The various Biological Reviews, agency concurrence letters and the SWRCB's TUCP Orders acknowledge the manifold threats to Delta smelt and other estuarine species but dismiss them and disregard the consequences of further weakening of already inadequate standards.

USBR's March Biological Review for Endangered Species Act Compliance with the WY 2015 Drought Contingency Plan April through September, submitted to the SWRCB and fish agencies, acknowledged that the Delta smelt population had plunged to an all time low. It observed that drought impacts Delta smelt by reducing the area of low salinity habitat and food availability, impacting reproductive potential impairing fecundity, and reducing turbidity, thereby limiting predator avoidance. It pointed out that warm, slow-moving water promotes conditions in which parasites and toxic *Microcystis* blooms thrive, and that non-native Delta smelt predators, like black bass, and food competitors, like *Corbicula*, have increased during the present drought. It admitted that Delta smelt have a strong positive association with the position of X2 and that under the TUCP Delta smelt would not be in areas optimal for growth and survival because X2 would move further upstream.

With respect to longfin smelt, the USBR biological review observed that the TUCP will reduce outflow and that increased outflow is one of the best predictors of longfin smelt year class strength. Consequently, it is likely that the TUCP will exacerbate poor longfin smelt recruitment and survival and that longfin smelt larvae will have an increased risk of entrainment into the south Delta where they are not expected to survive warming water temperatures.

Despite knowing that smelt were already at historically low abundances, that the drought had increased already deleterious conditions, and that further reductions in outflow would exacerbate impacts, the USBR and DWR proposed the TUCP on 24 March 2015 and requested agency concurrence. Incredibly and inexplicably, the USFWS and CDFW, acutely aware that subsequent fish surveys had revealed a catastrophic collapse in population abundance and knowing that the Biological Opinions assumed compliance with D-1641 criteria and that there were significant "uncertainties" in the conclusions of the Biological Review, issued brief, cursory three-page concurrence letters three days latter, on 27 March, that claimed that reducing Delta outflow by 25 to 40% below D-1641 critical dry year criteria would not jeopardize the continued existence of smelt.

Of course, senior agency supervisors made these decisions. And we know, from private discussions with fishery agency staff, that the senior agency supervisors, many of whom participate in the secret weekly meetings of the Real-Time Drought Operations Management Team (RTDOT), ignored and rejected the recommendations and pleas from biological and technical staff that the TUCPs posed a threat to the continued existence of these species. Over the last several years, we have consistently told the SWRCB what would occur should they approve the various TUCPs. Sadly, the results from subsequent fish surveys and trawls establish that we were right and the SWRCB, USBR, DWR and fishery agencies were wrong!

The SWRCB was acutely aware of the adverse consequences of approving the recent TUCP. The 3 July 2015 TUCP Order acknowledges on pages 12 and 13:

> "The extreme drought conditions that have been occurring for the last four years are having significant impacts on fish and wildlife," Delta smelt indices "…*are at record low numbers*," "*Delta smelt have a strong positive relationship with a specific location in the low salinity zone (LSZ) referred to as X2*…" and "*...habitat quality and quantity diminish the more frequently and further the LSZ movers upstream*…" It points out that "…*there are likely to be few adult Delta smelt that live through the summer*…" and "…it *appears fish density has become so low that the SKT (Spring Kodiak Trawl) has reached or gone below its minimum effective detection ability*," and that in supplemental USFWS in sampling in the lower San Joaquin River "catch of *adult Delta smelt declined precipitously to zero in the final month of sampling*." Emphasis added.

The 3 July 2015 TUCP Order, discussing the biological reviews, observes on page 14:

> The proposed TUCP changes will have effects on physical habitat and water quality which may affect Delta smelt. The changes *will add to the already unfavorable conditions* related to the dry conditions. The Biological Review finds that reductions in inflows and outflows associated with the changes to Delta outflow, Western Delta agricultural salinity and Sacramento River flows may *reduce the general quality of habitat conditions throughout the Delta*. Further, survival of Delta smelt that are currently in the interior and North Delta may be *reduced through increased exposure to degraded habitat and predators and increased travel time for migrating fish*. In the lower San Joaquin River, the upstream relocation of X2 may result in a greater proportion of the

> available habitat encompassing areas of high semi-aquatic vegetation and associated low turbidities. This could result in lower prey availability and higher predation rates on juvenile Delta smelt. Further constraining Delta Smelt closer to the upstream spawning areas in the lower Sacramento River, San Joaquin River, and the Cache Slough Complex/SDWSC *will increase Delta smelt exposure to less favorable conditions.* Conditions in these regions are generally warmer in the summer than locations further west due to prolonged heat waves and less marine influence. Juvenile Delta smelt may be able to reside in thermal refugia to reduce these effects, but *it is not clear how long that cool water refugia will be available this summer*. In addition, due to the more upstream location of X2, it is also likely that summer *Delta smelt distributions will not be in areas for optimal growth and survival* further west in Suisun Bay. Reduced inflows and outflows may also *affect Delta smelt's ability to move downstream to cooler habitats* with more food resources. These effects could *pose additional risks to the persistence of local populations.* Emphasis added.

With respect to estuarine habitat and species, the 3 July 2015 TUCP Order on page 15 observed:

> The Biological Review focused on species listed under ESA and CESA, but the proposed action is *also likely to have adverse effects on other beneficial uses protected under D-1641*," "Since most of these species are not afforded the protections of ESA and CESA, *many have undergone population declines over the history of water development in the Bay-Delta*" and "*...decreasing Delta out flow constrains habitat by moving X2 and the LSZ inland* from the shallow, more favorable habitats of Suisun Bay to the deeper, channelized, and less hospitable habitats of the lower Sacramento and San Joaquin Rivers and their confluence. This reduction in habitat quantity and quality *will also likely result in lower survival and recruitment of several other estuarine dependent species*. Emphasis added.

Despite the serious risks of extinction of Delta smelt and other estuarine species, the SWRCB issued the TUCP Order on 3 July 2015. Apparently, the determination to deliver large quantities of water to Sacramento Settlement Contractors similar to the quantities they received over the last several years outweighs the potential extinction of species. In other words, the irrigation of vast tracts of pasture, alfalfa and other low value crops in the Sacramento Valley is more important than the continued existence of species that evolved and prospered over millennia.

Violations of the Federal Clean Water Act

The Code of Federal Regulations, at 40 CFR §131.20 states that the "State shall from time to time, but at least once every three years, hold public hearings for the purpose of reviewing applicable water quality standards and, as appropriate, modifying and adopting standards." The State is required to submit the results of the review to USEPA for review and approval.

Over the last 20 years since adoption of the present standards in 1995, the SWRCB has reviewed the water quality standards pertaining to the Delta only once, in 2006. In the 2006 review, no changes were made in the 1995 standards despite the continued decline of the estuary's pelagic and anadromous fisheries. The present proceeding to review Bay-Delta standards is years away from completion. The SWRCB is in violation of the federal CWA.

Following disapproval of the results from the state's 1991 proceeding to revise the 1978 Water Quality Control Plan, USEPA promulgated specific water quality standards for the Delta. The federal standards are significantly more protective of the ecosystem than present state standards. Even though the SWRCB subsequently issued its present standards in late 1995, the federal standards remain at 40 CFR §131.37. The SWRCB has refused to acknowledge or comply with the federal standards. Consequently, the SWRCB is in violation of the federal CWA.

The SWRCB has failed to comply with state and federal antidegradation requirements in lowering water quality. At a minimum, antidegradation requirements require that water quality standards must protect "fishable" beneficial uses. The SWRCB has undertaken no analysis of the impacts to beneficial uses and the trade-offs or costs between a temporary loss of water to state and federal water contractors to irrigate low value crops like pasture and alfalfa and the decline of fisheries and likely extinction of species. Nor is there any analysis of the relative benefits of weakening water quality standards in order to provide water to state and federal water contractors at the cost of depriving Delta farmers of water and water quality.

USBR and DWR's pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards as successive dry years occur has been amply documented in multiple documents and TUCP proceedings over the last several years. The SWRCB has failed to establish minimum reservoir storage levels that ensure compliance with water quality standards in the event of successive dry years and then routinely weakens those standards when droughts occur.

The numerous violations of water quality criteria enumerated above, the serial weakening of water quality criteria and implementation requirements, the refusal to enforce violations of water quality criteria, the failure to timely review water quality criteria and the approval of the pattern and practice of creating conditions that prevent water quality criteria from being met in sequential dry years constitute violations of the CWA. Consequently, the SWRCB, USBR and DWR have violated the CWA.

Violations of the Endangered Species Act

In enacting ESA, Congress stated that the purpose of the ESA is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." 16 U.S.C. § 1531(b). As part of conserving endangered or threatened species, ESA prohibits the "taking" of any such listed species. 16 U.S.C. § 1538(a)(1)(B). A "take" is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(9). To "harm" a listed species in the context of a "take" includes "[any] act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." 50 C.F.R. § 17.3 (1994). An indirect injury to a listed species through habitat modification also constitutes a “take.” *Babbitt v. Sweet Home Chapter of Communities for A Great Oregon*, 515 U.S. 687 (1995). The 9th Circuit Court of Appeals ruled that “under Sweet Home, a habitat modification which significantly impairs the breeding and sheltering of a protected species amounts to ‘harm’ under the ESA.” *Marbled Murrelet v Pacific Lumber Company*, 83 F.3d 1060 (9th Cir. 1996).

USBR and DWR have operated to a pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards. The SWRCB has operated to a pattern and practice of weakening water quality standards and thereby significantly degrading the habitat and impairing essential behavioral patterns, breeding, feeding, or sheltering of listed species. The SWRCB, USBR and DWR are in violation of the ESA.

Delta smelt and other estuarine species’ abundances have plummeted over the last few years to the point where they are facing the likelihood of imminent extinction. Over this period, the SWRCB has acceded to multiple requests by USBR and DWR to weaken basic minimum standards adopted to protect listed species and their habitats. These serial actions by the SWRCB have seriously modified and degraded the habitat and impaired the breeding and sheltering of listed species to the point of impending extinction.

The fact that USFWS, NMFS and CDFW have routinely issued concurrence letters in response to the TUCPs, frequently within hours or several days of receiving Reinitiation of Consultation requests, cannot be a valid excuse or defense. Since initial listings under EWA or CESA, abundances of listed species have continued to plummet. USFWS, NMFS and CDFW have essentially defined themselves as “capture agencies” and chaperoned listed species on their road to extinction.

Notwithstanding the letters of concurrence from USFWS, NMFS and CDFW that claim these actions are consistent with existing Biological Opinions, nothing in the ESA legally allows or justifies the SWRCB, USBR or DWR to further degrade the habitats of species lingering on the precipice of extinction. Collectively, the excuses, justifications and serial weakening of water quality criteria emanating from the secret RTDOT meetings while the fishery agencies remain embraced in denial as fisheries plummet toward extinction, surely constitute one of the saddest and most wretched spectacles we’ve ever witnessed and could be easily construed as an illegal conspiracy to defraud the public of public trust resources to the benefit of special interests.

A Final Thought

It is not simply water quality, fisheries and public trust resources that have been sent to the scaffold: it is also the public’s security. With the exception of Shasta, water storage in all of the rim reservoirs is significantly below this time last year. Several are already below 1976-1977 levels and others are headed toward historic lows. As of 20 July, storage in the rim reservoirs totaled 5,632,522 AF and was being depleted by 43,703 AF daily or 1,354,796 AF monthly.

Historically, El Nino years have had an equal chance of being dry or wet. Should California experience another dry year, the impacts will be far greater than those endured this year. The

SWRCB's failure to establish minimum reservoir storage levels and its inability to protect the public and public trust resources by saying no to special interests in sequential dry years has placed the state in grave jeopardy. California deserves better.

In Conclusion

We request that the SWRCB immediately use its public trust, constitutional and water rights authorities to require USBR and DWR to comply with D-1641 critically dry year water quality objectives, reduce water deliveries to low value crops in order to meet Bay-Delta objectives and to ensure sufficient reservoir storage to comply with temperature and other water quality objectives, and issue sanctions against USBR and DWR for their willful disregard for public trust resources and Delta beneficial uses. We also request that the SWRCB accelerate the present review of Bay-Delta standards, including a comprehensive balancing of the public trust with competing uses, and provide us a response to our 13 August 2014 complaint regarding illegal diversion by DWR and USBR and petition to adjudicate Central Valley waters.

Thank you for considering these comments and responding to this complaint. If you have questions or require clarification, please don't hesitate to contact us.

Sincerely,

Bill Jennings

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Attachment
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2 August 2015

Mr. Thomas Howard
Executive Director
Ms. Barbara L. Evoy
Deputy Director, Division of Water Rights
State Water Resources Control Board
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VIA: Electronic Submission
Hardcopy if Requested

RE: COMPLAINT: Against SWRCB and USBR for Violations of Central Valley Basin Plan, WR Order 90-05, Clean Water Act, Endangered Species Act, Public Trust Doctrine and California Constitution

Dear Mr. Howard and Ms. Evoy:

The California Sportfishing Protection Alliance (CSPA) hereby submits a complaint against the State Water Resources Control Board (SWRCB) and United States Bureau of Reclamation (USBR) for violations of the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan), violations of WR Order 90-05 and Sacramento River temperature requirements and for violations of the Clean Water Act (CWA), Endangered Species Act (ESA), Public Trust Doctrine and the California Constitution.

Specifically, CSPA alleges that the SWRCB has failed to implement crucial Basin Plan water temperature criteria and CWA requirements protecting water quality and fish and wildlife beneficial uses with respect to USBR’s water rights permits and licenses and has failed to take enforcement actions against USBR’s habitual violations of the Basin Plan, CWA and WR Order 90-05 temperature criteria and requirements. CSPA alleges that USBR has failed to comply with explicit temperature criteria protecting fish and wildlife beneficial uses contained in the Basin Plan, CWA and WR Order 90-05. CSPA additionally alleges that the SWRCB and USBR have failed to comply with their respective responsibilities and obligations under the ESA, Public Trust Doctrine and Article X of the California Constitution.

CSPA incorporates by reference the comments, protests, objections (including exhibits) and workshop presentations submitted and presented over the last two years in the SWRCB drought proceedings related to Temporary Urgency Change Petitions (TUCP) and SWRCB TUCP Orders by CSPA et al., Bay Institute, Sequoia Forestkeeper and Restore the Delta. Those documents can be found on the SWRCB’s State Water Project and Central Valley Project Temporary

Urgency Change Petition webpage under the headings *Comments/Objections/Protests/Petitions for Reconsideration* and *Temporary Urgency Change Petitions and Drought Workshops.*

We file this complaint in the wake of poor natural production of the 2013 brood year of Sacramento River winter-run, spring-run and fall-run Chinook salmon and the destruction of the 2014 year classes. Given the presence of lethal temperatures in the Sacramento River this year that threaten a repeat of last year's disaster, CSPA asks the SWRCB to act expeditiously in responding and in requiring USBR to respond to the allegations herein. CSPA requests that the SWRCB immediately re-establish protective, non-lethal temperature criteria at the Clear Creek compliance point and that the SWRCB require USBR to reduce water deliveries in order to preserve what's left of cold water reserves in Shasta Reservoir. CSPA further requests the SWRCB to issue sanctions against USBR for failure to comply with the Basin Plan, CWA and ESA.

WR Order 90-05 and the initial listing of winter-run Chinook salmon came on the heels of myriad exceedances of temperature criteria and alarming salmon population declines following the drought of 1976-1977 and the initial years of the 1987-1992 drought. Subsequent droughts brought similar population declines followed by only partial rebounds in wetter years that show a parallel long-term decline in anadromous fisheries. Failure to adopt and enforce defensible temperature criteria has been a key factor in the continued decline of Sacramento Chinook salmon to the point where winter-run and spring-run are now threatened with extinction and California's commercial salmon fishery is wholly dependent on grow-and-truck hatchery production for survival.

As discussed more fully below, the Central Valley Regional Water Quality Control Board (Regional Board) established temperature criteria in the Sacramento River, pursuant to the CWA and the SWRCB implemented the temperature criteria in USBR's permits and licenses in WR Order 90-05. In doing so, the SWRCB implemented temperature criteria based on average daily temperatures without determining whether average daily temperatures were protective of aquatic life and, additionally, exempted almost 43% of identified fish spawning habitat from temperature requirements. The SWRCB then ignored the Basin Plan's Controllable Factors Policy and it's own admonition to USBR that water necessary to meet water quality criteria was not available for delivery. When the National Marine Fisheries Service (NMFS) listed winter-run Chinook salmon as threatened under the ESA, the SWRCB ignored the presence of other species and relocated the temperature compliance point further upstream.

Over the next 23 years, the SWRCB participated in back-room temperature management group meetings that recommended ever-changing temperature compliance points, based upon the quantities of water USBR had remaining in storage after deliveries to its water contractors. The SWRCB subsequently approved the recommendations of the temperature management group of which it is a participating member. These approvals generally relocated temperature compliance points further and further upstream, often eliminating as much as 90% or more of spawning habitat protected by the Basin Plan. And despite these yearly concessions, USBR has violated temperature criteria in nearly every year without a single enforcement sanction being issued by the SWRCB.

The SWRCB has ignored USBR's failure to comply with the National Marine Fisheries Service's (NMFS) OCAP Biological Opinion's (BO) Reasonable and Prudent Action (RPA) performance measures regarding end of September carryover storage at Shasta Reservoir and the percentages-of-time USBR is required to meet temperature criteria at specific compliance points. It has sidestepped the BO's RPA drought exception procedures when end of September Shasta storage is projected to be less that 1.9 million acre-feet (MAF). It refuses to address the conflict that exists under these conditions, between USBR delivering "nondiscretionary" water to Sacramento Settlement Contractors and achieving compliance with temperature objectives, despite the fact that the BO observes that these poor conditions "… could be catastrophic to the species, potentially leading to a significant reduction in the viability of winter-run."

The SWRCB is aware that USBR lacks the legal authority to curtail "nondiscretionary" contract water deliveries to Sacramento Settlement Contractors to meet ESA requirements. Despite being notified of a likely conflict between the delivery of this "nondiscretionary" water and compliance with temperature requirements, the SWRCB refused to use its authorities to reduce water deliveries in order to retain sufficient cold water storage necessary to meet temperature criteria. The BO does not address ESA section 7(a)(2) compliance for individual water supply contracts and, consequently, delivery of water that is "nondiscretionary" for the purposes of the ESA is not exempt from ESA section 9 take prohibitions. In effect, the SWRCB has sanctioned the illegal "take" of endangered species by the USBR and Sacramento Settlement Contractors.

USBR's delivery of 1.3 MAF of water to Sacramento River contractors in 2014 depleted limited cold water reserves in Shasta Reservoir leading to significant exceedances of water temperature criterion. The 2014 year classes of Sacramento winter-run, spring-run and fall-run Chinook salmon were virtually destroyed. Although the SWRCB acknowledged that it had made a serious mistake last year, it has inexplicably elected to repeat the mistake in 2015.

Rejecting the politically unpalatable option of reducing water deliveries to Sacramento Settlement Contractors to ensure compliance with temperature criteria, the SWRCB has instead approved USBR's request to increase the temperature compliance target from a daily average of 56ºF to 58ºF. This despite the fact that the NMFS pointed out in April that an increase to 58ºF would result in adverse impacts to incubating winter-run eggs and alevin in redds and that 58ºF was identified in the scientific literature as lethal to incubating salmon eggs and emerging fry. The subsequent concurrence by NMFS because "the plan provides a ***reasonable possibility*** that there will be ***some juvenile winter-run survival*** this year" is an unacceptable and illegal standard of compliance with the BO and ESA. [Emphasis added.]

The SWRCB justified the higher temperature criterion as necessary to preserve cold water in Shasta to avoid depletion of the cold water pool and more devastating impacts later in the year. However, the urgent need to preserve cold water was apparently unimportant to the SWRCB as USBR delivered 366,794 acre-feet (AF) of water in April and May to Sacramento River water contractors while exporting another 312,686 AF in the first five months of the year. Depletions (i.e., water deliveries) between Bend Bridge and Wilkins Slough in June and July of this year totaled another 500,771 AF.

CSPA et al. and others pleaded with the SWRCB to reduce these water deliveries in order to protect cold water storage. The NMFS summed up the situation in their 1 July 2015 concurrence letter regarding USBR's temperature management request in observing, "We note that these conditions could have been largely prevented through upgrades in monitoring and modeling, and reduced Keswick releases in April and May." Daily average June/July temperatures in the Sacramento River at the Clear Creek compliance point have been significantly higher this year than they were last year.

As we show below, a 56ºF daily average temperature criterion is not protective of Chinook salmon spawning, egg incubation and fry emergence. The U.S. Environmental Protection Agency (USEPA), the states of Washington, Oregon and Idaho, both North Coast and Central Valley Regional Boards, NMFS, California Department of Fish and Wildlife (CDFW), the Pacific Fishery Management Council and the majority of the scientific literature have either adopted or recommended more restrictive temperature criteria based upon a daily maximum and/or a seven-day mean of daily maximums.

In sum, the SWRCB essentially bases its implementation of temperature criteria for Sacramento River Chinook salmon on the amount of water USBR has left over after supplying its contractors. Notwithstanding the law and the fact that protection, restoration and enhancement of fish and wildlife is a coequal purpose of the Central Valley Project (CVP), water deliveries always come first regardless of water year type.

Should winter-run Chinook salmon, Delta and longfin smelt and potentially several other species that have evolved and thrived over millennia go extinct, it will not be because of drought. It will be because the SWRCB has refused to comply with its responsibilities under the Water Code, CWA, ESA, Public Trust Doctrine and California Constitution.

Sacramento River Salmon Fisheries are in a State of Collapse

The precipitous collapse of the Central Valley's pelagic and anadromous fish populations in recent decades has been extensively documented in our referenced documents and need not be repeated at length here. Numerous species dependent on the Sacramento River for all or part of their life cycle have been listed pursuant to state and federal endangered species acts.[1]

Since 1967-68, the U.S. Fish & Wildlife Service's (USFWS) Anadromous Fisheries Restoration Program (AFRP) documents that, since 1967, in-river natural production of Sacramento River

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[1] Southern DPS green sturgeon (*Acipenser medirostris*), federal threatened, candidate for federal endangered; Delta smelt (*Hypomesus transpacificus*), state endangered, federal threatened, Longfin smelt (*Spirinchus thaleichthys*), state threatened; Central Valley steelhead (Oncorhynchus mykiss), federal threatened; Sacramento winter-run Chinook salmon (Oncorhynchus tshawytscha), state endangered, federal endangered; Central Valley spring-run Chinook salmon (Oncorhynchus tshawytscha), state threatened, federal threatened; Central Valley fall/late-fall-run Chinook salmon (*Oncorhynchus tshawytscha*), federal species of concern, state species of special concern; Sacramento splittail (*Pogonichthys macrolepedotus*), state species of special concern; Pacific lamprey (*Entosphenus tridentate*), federal species of concern and river lamprey (*Lampetra ayresi*), state species of special concern. The Project also has potential to adversely affect Killer whales or Orcas (Southern Resident DPS) (*Orcinus orca*), federal listed as endangered because they are dependent upon Chinook salmon for 70% of diet and reduced quantity and quality of diet is one of the major identified causes of their decline.

winter-run, spring-run and fall-run Chinook salmon have decline by 98.2, 99.3 and 91.2 percent, respectively, and are only at 5.5, 1.2 and 31.6 percent, respectively, of doubling levels mandated by the Central Valley Project Improvement Act, California Water Code and California Fish & Game Code.

The construction of Shasta Dam eliminated the ability of Sacramento River winter-run, spring-run and late-fall-run Chinook salmon to reach the cold spring-fed headwaters of the Upper Sacramento, Pit, McCloud and Fall Rivers to spawn.[2] Before the Dam was constructed, there were an estimated 34,634 spawning sites for winter-run salmon available in the Upper Sacramento, McCloud, and Pit River systems. With the exception of Battle Creek, 100% of the winter-run salmon spawned upriver from the present site of Shasta Dam.[3] Pre-Shasta populations of spring-run salmon once had at least 51,377 spawning sites dispersed throughout the Upper Sacramento, the McCloud, and Pit Rivers (PG&E’s Pit River dams eliminated an additional 7,444 upriver spawning sites without mitigation). Only about 15% of the fall-run salmon generally spawned above the present site of Shasta Dam. Most fall-run spawned within the lower river and its foothill reaches at elevations less than 500 feet. The construction of Shasta Dam eliminated approximately 201 miles of historically available habitat in the Pit, McCloud and Upper (little) Sacramento Rivers.[4]

Shasta/Keswick dams not only eliminated the vast majority of spawning habitat for winter-run, spring-run and late-fall-run Chinook salmon, they eliminated the quality of drought-proof habitat. The remaining habitat is subject to droughts and USBR’s failure to retain sufficient reservoir storage in sequential low water years to meet temperature requirements. Additionally, the remaining spawning habitat is crammed into the 59 miles between Keswick and Red Bluff Diversion Dam (far less in most years) and does not provide necessary spatial separation between overlapping stocks, which leads to superimposition of redds. Under these degraded conditions, it is imperative that every effort be extended to ensure that the quality of remaining spawning habitat is protected. This means complying with temperature objectives for sensitive life stages during critical drought years.

Following the construction of Shasta Dam, significant numbers of winter-run Chinook salmon spawned below Red Bluff. Between 1987 and 1992, 19% of winter-run salmon spawned in the Sacramento River below Red Bluff as far down as Hamilton City. After construction of Red Bluff Diversion Dam in 1964, it was noted that 60% of fall-run Chinook salmon spawned below the Dam.[5] A 1988 DWR report titled *Water Temperature Effects on Chinook Salmon (Oncorhynchus tshawytscha), With Emphasis on the Sacramento River, A Literature Review*

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[2] Yoshiyama RM, Fisher FW, Moyle PB. 1998. Historical abundance and decline of Chinook salmon in the Central Valley region of California. N Am J Fish Manage 18(1998):487–521.

[3] Hallock RJ, Rectenwald H. 1989. Environmental factors contributing to the decline of the winter-run chinook salmon on the upper Sacramento River. In: Northwest Pacific chinook and coho salmon workshop proceedings. Bethesda (MD): American Fisheries Society. p 141–5.

[4] Yoshiyama RM, Gerstung ER, Fisher FW, Moyle PB. 1996. Historical and present distribution of chinook salmon in the Central Valley drainage of California. In: Sierra Nevada ecosystem project: final report to Congress. Volume III: assessments, commissioned reports, and background information. Davis (CA): University of California, Centers for Water and Wildlife Resources. p 309–61.

[5] Hallock, as cited in Lufkin 1991, p 100. Lufkin A, editor. 1991. California’s salmon and steelhead: the struggle to restore an imperiled resource. Berkeley (CA): University of California Press.

reported: “By 1976 spawning activity was nearly uniform in the reaches from Balls Ferry to Keswick, Red Bluff to Balls Ferry, and Hamilton City to Red Bluff. More recent data show that the reach from Hamilton City to Red Bluff receives more spawning activity than do both upper reaches combined.”[6]

SWRCB Order 90-05 limited temperature protection to Red Bluff, excluding 44 river miles and more than half of the then-extant Chinook spawning habitat from temperature protection. This had the effect of shifting spawning upriver. USBR’s failure to provide adequate temperature control on the Sacramento River has pushed spawning ever further upstream. Between 2001 and 2005, only about 1% of winter-run salmon spawned below Red Bluff.[7]

The CDFW annually surveys the Sacramento River to estimate numbers of Chinook salmon that return and spawn. The results are published in annual reports titled *Chinook Salmon Populations for the Upper Sacramento River Basin* and include the results of aerial surveys of spawning redds. CDFW staff recommends using aerial redd data only for comparisons of redd distributions by river sections or for specific needs such as use of a specific area as a spawning location. Aerial redd surveys do not provide complete counts of new redds, but it is assumed that the proportion of redds visible in the various sections during a single flight are identical.

These reports establish that significant Chinook salmon spawning occurs below Red Bluff and, consequently, the Basin Plan’s temperature criteria for the reach between Red Bluff and Hamilton City are both justified and necessary. They also illustrate the compression of salmon spawning that has occurred in the extreme upper reaches below Keswick because USBR has failed to provide adequate cold water flows to meet temperature criteria in the river.

- In 2005, 21.1% of fall-run, 15.2% of spring-run, 9.8% of late-fall-run redds were identified below Red Bluff Diversion Dam and 88.9% of winter-run, 30.3% of fall-run, 29.5% of spring-run, and 51.63% of late-fall-run redds were found above the Highway 44 Bridge in Redding.[8]
- In 2007, 17% of fall-run and 10% of late-fall-run redds were below Red Bluff and 83% of winter-run, 25% of fall-run, 43% of spring-run, and 60% of late-fall-run redds were compressed into the 5 miles above Highway Bridge 44 in Redding.[9]
- In 2008, 6% of fall-run and 10% of late-fall-run redds were found below Red Bluff and 92% of winter-run, 35% of spring-run 56% of late-fall-run and 7% of fall-run redds were compressed into the reach above the Highway 44 Bridge.[10]

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[6] Boles G, Turek S, Maxwell C. 1988. *Water Temperature Effects on Chinook Salmon (Oncorhynchus tshawytscha), With Emphasis on the Sacramento River,* California Department of Water Resources. pp. 2, 18.

[7] OCAP BA, 5-12, 2008.

[8] Killam D, Harvey-Arrison C, Chinook Salmon Populations for the Upper Sacramento River Basin 2005, SRSSAP Technical Report No. 6-3, 2006: California Department of Fish and Game, Summary of Aerial Redd Survey Data 2008, Table 2, p. 9.

[9] Killam D, Kreb B, Chinook Salmon Populations for the Upper Sacramento River Basin 2007, SRSSAP Technical Report No. 08-4, 2008: California Department of Fish and Game, Summary of Aerial Redd Survey Data 2008, Table 2, p. 8.

- In 2011, 11% of fall-run redds were below Red Bluff and 78% of winter-run and 88% of late-fall-run and 34% of fall-run redds were above the Highway 44 Bridge. There were no spring-run aerial flights.[11]
- In 2012, 21% of fall-run redds were observed below Red Bluff and 99% of winter-run and 83% of late-fall-run and 22% of fall-run redds were identified into the reach above the Highway 44 Bridge.[12]

Failure to provide adequate temperatures protective of sensitive life stages of Chinook salmon and the resultant compression of spawning habitat are major factors in the continued decline of the species and the threatened extinction winter-run and spring-run salmon.

Violations of the CWA, Basin Plan, WR Order 90-05 and CVPIA

The Regional Board's Basin Plan was adopted pursuant to the CWA and approved by the EPA. With respect to the Sacramento River, the Basin Plan explicitly states, "The temperature shall not be elevated above 56ºF in the reach from Keswick Dam to Hamilton City nor above 68ºF in the reach from Hamilton City to the I Street Bridge during periods when temperature increases will be detrimental to the fishery." Hamilton City is located at River Mile (RM) 199 on the Sacramento River. These temperature requirements protecting Chinook salmon extend up-river for 103 miles to Keswick Dam (RM 302).

As described above, the construction of Shasta and Keswick Dams eliminated virtually the entire historical spawning habitat for winter-run and spring-run Chinook salmon and forced these species to spawn in the river below Keswick. Historically, only 15% of fall-run Chinook salmon spawned in the Sacramento River upstream of Shasta Dan. The majority spawned in the lower river between Keswick and Hamilton City and until recently more than half spawned in the reach between Red Bluff Diversion Dam and Hamilton City.

The Basin Plan also states that temperature objectives are limited to "controllable factors" and "in determining compliance with the water quality objectives for temperature, appropriate averaging periods may be applied *provided that beneficial uses will be fully protected*." Emphasis added.

The Basin Plan's Controllable Factors Policy states:

> Controllable water quality factors are those actions, conditions, or circumstances resulting from human activities that may influence the quality of the waters of the State that are subject to the authority of the State Water Board or Regional Water Board, and that may be reasonably controlled.

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[10] Killam D. Chinook Salmon Populations for the Upper Sacramento River Basin in 2008, SRSSAP Technical Report No. 09-1, 2009: California Department of Fish and Game, Summary of Aerial Redd Survey Data 2008, Table 3 p. 9.

[11] Killam D. Chinook Salmon Populations for the Upper Sacramento River Basin in 2011, RBFO Technical Report No. 03-2012: California Department of Fish and Game, Summary of Aerial Redd Survey Data 2011, Table 2 p. 15.

[12] Killam D. Chinook Salmon Populations for the Upper Sacramento River Basin in 2012, RBFO Technical Report No. 02-2013: California Department of Fish and Game, Summary of Aerial Redd Survey Data 2012, Table 2, p. 14.

In 1990, the SWRCB issued WR Order 90-05, which implemented the Basin Plan with respect to USBR's water rights and licenses for the CVP. It requires USBR to meet a daily average water temperature of 56ºF in the Sacramento River at Red Bluff Diversion Dam (RM 243) during periods when higher temperatures will be detrimental to the fishery. WR Order 90-05 states that when factors beyond the control of USBR prevent attainment of 56ºF temperatures at Red Bluff Diversion Dam, USBR may, after consultations with the fishery agencies and subject to approval of the SWRCB, designate an upstream location where it can meet the 56ºF requirement.

The SWRCB addressed controllable factors in maintaining cold-water pools for temperature control in WR Order 92-02 (Order Establishing Drought-Related Requirements for the Bay-Delta Estuary During 1992) when it referenced WR Order 90-05, at page 9:

> The State Water Board also has advised the USBR that decisions on water deliveries are subject to the availability of water, and that water should not be considered available for delivery if it is needed as carryover to maintain an adequate cold water pool for the fishery.

WR Order 90-05 ignored and failed to protect the 44 miles of river between Hamilton City and Red Bluff that comprises almost 43% of the spawning habitat protected by the Basin Plan. The Order also violated the Basin Plan when it established an average temperature of 56ºF, without regard to whether daily average temperatures that allow daily exceedances above 56ºF will *fully protect beneficial uses* during critical periods. As we demonstrate below, daily average temperature criteria are not protective of the fishery, as daily maximums can be lethal to fish.

The SWRCB also ignores and violates the Basin Plan's Controllable Factors Policy and its own advice to USBR as it approves the yearly Sacramento River Temperature Management Plans (TMPs) submitted by USBR to the SWRCB that shifts the compliance point upstream thereby further restricting the amount of spawning habitat available to salmon. As discussed more fully below, in recent years the SWRCB has approved TMPs that establish the compliance point at Clear Creek. This compresses spawning to a 10 mile reach below Keswick: a 90% reduction of Basin Plan and 83% reduction in BO protected spawning habitat. In 2015, SWRCB even violated its average daily 56ºF criterion, when the Executive Officer unilaterally approved an USBR request to raise the temperature standard to a target of 57ºF not to exceed 58ºF.

USBR has consistently operated to a pattern and practice of maximizing water deliveries without regard to reserving sufficient water storage to comply with water quality standards. It schedules water deliveries in the spring based on assumptions of future rainfall and not what was stored from the preceding wet season. The adverse consequences of this reckless policy are magnified during drought sequences. Delivering excessive quantities of water and draining reservoirs to the point of not being able to comply with water quality standards is not a defensible excuse for the failure to provide adequate cold water to protect fisheries. The pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards has been extensively discussed and documented in previous protests, objections and SWRCB TUCP workshops and is referenced and need not be repeated here.

The SWRCB has acquiesced and participated in this pattern and practice. It has disregarded Basin Plan and CWA requirements, relied upon average temperature criteria, approved temperature criteria that permit lethality, excluded significant reaches of identified spawning habitat from requirements to comply with temperature criteria, approved relocated compliance locations based upon USBR's willingness to reserve storage to meet water quality standards, and failed to enforce violations of temperature criteria.

Enactment of the Central Valley Project Improvement Act (CVPIA) in 1992 seems to have been forgotten. Co-equal with water supply, the protection, restoration and enhancement of fish and wildlife are now primary purposes of the CVP. Mitigation for previous dam construction, contributions to efforts to protect the Bay-Delta and the doubling of natural production of anadromous fisheries in Central Valley rivers are now CVP purposes.

Yet, USBR, with SWRCB approval, ignores the CVPIA requirement to achieve a reasonable balance between competing demands, and continues to operate the CVP primarily to deliver water to its customers and only secondarily to protect and enhance fisheries and public trust values. Deliveries to Settlement Contractors cannot take precedence over fish and wildlife requirements because the water rights of both USBR and the Settlement Contractors are subject to compliance with water quality criteria, the reasonable use doctrine and public trust balancing.

Both the SWRCB and USBR appear to regard NMFS' BO for the Long-Term Operational Criteria and Plan for Coordination of the CVP and SWP (OCAP) as having primacy over the CWA, Basin Plan, WR Order 90-05 and Public Trust Doctrine. Additionally, NMFS appears to believe that its BO protecting Chinook salmon spawning on the Sacramento River is subservient to USBR's desires to maximize water deliveries to its Settlement Contractors.

The NMFS OCAP BO's Reasonable and Prudent Action (RPA) 1.2.1 (page 592) establishes performance measures for temperature compliance points and End-of-September (EOS) carryover storage that must be attained.

Performance measures for EOS storage at Shasta Reservoir include:

- 87 percent of years: Minimum EOS storage of 2.2 MAF
- 82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Ball's Ferry compliance point)
- 40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jerry's Ferry compliance point in the following year)

Review of Shasta Reservoir storage records reveals that, over the last 10 years, USBR has failed to meet the performance requirements. They met the 2.2 MAF EOS storage requirement only 50% of the time, met the 2.2 MAF EOS and 3.8 MAF end-of-April requirement only 60% of the time and met the EOS storage of 3.2 MAF requirement only 30% of the time.

Reasonable and Prudent Action performance measures for temperature compliance points during the summer season, measured as a 10-year running average, include:

- Meet Clear Creek Compliance point 95% of the time
- Meet Balls Ferry Compliance point 85% of the time
- Meet Jelly's Ferry Compliance point 40% of the time
- Meet Bend Bridge Compliance point 15% of the time

Review of daily average temperature data for the Clear Creek compliance point (RM 292), Balls Ferry (RM 276), Jelly's Ferry (RM 266) and Bend Bridge (RM 258) compliance points reveals that, between 2007 and 2015, there were temperature exceedances at Bend Bridge and Jelly's Ferry in all years, exceedances at Ball's Ferry 66.6% of the years and exceedances at Clear Creek 55.5% of the years.

The NMFS OCAP BO's RPA 1.2.3.C (page 600) establishes drought exception procedures if the February forecast, based on 90% hydrology, shows that the Clear Creek temperature compliance point or 1.9 MAF Shasta Reservoir EOS storage is not achievable. Under these conditions, there is clear potential that minimal requirements for winter-run egg survival and spring-run spawning requirements will not be achieved due to depletion of the cold water pool, resulting in temperature-related mortality to both winter-run spring-run salmon. The BO's effects analysis concludes that these conditions could be catastrophic to the species.

Consequently, RPA 1.2.3.C requires preparation of a contingency plan, relaxation of Wilkins Slough criteria to at most 4,000 cfs and:

> *Notification to State Water Resources Control Board that meeting the biological needs of winter-run* and the needs of resident species in the Delta, *delivery of water to nondiscretionary Sacramento Contractors* and Delta outflow requirements per D-1641, *may be in conflict* in the coming season and *requesting the Board's assistance* in determining appropriate contingency measures, and *exercising their authorities* to put these measures in place. [Emphasis added.]

The BO makes clear that an appeal to the SWRCB was necessary because Sacramento Settlement Contractor withdrawal volumes of water from the river can be substantial and because the court had concluded that USBR did not have discretion to curtail deliveries to Sacramento Settlement Contractors to meet federal ESA requirements. Unfortunately, while the SWRCB has the authority to reduce water deliveries to Settlement Contractors, it has demonstrated in this and previous droughts that it lacks the political will to do so.

Review of Shasta storage levels and deliveries to Sacramento Valley Contractors reveals that in the second drought year of 2013, USBR delivered 1.6 MAF to Sacramento Settlement Contractors and 249 TAF to Tehama-Colusa Canal, thereby drawing down EOS storage to only 1.9 MAF. In the third drought year of 2014, with a February projection of Shasta EOS storage to be less than 1.9 MAF, USBR delivered 1.99 MAF of water to Sacramento Settlement Contractors and Tehama-Colusa Canal drawing down Shasta EOS storage to only 1.16 MAF. Failure to meet temperature criteria in 2014 devastated the winter-run, spring-run and fall-run year classes.

In the fourth drought year of 2015, USBR scheduled 75% of contracted water deliveries on 27 February despite a February projection of Shasta EOS storage of only 903 TAF. In April and May, USBR delivered 337,339 AF of water to the Settlement Contractors and 36,898 AF to the Tehama-Colusa Canal, forcing USBR to request that the SWRCB increase the 56ºF temperature criterion at Clear Creek compliance point to 58ºF. In April 2015, the NMFS said that the fishery agencies believed an increase in the temperature criterion to 58ºF would result in significant impacts and a likelihood of adverse impacts to incubating winter-run eggs and alevin in redds compared to a daily average of 56ºF. But, by 1 July 2015, NMFS had been ***persuaded*** that an increase to 58ºF was consistent with the BO because there was a ***reasonable possibility*** that there would be ***some juvenile winter-run survival*** this year.

USBR's continuing lack of compliance with temperature requirements is illustrated in a review of Sacramento River temperature control history in the NMFS' OCAP BO. Figure 6-18, on page 263, titled *Historical exceedances and temperature control point locations in the upper Sacramento River from 1992 through 2008* shows Shasta storage, the starting compliance point and changes in temperature compliance points and the reasons for the changes. It reveals that compliance points were frequently moved, often multiple times in a single year, in response to exceedances of water quality criteria. Compared with recent actions discussed below, not much has changed: the compliance point is a floating target that is frequently relocated because it is dependent upon how much water USBR is prepared to provide to comply with water quality criteria and protect fisheries.

The rationale and justification for meeting temperature criteria is described in the OCAP BO at Page 91, Section 4.2.1.2.3.3.4 titled *Water Temperatures for Successful Spawning, Egg Incubation, and Fry Development.* It states:

> Reclamation releases cold water from Shasta Reservoir to provide for adult winter-run migration, spawning, and egg incubation. *However, the extent winter-run habitat needs are met depends on Reclamation's other operational commitments, including those to settlement contractors, water service contractors, D-1641 requirements, and projected end of September storage volume. Based on these commitments, and Reclamation's modeled February and subsequent monthly forecasts, Reclamation determines how far downstream 56ºF can be maintained and sustained throughout the winter-run spawning, egg incubation, and fry development stages. Although WRO 90-05 and 91-1 require Reclamation to operate Keswick and Shasta dams, and the Spring Creek Powerplant, to meet a daily average water temperature of 56ºF at RBDD, they also provide the exception that the water temperature compliance point (TCP) may be modified when the objective cannot be met at RBDD. In every year since the SWRCB issued WRO 90-05 and 91-1, operations plans have included modifying the RBDD compliance point to make best use of the coldwater resources based on the location of spawning Chinook salmon* (CVP/SWP operations BA page 2-40). Once a TCP has been identified and established, it generally does not change, and therefore, water temperatures are typically adequate for successful, egg incubation, and fry development for those redds constructed upstream of the TCP. *However, the annual change in TCP has degraded the conservation value of spawning habitat (based on water temperature).* [Emphasis added.]

Regardless of the OCAP BO's description of how USBR views its obligations to deliver water or the process of by which temperature compliance points are selected, it is USBR's ultimate responsibility to comply with the legal water quality criteria in the Basin Plan that was developed pursuant to the federal CWA and approved by USEPA as a condition of operations. USBR is not entitled to operate its project in violation of legal requirements simply because it is the USBR.

The approval of fishery agencies cannot be legally employed as an excuse for USBR's not complying with water quality standards. Nor is the SWRCB's failure to incorporate the full water quality protections in the Basin Plan a defensible excuse. Delivering contracted water and drawing down reservoir levels and depleting cold water storage to the point of not being able to meet temperature requirements is a controllable factor. USBR's contracts for delivering water are predicated on compliance with water quality standards, and USBR's desire to maximize water deliveries and the SWRCB's lack of political will to reduce deliveries to Sacramento Settlement Contractors cannot be used to justify failure to comply with the law.

Yet, over the years, USBR, the fishery agencies and SWRCB have gathered together in secret rooms to determine temperature compliance points. The Sacramento River Temperature Task Group (SRTTG) advises USBR on the best course of action to take regarding temperature compliance, based on fish surveys, real-time data and temperature modeling all functioning within the limits of the quantity of water USBR is willing to provide. The SRTTG is comprised of the USFWS, NMFS, CDFW, SWRCB, Western Area Power Administration and the Hoopa Tribe. A TMP is prepared yearly and submitted to the SWRCB for approval.

In an interesting conflict of interest conundrum, the SWRCB participates in the SRTTG that devises and recommends a TMP and then the SWRCB, as a regulatory agency, evaluates and approves the recommendation that is always less protective than CWA/Basin Plan requirements.

In 2009, the SRTTG set the temperature compliance point at Airport Road (RM 284) in Anderson, thus eliminating 85 miles of spawning habitat protected by the Basin Plan, 41 miles protected by the WR Order 90-05 or 26 miles under the BO. In 2010, Shasta Reservoir received above normal inflow and filled. The SRTTG set the temperature compliance point at Jelly's Ferry (RM 267), eliminating 68 miles of spawning habitat protected by the Basin Plan, 24 miles protected by WR Order 90-05 and 9 miles under the BP.

The SRTTG Annual Report for 2011 revealed that temperature compliance was targeted at Balls Ferry (RM 276) until 1 June and Jelly's Ferry (RM 266) until 31 October. Shasta Reservoir had 3.99 MAF of water, as of 1 April 2011, and inflow was expected to be above average. Yet USBR claimed that 56ºF temperatures could not be met at Red Bluff during a wet year and, with the approval of the fishery agencies, eliminated 61% of spawning habitat from any temperature requirement until 1 June and subsequently eliminated 46% of spawning habitat in the critical spawning period for winter-run Chinook salmon.

The 2011 Independent Panel report, as quoted in the 2012 SRTTG Annual Report observed:

> The TCP at Bend Bridge, which is required to be met only 15% of the time (i.e., 1.5 yrs out of 10), has not been met in either this or the previous year. *If the TCP at this location*

> *was not met in WY2011 –one of the least challenging years in terms of available reservoir storage – it seems unlikely that it can be met in any year.* [Emphasis added.]

In 2012, the temperature compliance point began at Jelly's Ferry (RM 266) was moved up to Balls Ferry (RM 276) and ended the year at Jelly's Ferry. The 2012 SRTTG Annual Report also highlighted another problem: when high releases to meet delivery and temperature requirements are dramatically reduced following the close of the irrigation and temperature control seasons, there is considerable dewatering of fall-run and late-fall-run Chinook salmon redds.

In 2013, the SRTTG recommended and USBR operated to meet an initial temperature compliance point at Balls Ferry (RM 276), but in June it was moved upstream to Anderson (RM 284). The 2013 SRTTG Annual Report demonstrated how relocating temperature compliance points upstream compressed spawning. In 2012, 63.6% of fall-run and 95.9% of late-fall-run Chinook salmon spawned in the 26 miles between Keswick and Balls Ferry and, in 2013, 98.4% of winter-run Chinook salmon spawned in the 3 miles between Keswick and the ACID Dam, with another 22.5% above the Highway 44 bridge. It also reported that 35% of monitored fall-run redds were dewatered when flows were abruptly reduced from 7,000 to 4,000 cfs in WY2013 and that 8,011 fall-run and 650 winter-run salmon were observed stranded by CDFW crews between 7 February 7 and 4 April 2013.

In 2014, the SRTTG established a temperature compliance point at Clear Creek (RM 292), with the approval of the SWRCB Executive Director. This provided 10 miles of spawning habitat but eliminated 34 miles of spawning habitat under the BO, 49 miles of spawning habitat under WR Order 90-05 and 93 miles of spawning habitat protected under the Basin Plan. However, flawed modeling and reckless mismanagement prevented USBR from even protecting this upper 10 miles of spawning habitat. The cold water pool in Shasta Reservoir was depleted because USBR delivered 1.2 MAF of water to Sacramento Settlement Contractors and 119 TAF to the Tehama-Colusa Canal and exported 1.5 MAF via the Jones Pumping Plant in the Delta during 2014, the third year of the drought. Shasta Reservoir was drawn down to 1.05 MAF by January 2015.

With cold water depleted, the temperature objective was exceeded and 100% of the winter-run Chinook salmon redds were exposed to temperatures above 56ºF. It is estimated that 95% of winter-run, 98% of fall-run and virtually all of the spring-run Chinook salmon brood year was lost because of the USBR's failure to comply with temperature objectives.

On 6 April 2015, the SWRCB Executive Director directed USBR to prepare and implement a 2015 TMP for the Sacramento River for the protection of winter-run, Chinook salmon and other salmonids. USBR submitted a draft TMP in mid-April and an updated plan on 4 May 2015. The Executive Director provisionally approved the TMP on 14 May. USBR subsequently informed the SWRCB that it could not meet the 56ºF temperature requirement at Clear Creek, and the Executive Director suspended his approval of the TMP on 29 May. The SWRCB held a workshop on 24 June, where CSPA, NRDC and the Bay Institute provided highly critical comments on the proposed TMP. USBR submitted a revised TMP on 25 June, the NMFS provide a concurrence letter on 1 July and the Executive Director approved the TMP on 7 July 2015.

The approved TMP set a daily average temperature target of 57ºF at Clear Creek, not to exceed 58ºF. To preserve cold-water storage, the Order limited Keswick releases to 7,250 cfs in June, July and August, 6,500 cfs in September and 5,000 cfs in October, subject to change in accordance with real-time monitoring and decision-making.

So far in 2015, daily average temperatures at the Clear Creek compliance point averaged 57.3ºF in June and 57.1ºF in July. Daily maximum temperatures at Clear Creek averaged 59.6ºF in June and 59.2ºF in July. USBR violated the not-to-exceed 58ºF weakened daily average criterion on June 16 (58.038), 17 (58.42), 18 (58.19) and 24 (58.18). Based upon the scientific literature, significant instantaneous mortality to the 2015 winter-run Chinook salmon brood class has already occurred, and substantial delayed mortality can be expected to occur.

The fishery agencies initially opposed USBR's proposal to increase temperature limits from 56ºF to 58ºF because they believed it was not protective of early Chinook salmon life stages. NMFS' 15 April 2015 *Evaluation of Alternatives for Sacramento River Water Temperature Compliance for Winter-fun Chinook Salmon* is posted on the SWRCB's website. The Evaluation points out, on page one:

> A requirement in NOAA's National Marine Fisheries Service's reasonable and prudent alternative is to provide water temperatures *no greater than a daily average of 56ºF in the upper Sacramento River to provide habitat needs for various life history stages of Sacramento River winter-run Chinook salmon.* [Emphasis added.]
>
> The fish agencies (NMFS, USFWS, and CDFW) have reviewed various alternatives to temperature compliance, including a targeted daily average water temperature Shasta Dam (e.g., 52ºF or 53ºF) and *increasing the temperature target from 56ºF to 58ºF* at the Sacramento River above Clear Creek CDEC monitoring station (CCR) compliance point after the eggs hatch. As a result of their assessment, the fish agencies *do not think that these alternatives would result in negligible impacts and/or little likelihood of adverse impacts to incubating winter-run eggs and alevin in redds compared to a daily average of 56ºF.* [Emphasis added.]
>
> For example, a heat wave in Redding (>105ºF) with these operation could lead to elevated *temperatures above 56ºF at CCR, leading to potentially significant winter-run egg mortality and sublethal effects.* [Emphasis added.]

Having acknowledged that NMFS, USFWS and CDFW believe that an increase of daily average temperatures from 56ºF to 58ºF would result in adverse impacts, the Evaluation observes, on page 5, that <u>violations occur nearly every year because of USBR commitments to water contractors</u>:

> Even though State Water Resources Control Board Orders 90-5 and 91-1 require Reclamation to operate Keswick and Shasta dams to meet a daily average temperature of 56ºF at Red Bluff Diversion Dam (RBDD) [or at a temperature compliance point (TCP) modified *when the objective cannot be met at RBDD based on Reclamation's other operational commitments including those to water contractors*, D-1641 regulations and

> criteria, and projected end of September storage volume], *nearly every year, Reclamation has exceeded the TCP at some point throughout the temperature control season.* Especially last year, 100% of winter-run brood year 2014 redds were exposed to temperatures above 56ºF degrees at the CCR TCP at some time period during the water year (see Figure 3). Emphasis added.

But USBR, with SWRCB acquiescence, did an end run around the fishery agencies and eliminated all possibility of using Shasta storage to meet a 56ºF temperature criterion, even at Clear Creek. In April and May of this year, USBR, despite pleas from CSPA, Bay Institute, NRDC and others to reduce deliveries in order to protect the cold water pool in Shasta Reservoir, delivered 366,794 AF to the Sacramento Settlement Contractors and Tehama-Colusa Canal and exported an additional 312,686 AF of water from the Delta. These deliveries eliminated any possibility that the water would be used to meet water quality standards and fishery needs.

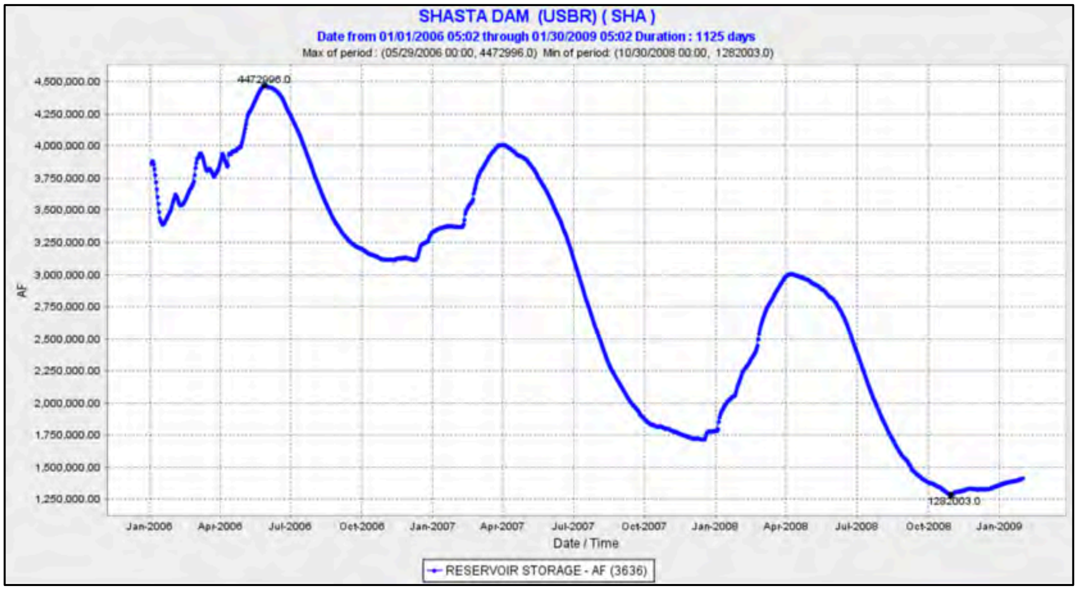
Faced with a *fait accompli* and unwilling to hold their partner accountable for violations of the CWA and ESA, the fishery agencies went along and issued consistency determinations that claimed the TMP was consistent with the BOs. The situation is described in the conclusion of NMFS's 1 July 2015 consistency determination for the TMP:

> NMFS acknowledges that storage in Shasta Reservoir at the beginning of the temperature management season in June, and the quantity and quality of the cold water pool, *will not provide for suitable winter-run habitat needs throughout their eggs and alevin incubation and fry rearing periods*. The base operations plan, including the Keswick release schedule, delayed use of full side gates, and real-time monitoring and decision-making based on winter-run timing, location of redds, air and surface water temperature modeling, and projected versus actual cold water storage conditions and downstream water temperatures, represents the best that can be done with a really bad set of conditions. *We note that these conditions could have been largely prevented through upgrades in monitoring and modeling, and reduced Keswick releases in April and May. Based on extensive analyses of alternative scenarios (6,000 to 8,000 cfs Keswick releases), the plan provides a reasonable possibility that there will be some juvenile winter-run survival this year.* [Emphasis added.]

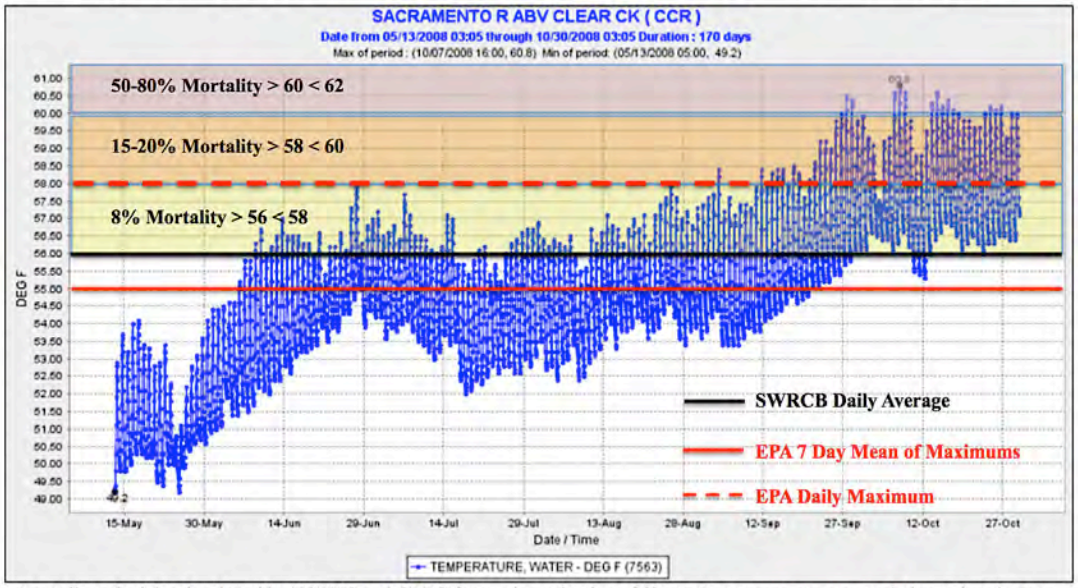
And that's the best that can be hoped for this year, "a reasonable possibility that there will be some juvenile winter-run survival this year." Had USBR and the SWRCB heeded the pleas to not deliver 2.8 MAF of water and draw down Shasta by 1.05 MAF of water last year in the third year of drought, had they heeded the pleas to not deliver 374,237 AF of water to Sacramento Settlement Contractors and the Tehama-Colusa Canal in April and May of this year, had they heeded pleas to not continue to further deplete cold water storage by delivering more than 500,000 AF in June and July to water agencies along the Sacramento River, there might be more than mere hope that some winter-run might survive this year.

But reserving water needed to meet water quality standards and public trust fishery needs has never been a part of USBRs operating protocols. The pattern and practice of draining reservoirs in the initial years of a drought sequence and then either violating water quality and fishery standards or turning to the SWRCB to bail them out of having to comply with water quality standards is deeply ingrained in USBR’s operations. The last two drought sequences illustrate the pattern.

During the drought of 2007-2009, USBR delivered 100% of the contracted water to water contractors along the Sacramento River. Deliveries to Sacramento Settlement Contractors and Tehama-Colusa Canal in 2006, 2007, 2008 and 2009 totaled 1.7, 1.9, 1.9 and 1.8 MAF, respectively. CVP Delta Exports in 2006, 2007, 2008 and 2009 were 2.6, 2.6, 1.8 and 1.9 MAF, respectively. Shasta Reservoir was drawn down from 4.47 MAF in April 2006 to 1.28 MAF in November 2008, leaving insufficient cold water remained to comply with temperature criteria.



Sacramento River Above Clear Creek Temperatures: 15 May – 30 November 2008



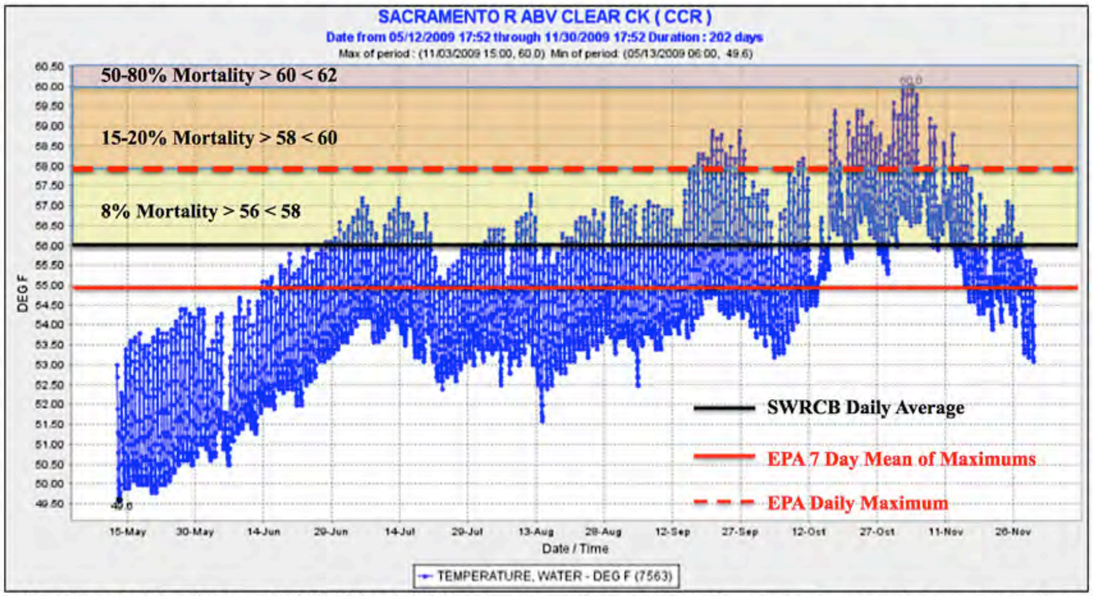
Mortality schedules developed by USFWS and CDFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990 (Richardson et al. 1990).

Winter-run Chinook salmon spawning generally begins in late April and extends into early

August, eggs hatch between late June and middle-to-late September, and fry emerge between late July and late October. Spawning through incubation to emergence are critical life stages.

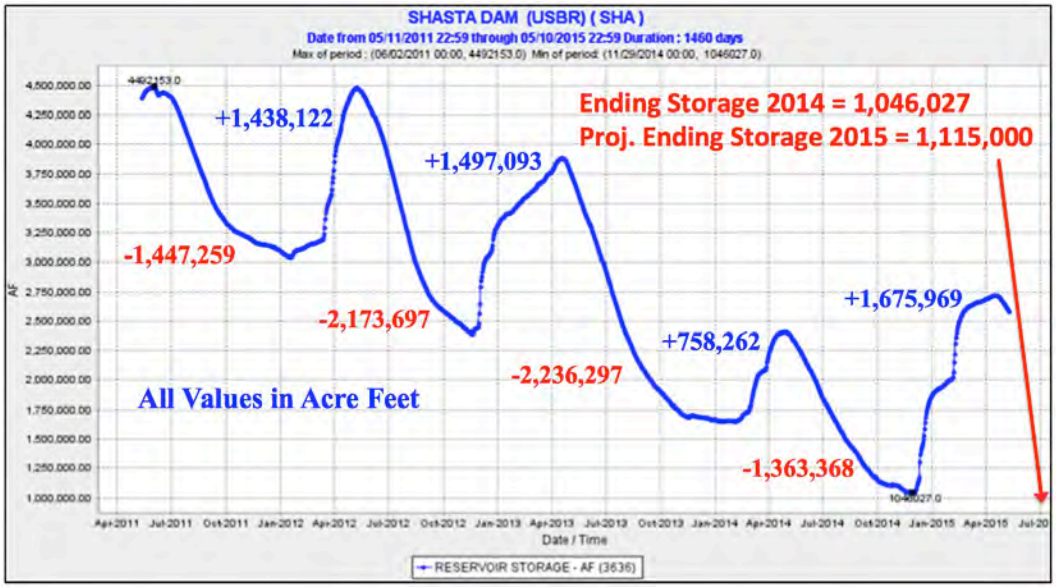
Temperatures at Clear Creek in 2008 ranged into lethal zones during spawning and egg incubation and exceeded even the SWRCB's inadequate daily averages during fry emergence. Temperatures in the 90% of identified spawning habitat below Clear Creek were much higher.

Sacramento River Above Clear Creek Temperatures: 15 May – 30 November 2009



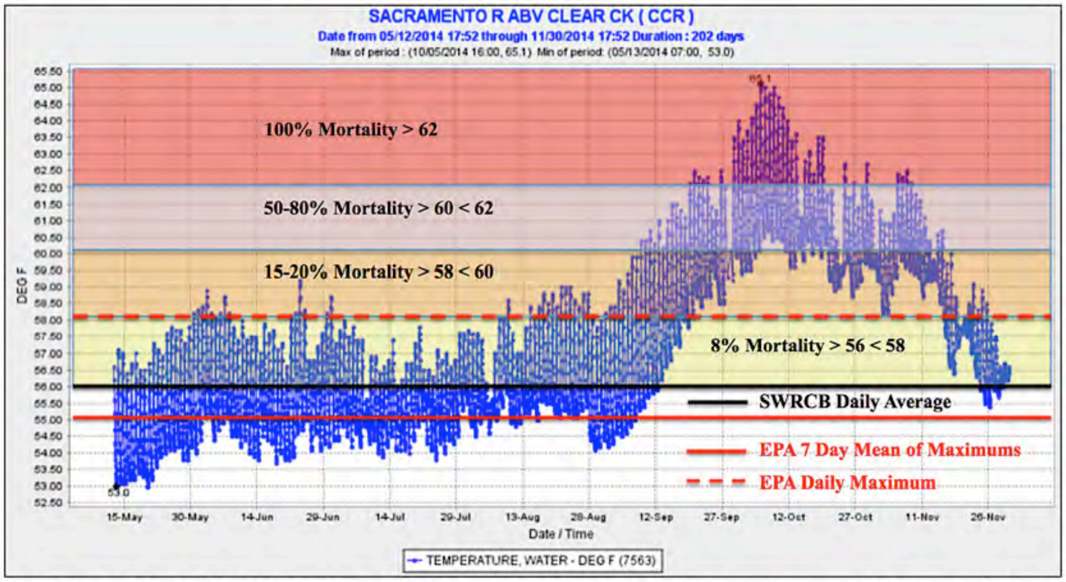
Mortality schedules developed by USFWS and CDFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990 (Richardson et al. 1990).

The pattern repeated itself in 2009 as shown above.



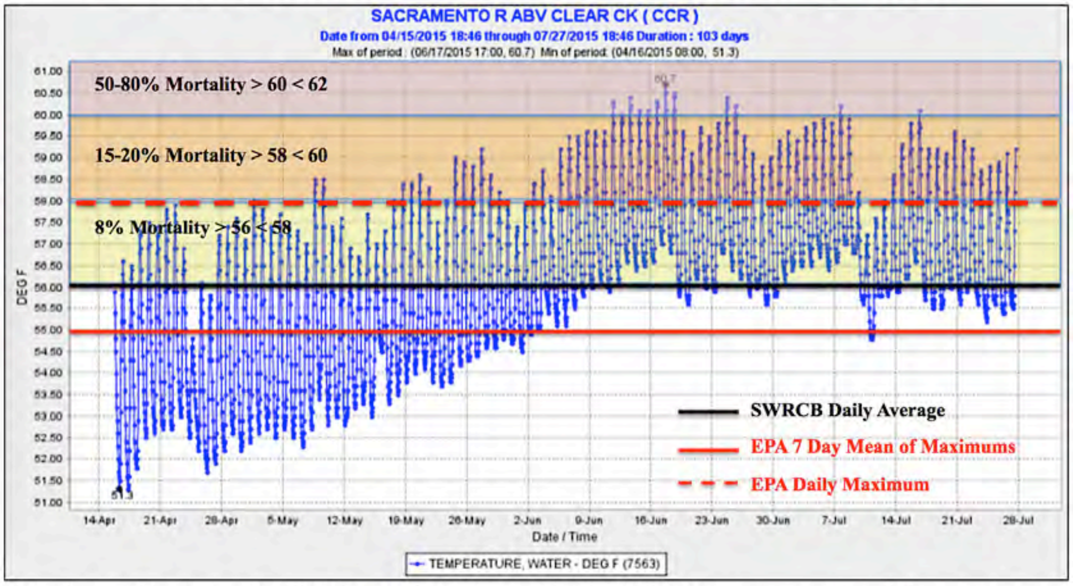
During the present drought, USBR scheduled deliveries of 100% of contracted water to Sacramento Contractors in 2012 and 2013 and 75% in 2014 and 2015. Deliveries to contractors along the Sacramento River in 2012, 2013 and 2014 totaled 1.8, 1.99 and 1.3 MAF, respectively. In 2012, 2013, 2014 and 2015 CVP Delta Exports were 2.1 MAF, 1.5 MAF, 874 TAF, and 334 TAF so far this year. Consequently, end-of-year storage in Shasta Reservoir plummeted.

Sacramento River Above Clear Creek Temperatures: 15 May – 31 October 2014



Mortality schedules developed by USFWS and CDFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990 (Richardson et al. 1990).

Sacramento River Above Clear Creek Temperatures: 15 April – 27 July2015



Mortality schedules developed by USFWS and CDFG for use in evaluation of Shasta Dam temperature control alternatives in June 1990 (Richardson et al. 1990)

Excessive water deliveries in the initial drought years depleted cold water pools in Shasta. Water temperature intruded well into lethal zones during spawning and egg incubation and soared during late incubation are fry emergence. The entire brood years of winter-run, spring-run and fall-run Chinook salmon were devastated.

CSPA has been unable to find a single example of the SWRCB taking an enforcement action against USBR for violations that occur "nearly every year," including the 2014 violations that destroyed an estimated 95% of winter-run, 98% of fall-run and virtually all of the spring-run brood class. Perhaps the SWRCB's participation in the closed-door meetings that recommends TMPs that fail to comply with CWA/Basin Plan requirements precludes it from taking an enforcement action against a fellow SRTTG member for violations of the TMP. This exhibits all of the characteristics of classic "conflict of interest" and "regulatory capture."

Average Temperature Requirements are Not Protective of Chinook Salmon

Following a long extensively peer-reviewed court ordered proceeding, USEPA Region 10 issued *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (Region 10 Guidance) in 2003. The Guidance establishes a recommended criterion of 13ºC (55ºF), as a 7 day average of the daily maximums (7DADM), for Chinook salmon, steelhead and trout spawning, egg incubation and fry emergence, 16ºC (61ºF) for salmon and steelhead "core" juvenile rearing and 18ºC (64ºF) for salmon and steelhead migration plus non-core juvenile rearing. The states of Washington, Idaho and Oregon have established temperature criteria for Chinook salmon spawning through fry emergence as 7DADM 13ºC (55.4ºF, 16ºC (60.8ºF) for salmonid core summer habitat and 17.5ºC (63.5ºF) for salmonid rearing and migration.

The 7DADM protects against not only the lethal effects of elevated temperatures but also the chronic and sublethal impacts that frequently occur in waters that meet weekly average temperatures. High daily maximum temperatures can lead to excessive mortality in waters that still meet weekly averages. Chronic and sublethal effects include reduce juvenile growth, increased incidence of disease, reduced viability of gametes in adults prior t spawning, increased susceptibility to predation and competitions and suppressed or reversed smoltification.

In 2011, USEPA Region 9, in disapproving the SWRCB's 2008-2010 306(d) list of impaired waterbodies, added the San Joaquin, Merced, Tuolumne and Stanislaus Rivers to the 303(d) list as impaired by temperature based partly on the Region 10 guidance and partly on recommendations by the California Department of Fish and Wildlife (CDFG) and the Regional Board, both of which used the Region 10 Guidance and other studies. The USEPA Region 9 letter stated,

> Additionally, EPA believes that EPA's Temperature Guidance values are appropriate for use in the Central Valley. The criteria have been used by California in their 303(d) list recommendation as well as selected as targets in Total Maximum Daily Loads (TMSLs) in the North Coast Regional of California (Carter 2008). They have also been used by National Marine Fisheries Service (NMFS") to analyze the effects of the long term operations of the Central Valley Project and State Water Project, and to develop the reasonable and prudent alternative actions to address temperature-related issues in the Stanislaus River (NMFS 2009a). Reviews of appropriate temperature criteria for use in

> the Stanislaus have yielded findings consistent with the EPA Temperature Guidance values (Deas (2004) and Marston (2003)).

The USEPA Region 9 letter also quoted a 2010 letter from Maria Rea, NMFS, to Alexis Straus (USEPA) that also supports the use of the Region 10 Guidance:

> The use of the US EPA 2003 criteria for listing water temperature impaired water bodies in the San Joaquin River basin is scientifically justified. It has been recognized that salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. There is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards (US EPA 2001). Based upon reviewing a large volume of thermal tolerance literature, McCullough (1999) concluded that there appears to be little justification for assuming large genetic adaptation on a regional basis to temperature regimes.
>
> Although many of the published studies on the responses of Chinook salmon and steelhead to water temperature have been conducted on fish from stocks in Oregon, Washington, and British Columbia, a number of studies were reported for the Central Valley salmonids. Myrick and Cech (2001, 2004) performed a literature review on the temperature effects on Chinook salmon and steelhead, with a focus on Central Valley populations…
>
> It is evident that the difference in thermal response is minimal in terms of egg incubation, growth, and upper thermal limit. Healey (1979, as cited in Myrick and Cech 2004) concluded that Sacramento River fall-run Chinook salmon eggs did not appear to be any more tolerant of elevated water temperature than eggs from the more northern races. Myrick and Cech (2001) concluded that it appears unlikely that there is much variation among races with regard to egg thermal tolerance because data from studies on northern Chinook salmon races generally agree with those from California. They further concluded that fall-run Central Valley and northern Chinook salmon growth rates are similarly affected by water temperature.

In fact, the Myrick and Cech's 2004 study titled *Temperatures effects on juvenile anadromous salmonids in California's central valley: what don't we know?* noted that a recent study on Sacramento River Chinook salmon by the US Fish and Wildlife Service (1999) concurred that fall-run egg mortality increased at temperatures greater than 12ºC (53.6ºF), that winter-run egg mortality increased at temperatures over 13.3ºC (55.8ºF), and that temperatures between 6 and 12ºC appear best suited to Chinook salmon egg and larval development.

Chapter 6, page 2 of USBR's Biological Assessment (BA) for the 2008 Long-Term Operational Criteria and Plan for Coordination of the Central Valley Project and State Water Project (OCAP) contains Table 6-1 titled *Recommended water temperatures for all life stages of Chinook salmon in Central Valley streams as presented in Boles et al. (1988).* Recommended temperatures for Chinook salmon are migrating adult (<65ºF), holding adult (<60ºF), spawning (53-57.5ºF), egg incubation (<55ºF), juvenile rearing (53-57.5ºF) and smoltification (<64ºF). Table 6-2 (page 6-3) titled *Relationship between water temperature and mortality of Chinook salmon eggs and pre-*

emergent fry used in Reclamation egg mortality model shows that instantaneous daily salmon egg mortality begins at 57ºF and instantaneous daily pre-emergent fry mortality begins at 59ºF.

The NMFS 8 March 2012 Biological Opinion for DWR's proposed construction and operation of the South Delta Temporary Barriers Program acknowledges, at page 12, that the "upper preferred water temperature for spawning Chinook salmon is 55ºF to 57ºF (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001)" and the "optimal water temperature for egg incubation ranges from 41ºF to 56ºF (44ºF to 54ºF [Rich 1997], 46ºF to 56ºF [NMFS 1997 Winter-run Chinook salmon Recovery Plan], and 41ºF to 55.4ºF [Moyle 2002]). It noted a "significant reduction in egg viability occurs at water temperatures above 57.5ºF and total embryo mortality can occur at temperatures above 62ºF (NMFS 1997)."

The NMFS 4 June 2009, Chinook Salmon/Sturgeon Biological Opinion for OCAP establishes, on page 621, an RPA for specific temperature criteria to protect steelhead adult migration of (< 56ºF at Orange Blossom Bridge [OBB], 1 Oct – 31 Dec), smoltification (< 52ºF at Knights Ferry and < 57ºF at OBB, 1 Jan – 31 May), spawning and incubation (< 55ºF at OBB), 1 Jan - 31May) and juvenile rearing (< 65ºF, 1 June – 30 September). It states, "Temperature compliance shall be measured based on a seven-day average daily maximum temperature. While NMFS requires USBR to meet specific temperature criteria specified as a 7DADM on the Stanislaus River, it fails to require USBR to meet any specific temperature criteria on the Sacramento River; leaving it to the SRTTG to develop an annual flexible TMP based upon water available after USBR meets its contractor obligations.

The North Coast Regional Water Quality Control Board developed a Klamath River TMDL in 2010. As part of the process, staff conducted an extensive literature review to evaluate temperature needs of the various life stages of steelhead trout, coho salmon and Chinook salmon. The purpose of the review was to identify temperature thresholds that are protective of salmonids by life stage, as a basis for evaluating stream temperatures in California temperature TMDLs within the North Coast region. The results were reported in Appendix 4, Effects of Temperature, Dissolved Oxygen/Total Dissolved Gas, Ammonia, and pH on Salmonids of the Final Klamath River TMDL Staff Report. Table 13, on page 25 of Appendix 4 identifies life stage temperature thresholds for salmonid spawning, egg incubation and fry emergence as 13ºC (55.4ºF), expressed as a MWMT, which is the same as a 7DADM.

The Pacific Fishery Management Council, in a 29 May 2015 letter from its Executive Director Dr. D. O. McIsaac, to SWRCB Executive Director Tom Howard, recommended that the SWRCB insist that USBR actively manage to meet a 56ºF maximum temperature, rather than a 56ºF daily average.

The 2013 SRTTG annual report revealed that NMFS had broached the subject of switching to a 7DADM. It stated on page 12:

> NMFS expressed the idea of tracking the 7-day maximum (7DADM) water temperature in order to determine whether sub-lethal effects on salmonid life history stages (spawning, egg incubation and fry emergence) exist, despite the current temperature requirement metric of a daily average (Appendix B). *The*

> *7DADM metric is recommended by EPA as of 2003 and has been used in other Central Valley rivers (e.g., Stanislaus, Tuolumne, and Merced rivers).* NMFS looked at the 7DADM and what that might mean to the current daily average criterion (Figures 3-6). *7DADM can exceed daily average temperatures by as much as 4ºF at Balls Ferry and as much as 3ºF at Airport Road.* [Emphasis added.]

The report then observed that:

> *SRTTG indicated that a change in compliance metric would require considerable time and effort in negotiations among all of the agencies and the State Water Resources Control Board and a change to decision 90-5.* Emphasis added.

The SRTTG 2013 report then posed the question:

> *How does the Panel view using 7DADM as a measurement to consider potential sub-lethal effects on salmonid life history stages in lieu of daily average temperature?* Emphasis added.

CSPA poses two additional questions: has the SWRCB abdicated its regulatory and public trust responsibilities to the SRTTG and ceded its authority to those it is required to regulate and to the fishery agencies that have chaperoned the continued decline of Chinook salmon in the Sacramento River? Where in the CWA, ESA or the California Water Code is authority granted to USBR, NMFS, USFWS, CDFG, the Western Area Power Administration and the Hoopa Tribe to secretly decide what are the appropriate water quality criteria to protect beneficial uses?

The 2014 SRTTG annual report reiterated NMFS' recommendation but did not mention any discussion or decision related to pursuing a change to a 7DADM temperature standard from the present daily average. It stated on page 16:

> In 2013, NMFS expressed to the SRTTG the idea of tracking 7-day average of daily maximum water temperature in order to determine whether sub-lethal effects on salmonid life history stages (spawning, egg incubation, and fry emergency) exist, despite the current temperature requirement metric of daily average. As explained in Appendix B of the 2013 SRTTG Annual Report of Activities, daily average temperature does not consider the impacts of diurnal temperature changes and daily maximum temperature. The stressful impacts of higher water temperatures on salmonids are cumulative and positively correlated to the duration and severity of exposure. The longer the salmonid is exposed to thermal stress, the less chance it has for long-term survival. Sub-lethal effects from high water temperature can lead to delayed mortality due to reduced fry and smolt sizes from sub-optimal growth. These effects could result in reduced productivity of a stock and reduced population size. As the term suggests, 7-day average of daily maximum (7DADM) reflects an average of maximum temperatures that fish are exposed to in a week long period. Since this metric is oriented to daily maximum temperatures, it can be used to protect against acute and sub-lethal or chronic effects.

It then observed that:

> *7DADM was monitored for WY2014 and it was found that the reported 7DADM temperature was as much as 3ºF higher in the Sacramento above Clear Creek than was shown by the SWRCB's 56ºF average temperature criterion.* Emphasis added.

Violations of the Endangered Species Act

In enacting ESA, Congress stated that the purpose of the ESA is "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved." 16 U.S.C. § 1531(b). As part of conserving endangered or threatened species, ESA prohibits the "taking" of any such listed species. 16 U.S.C. § 1538(a)(1)(B). A "take" is defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(9). To "harm" a listed species in the context of a "take" includes "[any] act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering." 50 C.F.R. § 17.3 (1994). An indirect injury to a listed species through habitat modification also constitutes a "take." *Babbitt v. Sweet Home Chapter of Communities for A Great Oregon,* 515 U.S. 687 (1995). The 9th Circuit Court of Appeals ruled that "under Sweet Home, a habitat modification which significantly impairs the breeding and sheltering of a protected species amounts to 'harm' under the ESA." *Marbled Murrelet v Pacific Lumber Company,* 83 F.3d 1060 (9th Cir. 1996).

USBR has operated to a pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards. The SWRCB has operated to a pattern and practice of weakening water quality standards and thereby significantly degrading the habitat and impairing essential behavioral patterns, breeding, feeding, or sheltering of listed species. The SWRCB and USBR are in violation of the ESA.

As discussed at length above, USBR does not have discretion to curtail water deliveries to Sacramento Settlement Contractors to meet ESA requirements to comply with temperature requirements. The SWRCB has the authority but has refused to use it reduce water deliveries to Settlement Contractors in order to retain sufficient cold water storage necessary for temperature compliance. Both the SWRCB and USBR have failed to ensure compliance with the terms and conditions in the incidental take statement, i.e., that the reasonable and prudent measures in the RPAs and, consequently, are no longer in compliance with the ESA.

The BO does not address ESA section 7(a)(2) compliance for individual water supply contracts and, consequently, delivery of water that is "nondiscretionary" for the purposes of the ESA is not exempt from ESA section 9 take prohibitions. The SWRCB has sanctioned the illegal "take" of endangered species by the USBR and Sacramento Settlement Contractors.

Abundances of anadromous and pelagic species listed pursuant to the ESA have plummeted over the last few years to the point where they are facing the likelihood of imminent extinction. Over this period, the SWRCB has acceded to multiple requests by USBR to weaken basic minimum standards adopted to protect listed species and their habitats and the fishery agencies have acquiesced in issuing concurrence letters, frequently within hours or several days of receiving TUCPs and Reinitiation of Consultation requests. These serial actions have seriously modified and degraded the habitat and impaired the breeding and sheltering of listed species to the point of impending extinction.

For example, a year after violations of temperature criteria had decimated the year classes of Sacramento Chinook salmon, a month and a half after identifying Sacramento winter-run Chinook salmon as one of the eight species in the nation "most at risk of extinction in the near future" and after it had stated than an increase in the temperature compliance target would result in adverse impacts to incubating winter-run eggs and alevin in redds and that 58ºF was identified in the scientific literature as lethal to incubating salmon eggs and emerging fry, the NMFS issued a concurrence letter claiming that that increasing the temperature target was consistent with the BO because "the plan provides a ***reasonable possibility*** that there will be ***some juvenile winter-run survival*** this year." [Emphasis added.] A reasonable possibility that some winter-run might survive is not an acceptable ESA legal standard.

Notwithstanding the letters of concurrence from USFWS, NMFS and CDFW that claim these actions are consistent with existing Biological Opinions, nothing in the ESA legally allows or justifies the SWRCB and USBR to further degrade the habitats of species lingering on the precipice of extinction. Collectively, the excuses, justifications and serial weakening of water quality criteria emanating from the secret SRTTG meetings while the fishery agencies remain embraced in denial as fisheries plummet toward extinction, surely constitute one of the saddest and most wretched spectacles we've ever witnessed and could be easily construed as an illegal conspiracy to defraud the public of public trust resources to the benefit of special interests.

Violations of the Public Trust and Article X of the California Constitution

Article X, Section 2 of the California Constitution provides that:

> The right to water or to the use of the flow of water in or from any natural stream or water course in this state is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of use or unreasonable method of diversion of water.

Because of this Constitutional requirement, the SWRCB must consider the reasonableness of a particular method of diversion of water when evaluating (or reevaluating) all permitted uses of water and the requirements controlling those uses. "The limitations of Art. X, Section 2 … apply to all water users of the state and serve as a limitation on every water right and method of diversion." See *Yuba River D-1644* at p. 29. USBR is a water user subject to Article X, Section 2 in the operation of its respective projects in the Central Valley. The SWRCB's responsibility under the reasonable use doctrine is illustrated in the recent summary of this doctrine by the First District Court of Appeal, in *Light v. SWRCB (2014) 226 Cal.App.4th 1463, 1479–80*:

> Water use by both riparian users and appropriators is constrained by the rule of reasonableness, which has been preserved in the state Constitution since 1928. (Cal. Const., art. X, § 2; hereafter Article X, Section 2.) ... As the Supreme Court recognized soon after Article X, Section 2 was added, the rule limiting water use to that reasonably necessary "appl[ies] to the use of all water, under whatever right the use may be enjoyed." (Peabody v. City of Vallejo (1935) 2 Cal.2d 351, 367–68 (Peabody).) The rule of reasonableness is now "the overriding principle governing the use of water in California." (People ex rel. State Water Resources Control Bd. v. Forni (1976) 54 Cal.App.3d 743, 750 (Forni).)
>
> California courts have never defined, nor as far as we have been able to determine, even attempted to define what constitutes an unreasonable use of water, perhaps because the reasonableness of any particular use depends largely on the circumstances. (Peabody, supra, 2 Cal.2d at p. 368.) "What may be a reasonable beneficial use, where water is present in excess of all needs, would not be a reasonable beneficial use in an area of great scarcity and great need. What is a beneficial use at one time may, because of changed conditions, become a waste of water at a later time." (Tulare Dist. v. Lindsay–Strathmore Dist. (1935) 3 Cal.2d 489, 567.) In this regard, the Joslin court commented, "Although, as we have said, what is a reasonable use of water depends on the circumstances of each case, such an inquiry cannot be resolved in vacuo isolated from statewide considerations of transcendent importance. Paramount among these, we see the ever increasing need for the conservation of water in this state, an inescapable reality of life quite apart from its express recognition in [Article X, Section 2]." ([Joslin v. Marin Municipal Water District (1967) 67 Cal.2d 132, 140 (Joslin)]; see similarly In re Waters of Long Valley Creek Stream System (1979) 25 Cal.3d 339, 354 ["it appears self-evident that the reasonableness of a riparian use cannot be determined without considering the effect of such use on all the needs of those in the stream system [citation], nor can it be made 'in vacuo isolated from statewide considerations of transcendent importance'"].) Few decisions have ruled on the reasonableness of a specific use of water, but in separate cases the Supreme Court has concluded, essentially as self-evident, that the use of water for the sole purpose of flooding the land to kill gophers and squirrels is unreasonable (Tulare Dist., at p. 568), as is the use of floodwaters solely to deposit sand and gravel on flooded land (Joslin, at p. 141.)

And the responsibility and authority of the SWRCB to prevent unreasonable use of water extends to all users, The Board's authority to prevent unreasonable or wasteful use of water extends to all users, regardless of the basis under which the users' water rights are held. ([*California Farm Bureau Federation vs. State Water Resources Control Board (2011) 51 Cal.4th 421, 429].)*

Considering the conditions of drought which are described in the "drought emergency" declared by Governor Brown - the curtailments of water rights, the serial waivers of D-1641 standards to protect fish and wildlife and water quality in the Delta watershed, and the continual weakening of temperature compliance requirements on the Sacramento River - it is time for the SWRCB to declare flood irrigation by agriculture during the drought emergency a waste and unreasonable use until the emergency is over.

If the SWRCB can require urban conservation, it can also require conservation in agriculture. As former SWRCB chief counsel and Delta Watermaster Craig Wilson put it “flood irrigating a field during drought can be considered unreasonable. Flood irrigation in the Sacramento Valley in particular is unreasonable when endangered salmon are facing extinction.

Alfalfa and irrigated pasture alone consumes 8.6 MAF of water in California and provides low net revenue and few jobs. The SWRCB can and must reduce the quantity of water allocated to irrigated pasture and low-value crops like alfalfa that use prodigious amounts of water and have very high “applied water” coefficients relative to other crops during the drought emergency. To continue this use is unreasonable and a waste of water, and must be stopped or reduced until the drought emergency is declared over.

The continued killing of threatened and endangered species by obsolete and non-protective export pumping facilities simply because the state and federal water contractors refuse to pay for new state-of-the-art fish screens is an unreasonable method of diversion. This is especially true when water diverted through those facilities deprives listed species of water and primary production necessary for survival. The SWRCB can and must curtail south Delta exports during the drought emergency until D-1641 water quality standards are met.

The SWRCB must also consider public trust issues in proceedings that concern water rights and water quality based on reserved jurisdiction or under the doctrine of reasonable use. The SWRCB may also modify permits of “the projects” that require the appropriator to reduce the quantity of exports. *United States v. SWRCB* (1986) 182 Cal.App. 3d 82, 124-131. The SWRCB has a complaint procedure that can exercise authority over both federal and state water projects by virtue of having state water rights permits issued by the Board.

The State’s management responsibilities include broad discretion to promote trust uses, such as the continued survival Chinook salmon in the Sacramento River, provided the discretion is exercised consistent with constitutional and statutory constraints. *People v. California Fish Co.* (1913) 166 Cal. 576, 597. While the State has discretion to promote trust issues, the SWRCB has “an affirmative duty” to protect trust resources. See *Illinois Central Railroad v. Illinois,* 146 U.S. 387; and *National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419 (The state may not abdicate its supervisory role any more than the state may abdicate its police power); see also Stevens, The Public Trust: *A Sovereign’s Ancient Prerogative Becomes the People’s Environmental Right,* 14 U.C. Davis Law Review 195, 223.

Fish and wildlife are natural resources unequivocally protected by state sovereignty, whereby ownership of the resource is reserved to the states. *Geer v. Connecticut,* (1896) 161 U.S. 519. The court in *Audubon v. Superior Court,* (1983) 33 Cal.3d. 419 held that “no one may obtain a vested right to undertake an act that is harmful to the trust.” See also *SWRCB D-1644* (Yuba River) at page 29. The supremacy of the public trust over private individuals is reflected in a “judicial presumption against state or legislative alienation of trust resources.” *People v. California Fish*; see also *Illinois Central v. Illinois* (1892) 146 U.S. 387; *Montana v. U.S.*, (1981) 450 U.S.544. Historically, state sovereign ownership was limited to “the traditional triad of uses” – commerce, navigation, and fishing.

However, in 1971 the California Supreme Court expanded the protected uses to cover the environment generally. *Marks v. Whitney* (1971) 6 Cal 3d. 251, 259-260. State sovereign ownership imposes restraints on the state's discretion regarding the use of navigable waters. The use of trust resources must be consistent with the general trust purposes or it is invalid. *State of California v. Superior Court* (Lyon) (1981) 29 Cal 3d. 210, 220-230; *Marks v. Whitney*, supra; *City of Long Beach v. Mansell*, (1970) 3 Cal 3d. 462, 482-485. Preservation of a public trust resource such as the Sacramento River and San Francisco Bay/Delta estuary is a legitimate disposition of the public trust resource, and is consistent with general trust purposes. Thus, tidelands and water may be burdened with a negative easement against any active use or disposition of the trust reserve. Id; *National Audubon*, supra; *State of California v. Superior Court* (Fogerty), (1981) 29 Cal 3d. 240, 249-250.

Consequently, the SWRCB has both the authority and responsibility under its reserved jurisdiction in the permits and licenses of the USBR, and under its continuing authority and responsibilities pursuant to the public trust and reasonableness doctrine to protect fisheries, public trust resources and beneficial uses. To protect those resources and uses, it approved, among other things, the Basin Plan and issued WR Order 90-05 to protect the Sacramento River and issued the Bay-Delta Plan and D-1641 to protect the Sacramento-San Joaquin Delta Estuary.

Unfortunately, the SWRCB has ignored reasonable use and public trust considerations in its decision-making. It failed to analyze, discuss or justify its decision to significantly weaken protection for Sacramento River fisheries as opposed to maintaining near 75% deliveries to Settlement Contractors in its 7 July 2015 Order. The Order is devoid of any analysis and discussion weighing the costs and benefits of sending public trust species into extinction versus fallowing cropland that will be replanted when rains return. There is no economic study of Sacramento Valley agricultural beneficial uses to determine which crops provide important employment and economic benefits relative to crops that require large quantities of water but provide low net economic return and few jobs. Nor is there any analysis of "health and safety" needs and urban uses as opposed to agricultural or environmental.

USBR's pattern and practice of delivering near normal water supplies in the early years of drought, depleting carryover storage and then relying on the SWRCB to weaken water quality standards established to protect public trust resources as successive dry years occur has been amply documented in multiple documents and TUCP proceedings over the last several years. The SWRCB has failed to establish minimum reservoir storage levels that ensure compliance with water quality standards protective of public trust resources. When successive dry years occur, it then routinely weakens those standards, with little regard to its public trust and constitutional obligations.

In WR Order 92-02, the SWRCB previously made clear that water necessary to comply with water quality standards is not available for delivery for consumptive purposes. It must now explain or justify why it now chooses to reallocate that water to the Sacramento Settlement Contractors. Weakening water quality objectives and requirements simply because USBR recklessly delivered water that was otherwise necessary to maintain sufficient carryover storage to comply with water quality objectives and to protect public trust resources and agricultural beneficial uses in the Delta is a violation of Public Trust Doctrine. To send fisheries into extinction while continuing to supply water for low value crops like pasture and alfalfa is an unreasonable use of water and a violation of Public Trust Doctrine and the California Constitution.

It is not the SWRCB's responsibility or legal right to sacrifice public trust resources and the Sacramento River's beneficial uses in order to absolve USBR of the consequences of egregious mismanagement. If customers of water contractors are now suffering because USBR failed to exercise prudence and due diligence in water management and rashly delivered near normal water supplies in initial drought years with little thought that another dry year might occur, it is USBR and not the SWRCB that has the responsibility to alleviate the suffering it caused.

In Conclusion

We request that the SWRCB immediately use its public trust, constitutional and water rights authorities to reduce water deliveries to low valued crops that are further depleting already inadequate cold water reserves, to require USBR to modify operations to ensure that sufficient carryover reserves of cold water necessary to comply with CWA and Basin Plan temperature criteria remain in Shasta Reservoir, and to issue sanctions against USBR for its willful disregard for public trust resources and beneficial uses. We also request that the SWRCB accelerate the present review of Bay-Delta standards, including a comprehensive balancing of the public trust with competing uses, and provide us a response to our 13 August 2014 complaint regarding illegal diversion by DWR and USBR and petition to adjudicate Central Valley waters.

Thank you for your consideration. If you have questions or require clarification, please don't hesitate to contact us.

Sincerely,

Bill Jennings

Bill Jennings, Executive Director
California Sportfishing Protection Alliance

Enclosures
Cc: Felicia Marcus
Frances Spivy-Weber
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Steven Moore
Tom Howard
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1.D.2.3 Attachments to Comments of Natural Resources Defense Council and The Bay Institute

2012 South Delta Chinook Salmon Survival Study

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Introduction

The Vernalis Adaptive Management Plan (VAMP) as part of the San Joaquin River Agreement has been measuring juvenile salmon survival through the Delta since 2000 (SJRGA 2013). Prior to 2000, similar south Delta coded-wire-tag (CWT) studies were funded by the Interagency Ecological Program and others (Brandes and McLain 2001). Since 2008, survival of juvenile Chinook Salmon through, or in, the Delta has been measured using acoustic tags. The main objective of the VAMP was to better understand the relationship between Chinook Salmon smolt survival through the Delta and San Joaquin River flows and combined CVP and SWP exports in the presence of the physical head of Old River barrier (HORB). The San Joaquin River Agreement and the VAMP study ended in 2011.

In 2012, the main objective of the Chinook Salmon survival study was to estimate survival through the Delta during the San Joaquin River Flow Modification Project (USBR 2012), during which the Merced River flows were augmented between April 15 and May 15, and compare it to survival, without the flow augmentation (after May 15), in the presence of the HORB. As part of the National Marine Fisheries Service and California Department of Water Resources Joint Stipulation Regarding South Delta Operations during April and May of 2012 (http://www.westcoast.fisheries.noaa.gov/central_valley/water_operations/ocapstip.html; accessed 8/27/15), the physical HORB was installed in 2012. The barrier had eight culverts in 2012, compared to between two and six culverts as in past years. Funding for this study was provided by the restoration fund of the Central Valley Project Improvement Act, the California Department of Water Resources (CDWR) and the U.S. Bureau of Reclamation (USBR).

These salmon studies also estimated route selection at some channel junctions in the south Delta along the main stem San Joaquin River and provided information on how route selection into some reaches influences overall survival through the Delta to Chipps Island. Recent advances in acoustic technology have allowed investigators to evaluate the influence of route selection and reach-specific survival of salmon to overall survival through the Sacramento-San Joaquin Delta (Perry et al. 2010). In this study, the hypothesis focused on the impact of changes in hydrology with the HORB, as the primary factor relative to juvenile salmon survival however we are aware that many other factors also influence survival through the Delta.

Goals and Objectives

The goal of this study was to determine if there were differences in survival resulting from changes in hydrology (i.e. increased flow) with the HORB installed.

Objectives:

1. Determine survival of emigrating salmon smolts from Mossdale to Chipps Island during two time periods (prior to May 15 and after May 15) in the presence of the HORB to determine if there was a benefit from the flow augmentation from the Merced River in the spring of 2012.
2. Assess whether the higher flows resulted in a reduction in travel time; a potential mechanism for why survival may be higher with higher flows.
3. Identify route selection at HOR and Turner Cut under the two periods with varied flows to determine its effect on survival to Chipps Island in 2012.
4. Assess the influence of flow on survival between Mossdale and Jersey Point with the HOR barrier installed in 2012 and compare it to past years to further evaluate if the increased flow from the Merced River flow augmentation likely resulted in higher smolt survival through the Delta.

Background

Survival during the smolt life-stage was assumed to be the link associated with two statistically significant relationships between San Joaquin basin escapement and 1) San Joaquin River flow at Vernalis and 2) the ratio of San Joaquin River flow to Central Valley Project and State Water Project exports, 2 ½ years earlier (Figures 5-20 and 5-21 in SJRGA 2007). It is these relationships between flow and flow/exports and escapement that are the basis for the hypothesis that increasing flow and decreasing exports during the smolt outmigration would increase adult escapement and production in the San Joaquin basin.

The early, pre-VAMP studies compared survival of CWT Feather River Hatchery (FRH) smolts released into upper Old River to those released on the main stem San Joaquin River at Dos Reis. Dos Reis is located on the San Joaquin River downstream of the head of Old River. These studies were conducted between 1985 and 1990 and suggested that survival was higher for salmon smolts released on the main stem San Joaquin River at Dos Reis than for fish released into Old River (Brandes and McLain 2001). The results of these studies were the basis for recommending a rock barrier at the head of Old River (HORB) to prevent juvenile salmon from migrating down Old River where survival appeared to be less.

CWT releases made at Dos Reis were also used to assess the survival of salmon smolts on the San Joaquin River downstream of Old River. Although it is assumed that fish released at Dos Reis migrated downstream via the main stem San Joaquin River, there is the potential for fish released at Dos Reis to have moved upstream into Old River on flood tides, especially during periods of low San Joaquin River flows and high exports or into the interior Delta via Turner or Columbia Cuts or other downstream connections to the interior Delta. Data from 1989 to 1999 indicated that as San Joaquin River flows increased downstream of Old River, survival increased from Dos Reis to Jersey Point (Figure 5-14 in SJRGA 2007). These data provided the basis for the hypothesis that increased flow in the San Joaquin

River would increase salmon smolt survival. However, with the addition of more recent data (2005 and 2006) from recoveries in the trawls (as there were no or limited recovery data from the ocean fishery due to fishery closures in 2008 and 2009), the strength of this relationship appeared to lessen (Figure 5-13 in SJRGA 2007).

With the HORB in place, the majority of the fish migrating downstream would stay on the main stem San Joaquin River at the junction between the San Joaquin River and the head of Old River. With the HORB, a statistically significant relationship between CWT survival in the reach between Mossdale or Durham Ferry and Jersey Point and San Joaquin River flow at Vernalis has been observed ($r^2 = 0.73$, $p<0.01$; Figure 5-11 in SJRGA 2007), further supporting our hypothesis that increased flow in the San Joaquin River would increase juvenile salmon survival in the Delta.

In 2010, as part of the VAMP peer review, a statistical model was used to model survival through the Delta as a function of flow and exports, based on the CWT releases in the south Delta (Appendix 1). The results of this modeling also suggested survival was generally higher on the San Joaquin River than in Old River and flow tended to improve survival in the San Joaquin River route, but there was a lot of environmental noise (low signal to noise ratio). This modeling also supported our hypothesis that a HORB would improve survival, because it would reduce the number of smolts migrating through Old River.

Conceptual Model

Our hypothesis in 2012 was that survival would increase with increased flow from the Merced River flow augmentation in the presence of the HORB. Flows were an average of 3,543 cfs during the flow augmentation period and 2,327 cfs afterwards. A potential mechanism for increased survival with increased flow is that increased flow results in shorter travel times (i.e. increased migration rates) through the riverine parts of the Delta, and thus reduces the period of exposure to mortality factors such as high water temperature, predation and toxics (Figure 1). Increased flow is also expected to reduce the effect of the mortality factors by 1) decreasing water temperatures to less stressful levels for juvenile salmon, 2) decreasing the impacts of predation due to lower metabolic rates of predators at lower water temperatures and 3) reducing toxicity concentrations through dilution (Figure 1). Survival through the entire Delta (i.e. to Chipps Island) was expected to increase with the higher flows in 2012 as a consequence of higher survival through the riverine portion of the Delta because of these hypothesized relationships.

The higher flows provided by the Merced flow augmentation in 2012 may also have resulted in the tidal prism moving further downstream, because most of the increased flow would have stayed in the San Joaquin River at the head of Old River (HOR) junction with the HORB, in contrast to when there is no HORB and a large majority of the flow moves into Old River at that junction. The shift in the tidal prism's position serves to increase the portion of the Delta that is riverine and the portion of the migration pathway that potentially responds to decreases in travel time in response to increased flow (Figure 1). It is unclear how far the tidal prism would be moved downstream from the increase in flow of approximately 1200 cubic feet per second (cfs) from the Merced flow augmentation in 2012. Additionally, the shifted position of the tidal prism further downstream, which is dependent on the magnitude of the increased flow, could also potentially reduce the proportion of flow and tagged fish that enter Turner Cut (Figure 1). In summary, survival through the entire Delta was expected to increase as the riverine component of the Delta increased and the proportion of water and fish that were diverted into Turner Cut was reduced from a positional shift of the tidal prism downstream from higher flows.

Once fish enter the interior Delta or into the strongly tidally influenced San Joaquin River, residence times are hypothesized to increase and survival is hypothesized to decrease compared to the river reaches. The increased residence times are anticipated to increase the exposure time of juvenile salmonids to predation or other mortality factors. The incremental increase in flow from the Merced River flow augmentation was not anticipated to decrease water temperatures or dilute toxics in the tidally dominant areas of the Delta as much as the riverine reaches because inflow is a much lower proportion of overall flow in these tidally dominated regions. Lastly, the change to the flow patterns at the HOR from the installation and operation of the HORB was expected to result in fewer tagged fish being salvaged or entrained at the CVP and SWP in 2012 because a low proportion of the San Joaquin flow (~ 5%) and tagged fish enter Old River when the HORB is in place.

Study Design and Methods

This study was conducted in conjunction with a separate, but coordinated study assessing the HORB in 2012 (CDWR, 2015). As part of this HORB assessment, other groups of juvenile salmon were tagged with Hydroacoustic Technology Incorporated (HTI) tags prior to, during, and after the salmon tagging as part of this study (with VEMCO V5 tags). While the methods and results of the HTI study will not be discussed in this report, we have listed when the HTI fish were released with our study fish (Table 1).

Sample Size Analyses

A unique sample size analyses was not conducted for the 2012 study, instead we used information derived from the 2011 VAMP sample size analyses to guide release numbers for the 2012 study (SJRGA 2013). For a single release at Durham Ferry it was determined that a sample size of 475 fish would allow estimation of parameters for low route specific survival (0.05), with high detection probability (90-97%) at Chipps Island. To estimate a relative effect of 100%, between two routes (San Joaquin and Old River), 790 fish would need to be tagged with low survival and 410 for medium survival (SJRGA 2013). To estimate a relative effect between the two routes of 50%, 3,510 would need to be released in years with low survival and 1,800 would need to be released in years with medium survival (SJRGA 2013). We did not have the resources to purchase enough tags to provide the power to estimate the relative effects between routes at either of these levels for the two groups released in 2012.

Study Fish

Study fish were obtained from the Merced River Hatchery (MRH) and transported to the Tracy Fish Collection Facility (TFCF) of the CVP on April 20 and May 7 for tagging. Fish were kept in chilled, ozonized, Delta water (14-15 ° C) until 3-4 days before tagging to minimize the progression of proliferative kidney disease (PKD). Low water temperatures inhibit the development of PKD (Ferguson 1981): PKD is progressive at temperatures greater than 15° C (Ferguson 1981). Thus 3-4 days before tagging, tanks holding the fish were slowly switched to ambient Delta water so that they could acclimate to Delta water temperatures prior to tagging and transport to the release site. Fish were sorted such that they were greater than 13 grams (~105 mm forklength [FL]) prior to tagging. Tagged study fish averaged 18.0 grams (SD = 3.7), and 112.8 mm FL (SD = 7.2). Fish were taken off feed 24 hours prior to moving them from MRH to the TFCF and 24 hours prior to surgery.

Tags

Juvenile salmon were tagged with VEMCO V5 180 kHz transmitters that weighed 0.66 grams (g) in air on average (SD = 0.012). Tags were 12.7 millimeters (mm) long, 4.3 mm in height, and 5.6 mm wide (http://vemco.com/products/v4-v5-180khz/; accessed 6/15/15). The percentage of tag weight to body weight averaged 3.8% (SD = 0.7%) for the 960 fish tagged, well below the recommended 5%. Only 3% (34 of the 960 fish) had a tag weight to body weight ratio slightly greater than 5%, with all less than 5.4%.

Tags were custom programmed with two separate codes; a traditional Pulse Position Modulation (PPM) style coding along with a new hybrid PPM/High Residence (HR) coding. The HR component of the coding allows for detection at high residence receivers. High residence receivers were placed where tag signal collisions (i.e. many tags emitting signals at the same time to the same receiver) were anticipated (CVP, CCF). The transmission of the PPM identification code was followed by a 25-35 second delay, followed by the PPM/HR code, followed by a 25-35 second delay, and then back to the PPM code, etc. The PPM code consisted of 8 pings approximately every 1.2 to 1.5 seconds. The PPM/HR code consisted of 1 PPM code and 8 HR codes (all the same for each individual fish) with 8 pings approximately every 1.2-1.5 seconds.

Tags were soaked in saline water for at least 24 hours prior to tag activation. Tags were activated using a VEMCO tag activator approximately 24 hours prior to tag implantation. For the first week of releases, time of activation was estimated to the nearest hour, whereas tag activation was identified to the nearest minute for the second group of releases.

Photo credit: Jake Osborne

Tagging training

Training those who conducted the tagging occurred between April 9 and April 13 at the TFCF using Chinook Salmon from MRH. Three hundred fish were used for training, and were brought to the TFCF on April 4. The training was conducted by staff from the U.S. Geological Survey (USGS)'s Columbia River Research Laboratory (CRRL). During training, the CRRL refined standard operating procedures, (SOP), and trained personnel to surgically implant acoustic tags (Liedtke 2012). Returning taggers received a refresher course on training during which they were required to tag a minimum of 35 fish. New taggers received a more thorough training on surgical techniques and were required to tag a minimum of 75 fish during training. Training included sessions on knot tying, tagging bananas, tagging dead fish and finally tagging live fish, holding them overnight and necropsying them to evaluate techniques and provide feed-back. Lastly, a mock tagging session was held on April 13 to practice logistic procedures and to identify potential problems and discuss solutions.

Tagging

In 2012, two groups of 480 Chinook Salmon were tagged with VEMCO V5 tags over two weekly periods: May 1-5 and May 16-20. Each group of salmon was tagged in 3 days, over a 6 day period; Chinook Salmon were tagged every other day, to facilitate survival comparisons between Chinook Salmon and steelhead (the comparison between salmon and steelhead will not be discussed in this report). Two sessions of tagging were conducted for salmon: one in the morning and one in the afternoon. Morning and afternoon tagging sessions were further divided into shifts with each shift incorporating groups of salmon tagged with either VEMCO or HTI tags. The salmon tagged as part of this study were tagged on May 1, May 3, May 5 and May 16, May 18 and May 20 (Table 1). Tagging was conducted at the TFCF as was done since 2009. Four surgeons were used to tag the fish and each surgeon had an assistant. Three additional individuals (runners) helped to move fish into and out of the tagging operation.

Tags were inserted into the fish body cavity after the fish had been anesthetized with between 6.0 and 6.5 millileters (ml) of tricane methanesulfonate (MS-222) buffered with sodium bicarbonate, until they lost equilibrium. Fish were weighed (to the nearest 0.1 g) and measured to the nearest mm (FL). Surgeries took between 1 minute 20 seconds and 6 minutes 57 seconds, but most were within 2 to 3 minutes. Tagging was done using standard operating procedures (SOP) developed by the CRRL and refined during the training week. The SOP (Appendix 2) directed all aspects of the tagging operation and was based on Adams et al. (1998) and Martinelli et al (1998) and modified as needed.

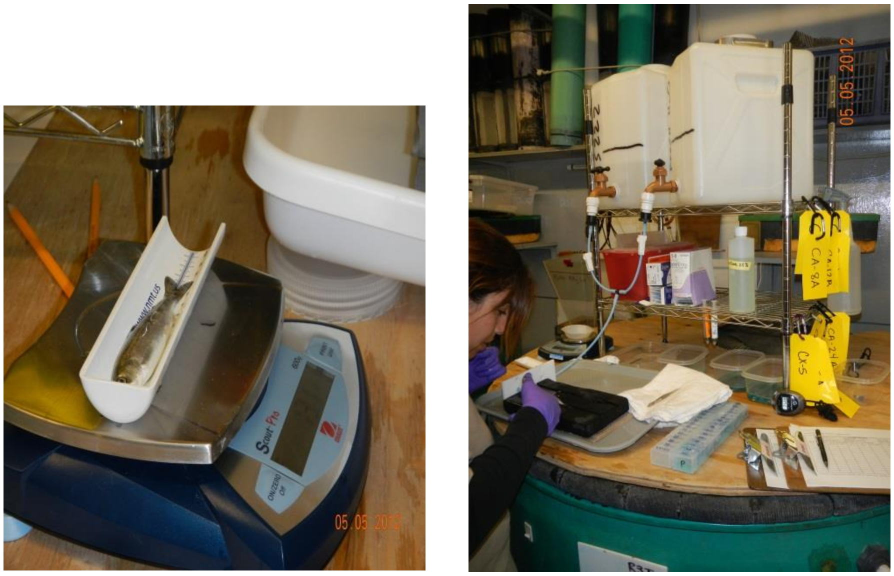

Photo credits: Pat Brandes

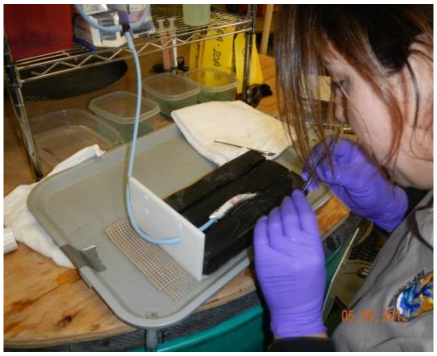

Photo credit: Pat Brandes

Photo credit: Jake Osborne

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Transmitter Validation

After the surgical implantation of tags, one or two fish were placed into 19 liter (L) (5 gal) perforated buckets with high dissolved oxygen concentrations (110-130%) and allowed to recover from anesthesia for 10 minutes. During this time, tag codes were verified using a 180 khz hydrophone connected to a VR100.   Tags that would not verify using the VR100 were replaced with a new tag in a new fish. After validation, a pair of buckets containing either one or two fish was combined to create a bucket of 3 fish. The bucket was then moved into a holding flume of circulating water to await loading to the transport truck once the tagging session was completed.

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Photo credits: Pat Brandes

Transport to Release Site

After tagging, the 19L perforated buckets, which usually contained three tagged Chinook Salmon each, were held in a flume at the TFCF until they were loaded into transport tanks at the end of each tagging session (morning or afternoon). Immediately prior to loading, all fish were visually inspected for mortality or signs of poor recovery from tagging (e.g. erratic swimming behavior). Fish that died or were not recovering from surgery were replaced with a new tagged fish.

In order to minimize the stress associated with moving fish and for tracking smaller groups of individually tagged fish, two specially designed transport tanks were used to move Chinook Salmon from the TFCF, where the tagging occurred, to the release site at Durham Ferry. The transport tanks for Chinook Salmon were designed to securely hold a series of 19 L perforated buckets filled with fish. Tanks had an internal frame that held 21 or 30 buckets in individual compartments to minimize contact between containers and to prevent tipping.   Buckets were covered in the transport tanks with stretched cargo nets to assure buckets did not tip over and lids did not come off. Both transport tanks were mounted on the bed of a 26 foot flatbed truck that was equipped with an oxygen tank and hosing to deliver oxygen to each of the tanks during transport. Two trips to the release site were made each tagging day, with the morning and afternoon sessions of tagged fish being transported separately (Table 1).

Photo credits: Jake Osborne

Photo credits: Jake Osborne

Photo credit: Pat Brandes

After loading buckets into the transport tank, de-chlorinated ice was usually added to the transport tanks to either 1) reduce water temperatures during transport such that they would be closer to the river temperature at the release site, or 2) to prevent water temperatures from increasing during transport. Water temperature and dissolved oxygen (DO) in the transport tanks were recorded after loading buckets and ice (if added) into transport tanks; before leaving the TFCF and at the release site after transport, prior to unloading buckets. The temperature and DO were also measured in the river at the holding/release site.

Transfer to Holding Containers

Once at the release site, the perforated buckets, which typically contained three Chinook Salmon each, were removed from the transport tanks and moved to the river. For all releases, perforated buckets were placed into "sleeves" in a pick-up truck and driven a short distance to the river's edge. A "sleeve" is a similar-sized, non-perforated bucket that allows more water to stay in the perforated bucket than would be the case without placing it in a "sleeve". Perforated buckets in sleeves were unloaded from the pick-up truck and carried to the river. Perforated buckets were then separated from the sleeves at the shoreline and submerged in-river to be transported to the holding containers which were anchored one to two meters from shore. Water temperature and dissolved oxygen levels were measured in the river prior to placing the salmon into the holding containers in the river.

Once at the river's edge, the tagged Chinook Salmon were transferred from the perforated buckets to the holding containers; 120 L (32 gal) perforated plastic garbage cans held in the river. These holding containers were perforated with hole sizes of 0.64 cm in diameter. Five buckets containing fish were emptied into each perforated garbage can. Only four of the five buckets emptied into the garbage cans contained VEMCO tagged fish while the fifth bucket of each group held 3 to 4 HTI fish. Each bucket and garbage can was labeled to track the specific tag codes and assure fish were transferred to the correct holding can for later release at the correct time. Tagged salmon were held in the perforated garbage cans for approximately 24 hours prior to release. Steelhead for the 6 Year Study were held at the same location and released either the day before or the day after the releases of Chinook Salmon; steelhead were released May 1-2, May 3-4, and May 5-6, and May 18-19, May 20-21, and May 22-23.

Photo credit: Pat Brandes

Fish Releases

The Chinook Salmon, held in perforated garbage cans, were transported downstream by boat to the release location which was in the middle of the channel downstream of the holding location. The fish were released downstream of the holding site to potentially reduce initial predation of tagged fish immediately after release, under the assumption that predators may congregate near the holding location. Releases were made every 4 hours after the 24 hour holding period, at approximately 1500, 1900, 2300 hours (the day after tagging), and 0300, 0700, and 1100 hours (2 days after tagging)(Table 1). Fish releases were made at these four-hour increments through-out the 24-hour period to spread the fish out and to better represent naturally spawned fish that may migrate downstream through-out the 24 hour period. The Chinook Salmon releases were made on May 2-3, May 4-5, May 6-7 and May 17-18, May 19-20, May 21-22 (Table 1).

Immediately prior to release, each holding container was checked for any dead or impaired fish. At the release time, the lid was removed and the holding container was rotated to look for mortalities. The container was then inverted to allow the fish to be released into the river. After the holding container was inverted, the time was recorded. As the holding containers were flipped back over, they were inspected to make sure that none of the released fish swam back into the container. Some exceptions to this procedure occurred as one group was released from shore due to high winds and waves, and three groups were released from shore due to a dead battery in the boat (Table 1).

Once the release was completed, the information on any dead fish was recorded and the tags removed. The tags were bagged and labeled and returned to the tagging location or office for tag code identification.

05 05 2012

Photo credit: Pat Brandes

Dummy-tagged fish

In order to evaluate the effects of tagging and transport on the survival of the tagged fish, several groups of Chinook Salmon were implanted with inactive ("dummy") transmitters. Dummy tags in 2012 were systematically interspersed into the tagging order for each release group. For each day of tagging and transport, 15 fish were implanted with dummy transmitters and included in the tagging process (Table 1). Procedures for tagging these fish, transporting them to the release site, and holding them at the release site were the same as for fish with active transmitters. Dummy-tagged fish were evaluated for condition and mortality after being held at the release site for approximately 48 hours. After being held, dummy tagged fish were assessed qualitatively for percent scale loss, body color, fin hemorrhaging, eye quality, and gill coloration (Table 2). In addition, two additional groups of 15 dummy-tagged fish (tagged on the same day) were held for approximately 48 hours and assessed for pathogens and other diseases (discussed below).

Fish Health Assessment

As a part of the 2012 South Delta Chinook Salmon Survival Study, the U.S. Fish and Wildlife Service's CA-NV Fish Health Center (CNFHC) conducted a general pathogen screening and smolt physiological assessment on dummy-tagged fish held at the release site for 48 hours. The health and physiological condition of the study fish can help explain their performance and survival during the studies. Pathogen screenings during past VAMP studies using MRH Chinook Salmon have regularly found infection with the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD). This parasite has been shown to cause mortality in Chinook Salmon with increased mortality and faster disease progression in fish at higher water temperatures (Ferguson 1981; Foott et al. 2007). The objectives of this element of the project were to evaluate the juvenile Chinook Salmon used for the studies for specific fish pathogens including *Tetracapsuloides bryosalmonae* and assess smolt development from gill Na^+ - K^+- ATPase activity to determine potential differences in health between groups. For a complete description of methods see Appendix 4.

Tag life tests

Two tag life tests were conducted in conjunction with this study. The first tag-life study began on May 16, with 43 tags. The second tag-life study began on May 24, with 40 tags. Tags were activated and then put into mesh bags and held in holding tanks at the TFCF containing ambient Delta water. A VEMCO VR2W was installed in each tank for recording detections of each individual tag. Files of detections were reviewed to identify the tag failure of each individual tag used in the tag life study. These results were then compared to observed tag travel times of the tags used in the study to estimate their tag life and make any necessary corrections to fish survival estimates.

Tag retention test

On May 25, 2012, each of the 4 surgeons tagged 9 to 10 fish with dummy tags to assess tag retention and longer-term mortality of tagged fish. Thirteen of these fish were held in each of 3 separate tanks for 30 days to determine if there was any longer-term mortality of the tagged fish and whether any tags were expelled. Fish were held in tanks at the TFCF for the duration of the 30 days.

Receiver deployment, retrieval, and receiver database

The 2012 Chinook Salmon Survival Study, in conjunction with the 6-Year Steelhead Study used receivers at 26 locations in the lower San Joaquin River and South Delta to Chipps Island (i.e. Mallard Slough) for detecting juvenile salmon and steelhead as they migrated through the Delta (Figure 2). These receivers were placed at key locations throughout the south Delta and similar to those used in VAMP in 2010 and 2011 (Figure 2). Although locations of receivers are similar, the VAMP study used an HTI receiver array, whereas the 2012 study used a VEMCO receiver array. The USBR funded the USGS to deploy, maintain and remove all of the receivers in the array, including receivers at both Jersey Point and Chipps Island in 2012. The detections of tagged salmon on these receivers allowed survival of juvenile salmon to be estimated from Durham Ferry to Chipps Island.

Data processing and survival model

This study used the tag detection data recorded on the receiver array to populate a release-recapture model similar to that used in the 2010 and 2011 VAMP studies (SJGRA 2011, 2013). The release-recapture model used the pattern of detections among all tags to estimate the probabilities of route selection, survival, and transition in various reaches and detection probability at receivers. Parameter estimates were then combined to calculate estimates of reach-specific survival, route-specific survival, and total survival through the Delta to Chipps Island. The release-recapture model (described in more detail below) is a multi-state model based on the models of Cormack (1964), Jolly (1965), and Seber (1965), in combination with the route-specific survival model of Skalski et al. (2002). Tags that appeared to be in predators were identified, and the model was fit first to the complete data set that included all detections, including those from predators, and then to the reduced data set that omitted detections that appeared to come from predators. This allowed comparison of estimates of survival and route selection probabilities with and without tags that appeared to come from predators in order to assess the potential bias associated with predator detections; this approach was similar to that used in the 2010 and 2011 VAMP studies (SJRGA 2011, 2013). More details on all statistical methods follow.

Statistical Methods

Data Processing for Survival Analysis

The University of Washington (UW) received the database of tagging and release data from the US Fish and Wildlife Service (USFWS). The tagging database included the date and time of tagging surgery for each tagged Chinook Salmon released in 2012, as well as the name of the surgeon (i.e., tagger), and the date and time of release of the tagged fish to the river. Fish size (length and weight), tag size, and any notes about fish condition were included, as well as the survival status of the fish at the time of release. Tag serial number and three unique tagging codes were provided for each tag, representing codes for various types of signal coding. Tagging data were summarized according to release group and tagger, and were cross-checked with Pat Brandes (USFWS) for quality control.

Acoustic tag detection data collected at individual monitoring sites (Table 3) were transferred to the USGS in Sacramento, California. A multiple-step process was used to identify and verify detections of fish in the data files, and produce summaries of detection data suitable for converting to tag detection histories. Detections were classified as valid if two or more pings were recorded within a 30 minute time frame on the hydrophones comprising a detection site from any of the three tag codes associated with the tag. The UW received the primary database of autoprocessed detection data from the USGS. These data included the date, time, location, and tag codes and serial number of each valid detection of the acoustic Chinook Salmon tags on the fixed site receivers. The tag serial number was linked to the acoustic tag ID, and was used to identify tag activation time, tag release time, and release group from the tagging database.

The autoprocessed database was cleaned to remove obviously invalid detections. The UW identified potentially invalid detections based on unreasonable travel times or unlikely transitions between detections, and queried the USGS processor about any discrepancies. All corrections were noted and made to the database. All subsequent analysis was based on this cleaned database.

The information for each tag in the database included the date and time of the beginning and end of each detection event when a tag was detected. Unique detection events were distinguished by detection on a separate hydrophone or by a time delay of 30 minutes between repeated hits on the same receiver. Separate events were also distinguished by unique tag encoding schemes (e.g., PPM vs. hybrid PPM/HR). The cleaned detection event data were converted to detections denoting the beginning and end of receiver “visits,” with consecutive visits to a receiver separated either by a gap of 12 hours or more between detections on the receiver, or by detection on a different receiver. Detections from receivers in dual or redundant arrays were pooled for this purpose, as were detections using different tag coding schemes.

Distinguishing between Detections of Salmon and Predators

The possibility of predatory fish eating tagged study fish and then moving past one or more fixed site receivers complicated analysis of the detection data. The Chinook Salmon survival model depended on the assumption that all detections of the acoustic tags represented live juvenile Chinook Salmon, rather than a mix of live salmon and predators that temporarily had a salmon tag in their gut. Without removing the detections that came from predators, the survival model would produce potentially biased survival estimates of actively migrating juvenile Chinook Salmon through the Delta. The size and type (positive or negative) of the bias would depend on the amount of predation by predatory fish and the spatial distribution of the predatory fish after eating the tagged salmon. In order to minimize bias, the detection data were filtered for predator detections, and detections assumed to come from predators were identified.

The predator filter used for analysis of the 2012 data was based on the predator filter designed and used in the analysis of the 2011 data (SJRGA 2013). That predator filter in turn was based on predator analyses presented by Vogel (2010, 2011), as well as conversations with fisheries biologists familiar with the San Joaquin River and Delta regions and the predator decision processes used in previous years (SJRGA 2010, 2011). The filter was applied to all detections of all tags. Two data sets were then constructed: the full data set including all detections, including those classified as coming from predators (i.e., "predator-type"), and the reduced data set, restricted to those detections classified as coming from live Chinook Salmon smolts (i.e., "smolt-type"). The survival model was fit to both data sets separately. The results from the analysis of the reduced "smolt-type" data set are presented as the final results of the 2012 Chinook Salmon tagging study. Results from analysis of the full data set including "predator-type" detections were used to indicate the degree of uncertainty in survival estimates arising from the predator decision process.

The predator filter was based on assumed behavioral differences between salmon smolts and predators such as striped bass and white catfish. All detections were considered when implementing the filter, including detections from acoustic receivers that were not otherwise used in the survival model. As part of the decision process, environmental data including river flow, river stage, and water velocity were examined from several points throughout the Delta (Table 4), as available. Hydrologic data were downloaded from the California Data Exchange Center website (http://cdec.water.ca.gov/selectQuery.html) and the California Water Data Library (www.water.ca.gov/waterdatalibrary/) on 27 September 2013. Environmental data were reviewed for quality, and obvious errors were omitted.

For each tag detection, several steps were performed to determine if it should be classified as predator or salmon. Initially, all detections were assumed to be of live smolts. A tag was classified as a predator upon the first exhibition of predator-type behavior, with the acknowledged uncertainty that the salmon smolt may actually have been eaten sometime before the first obvious predator-type detection. Once a detection was classified as coming from a predator, all subsequent detections of that tag were likewise classified as predator detections. The assignment of predator status to a detection was made conservatively, with doubtful detections classified as coming from live salmon. In general, the decision process was based on the assumptions that (1) salmon smolts were unlikely to move against the flow, and (2) salmon smolts were actively migrating and thus wanted to move downriver, although they may have temporarily moved upstream with reverse flow.

A tag could be given a predator classification at a detection site on either arrival or departure from the site. A tag classified as being in a predator because of long travel time or movement against the flow was typically given a predator classification upon arrival at the detection site. On the other hand, a tag classified as being in a predator because of long residence time was given a predator classification upon departure from the detection site. Because the survival analysis estimated survival within reaches between sites, rather than survival during detection at a site, the predator classifications on departure from a site did not result in removal of the detection at that site from the reduced data set. However, all subsequent detections were removed from the reduced data set.

The predator filter used various criteria on several spatial and temporal scales, as described in detail in previous reports (e.g., SJRGA 2013). Criteria fit under various categories, described in more detail in SJRGA (2013): fish speed, residence time, upstream transitions, other unexpected transitions, travel time since release, and movements against flow. The criteria used in the 2011 study were updated to reflect river conditions and observed tag detection patterns in 2012 (Table 5a and 5b). Differences between the 2011 filter and the filter used for the 2012 study (in addition to those identified in Table 5a and 5b) were:

1. Minimum migration rates on upstream-directed transitions were set to 0.1-0.2 km/hr for most upstream transitions. Upstream transitions in Old River from the Highway 4 area to the CVP trashracks and in the Sacramento or San Joaquin River from Threemile Slough to Chipps Island were limited to migration rates no less than 0.5 km/hr.
2. Maximum regional residence times allowed for smolts were set at 60 hours for the San Joaquin River upstream of the head of Old River, and 360 hours in all other regions. In most cases, the maximum regional residence time allowed for smolts making a downstream-directed transition was set at 3 – 5 times the maximum allowable near-field residence time.
3. A maximum of 3 upstream forays and 15 upstream river kilometers was imposed.
4. Maximum allowable travel time since release at Durham Ferry was set at 15 days (360 hours).

The predator scoring and classification method used for the 2011 study was used again for the 2012 study, resulting in tags being classified as in either a predator or a smolt upon arrival at and departure from a given receiver site and visit; for more details, see SJRGA (2013). All detections of a tag subsequent to its first predator designation were classified as coming from a predator, as well.

The criteria used in the predator filter were spatially explicit, with different limits defined for different receivers and transitions (Table 5a and 5b). General components of the approach to various regions are described below. Only regions with observed detections are described; regions that follow the general guidelines described in SJRGA (2013) are not highlighted here.

DFU, DFD = Durham Ferry Upstream (A0) and Durham Ferry Downstream (A2): ignore flow and velocity measures, allow long travel time to accommodate initial disorientation after release, and allow few if any repeat visits.

SJL = San Joaquin River near Lathrop (A5): upstream transitions from Stockton sites are not allowed.

ORE = Old River East (B1): repeat visits are not allowed.

SJG = San Joaquin River at Garwood Bridge (A6): transitions from upstream require arrival on flood tide

SJNB = San Joaquin River at Navy Bridge Drive (A7): allow longer residence time if arrive at slack tide; repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

MAC, MFE/MFW = MacDonald Island (A8), Medford Island (A9): repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

TCE/TCW = Turner Cut (F1): should not move against flow; repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

ORS = Old River South (B2): repeated visits require arriving with opposite flow and velocity conditions to departure conditions.

CVP = Central Valley Project (E1): allow multiple visits; transitions from downstream Old River should not have departed Old River site against flow; no repeat visits or arrivals from downstream if not pumping.

JPE/JPW, FRE/FRW = Jersey Point (G1), False River (H1): no flow/velocity restrictions; allowed for transition from Threemile Slough (TMS/TMN)

Constructing Detection Histories

For each tag, the detection data summarized on the "visit" scale was converted to a detection history (i.e., capture history) that indicated the chronological sequence of detections on the fixed site receivers throughout the study area. In cases in which a tag was observed passing a particular receiver or river junction multiple times, the detection history represented the final route of the tagged fish past the receiver or river junction. Detections from the receivers comprising certain dual arrays were pooled, thereby converting the dual arrays to redundant arrays: the San Joaquin River near Mossdale Bridge (MOS, site A4), Lathrop (SJL, A5), and Garwood Bridge (SJG, A6); and Old River East near the head of Old River (ORE, B1). For some release groups, the receivers comprising the dual array just downstream of the initial release site (DFD, A2) were also pooled in order to achieve a better model fit; in other cases, very low detection probabilities at this site required omitting this site from analysis. Likewise, in some cases the dual arrays at either MacDonald Island (MAC, A8) or Old River South (B2) were pooled in order to improve model fit.

Survival Model

A two-part multi-state statistical release-recapture model was developed to estimate salmon smolt survival and migration route parameters throughout the study area. The full two-part model incorporates all receivers, with the exception of the San Joaquin River receiver just upstream of the head of Old River (HOR = B0), the northern-most receivers in Old and Middle rivers (OLD =B4 and MRE = C3) and the Threemile Slough receivers (TMS/TMN = T1) (Table 3, Figure 2). Because many acoustic receivers in the interior delta had no or few detections, a reduced model was developed by simplifying the full model and limiting it to receivers with sufficient detections for analysis. The full model is described in detail first, and then the reduced model is presented.

Full Model

The full release-recapture model is a slightly simplified version of the model used to analyze 2011 steelhead data (Buchanan 2013), and similar to the model developed by Perry et al. (2010) and the model developed for the 2009 – 2011 VAMP studies (SJRGA 2010, 2011, 2013). Figure 2 shows the layout of the receivers using both descriptive labels for site names and the code names used in the survival model (Table 3). The survival model represents movement and perceived survival throughout the study area to the primary exit point at Chipps Island (i.e., Mallard Island) (Figure 3, Figure 4). Individual receivers comprising dual arrays were identified separately, using “a” and “b” to represent the upstream and downstream receivers, respectively. Not all sites were used in the survival model, although all were used in the predator filter.

Fish moving through the Delta toward Chipps Island may have used any of several routes. The two primary routes modeled were the San Joaquin River route (Route A) and the Old River route (Route B). Route A followed the San Joaquin River past the distributary point with Old River near the town of Lathrop and past the city of Stockton. Downstream of Stockton, fish in the San Joaquin River route (Route A) may have remained in the San Joaquin River past its confluence with the Sacramento River and on to Chipps Island. Alternatively, fish in Route A may have exited the San Joaquin River for the interior Delta at any of several places downstream of Stockton, including Turner Cut, Columbia Cut (just upstream of Medford Island), and the confluence of the San Joaquin River with either Old River or Middle River, at Mandeville Island. Of these four exit points from the San Joaquin River between Stockton and Jersey Point, only Turner Cut was monitored and assigned a route name (F, a subroute of route A). Fish that entered the interior Delta from any of these exit points may have either moved north through the interior Delta and reached Chipps Island by returning to the San Joaquin River and passing Jersey Point and the junction with False River, or they may have moved south through the interior Delta to the state or federal water export facilities, where they may have been salvaged and trucked to release points on the San Joaquin or Sacramento rivers just upstream of Chipps Island. All of these possibilities were included in both subroute F and route A.

For fish that entered Old River at its distributary point on the San Joaquin River just upstream of Lathrop (route B), there were several pathways available to Chipps Island. These fish may have migrated to Chipps Island either by moving northward in either the Old or Middle rivers through the interior Delta, or they may have moved to the state or federal water export facilities to be salvaged and trucked. The Middle River route (subroute C) was monitored and contained within Route B. Passage through the State Water Project via Clifton Court Forebay was monitored at the entrance to the forebay and assigned a route (subroute D). Likewise, passage through the federal Central Valley Project was monitored at the entrance trashracks and in the facility holding tank and assigned a route (subroute E). Subroutes D and E were both contained in subroutes C (Middle River) and F (Turner Cut), as well as in primary routes A (San Joaquin River) and B (Old River). All routes and subroutes included multiple unmonitored pathways for passing through the Delta to Chipps Island.

Several exit points from the San Joaquin River were monitored and given route names for convenience, although they did not determine unique routes to Chipps Island. The first exit point encountered was False River, located off the San Joaquin River just upstream of Jersey Point. Fish entering False River from the San Joaquin River entered the interior Delta at that point, and would not be expected to reach Chipps Island without subsequent detection in another route. Thus, False River was considered an exit point of the study area, rather than a waypoint on the route to Chipps Island. It was given a route name (H) for convenience. Likewise, Jersey Point and Chipps Island were not included in unique routes. Jersey Point was included in many of the previously named routes (in particular, routes A and B, and subroutes C and F), whereas Chipps Island (the final exit point) was included in all previously named routes and subroutes except route H. Thus, Jersey Point and Chipps Island were given their own route name (G). Three additional sets of receivers located in Old River (Route B) and Middle River (Subroute C) north of Highway 4 and in Threemile Slough (Route T) were not used in the survival model. The routes, subroutes, and study area exit points are summarized as follows:

A = San Joaquin River: survival
B = Old River: survival
C = Middle River: survival
D = State Water Project: survival
E = Central Valley Project: survival
F = Turner Cut: survival
G = Jersey Point, Chipps Island: survival, exit point
H = False River: exit point
T = Threemile Slough: not used in survival model

The release-recapture model used parameters that denote the probability of detection (P_{hi}), route entrainment (ψ_{hl}), Chinook Salmon survival (S_{hi}), and transition probabilities equivalent to the joint probability of movement and survival ($\phi_{kj,hi}$) (Figure 3, Figure 4, Table A5-1). Unique detection probabilities were estimated for the individual receivers in a dual array: P_{hia} represented the detection probability of the upstream array at station i in route h, and P_{hib} represented the detection probability of the downstream array.

The model parameters are:

P_{hi} = detection probability: probability of detection at telemetry station i within route h, conditional on surviving to station i, where i = ia, ib for the upstream, downstream receivers in a dual array, respectively.

S_{hi} = perceived survival probability: joint probability of migration and survival from telemetry station i to station i+1 within route h, conditional on surviving to station i.

ψ_{hl} = route entrainment probability: probability of a fish entering route h at junction l (l =1, 2), conditional on fish surviving to junction l.

$\phi_{kj,hi}$ = transition probability: joint probability of route entrainment, and survival; the probability of migrating, surviving, and moving from station j in route k to station i in route h, conditional on survival to station j in route k.

A variation on the parameter naming convention was used for parameters representing the transition probability to the junction of False River with the San Joaquin River, just upstream of Jersey Point (Figure 2). This river junction marks the distinction between routes G and H, so transition probabilities to this junction are named $\phi_{kj,GH}$ for the joint probability of surviving and moving from station j in route k to the False River junction. Fish may arrive at the junction either from the San Joaquin River or from the interior Delta. The complex tidal forces present in this region prevent distinguishing between smolts using False River as an exit from the San Joaquin and smolts using False River as an entrance to the San Joaquin from Frank's Tract. Regardless of which approach the fish used to reach this junction, the $\phi_{kj,GH}$ parameter (e.g. $\phi_{A9,GH}$) is the transition probability from station j in route k to the junction of False River with the San Joaquin River via any route; ψ_{G1} is the probability of moving downstream toward Jersey Point from the junction; and $\psi_{H1} = 1 - \psi_{G1}$ is the probability of exiting (or re-exiting) the San Joaquin River to False River from the junction (Figure 3).

Because of the complexity of routing in the vicinity of MacDonald Island (referred to as "Channel Markers" in reports from previous years, e.g., SJRGA 2013) on the San Joaquin River, Turner Cut, and Medford Island, and the possibility of reaching the interior Delta via either route A or route B, the full survival model that represented all routes was decomposed into two submodels for analysis. Submodel I modeled the overall migration from release at Durham Ferry to arrival at Chipps Island without modeling the specific routing from the lower San Joaquin River (i.e., from the Turner Cut Junction) through the interior Delta to Chipps Island, although it included detailed subroutes in route B for fish that entered Old River at its upstream junction with the San Joaquin River (Figure 3). In Submodel I, transitions from MacDonald Island (A8) and Turner Cut (F1) to Chipps Island were interpreted as survival probabilities ($S_{A8,G2}$ and $S_{F1,G2}$) because they represented all possible pathways from these sites to Chipps Island. Submodel II, on the other hand, focused entirely on Route A, and used a virtual release of tagged fish detected at the San Joaquin River receiver array near Lathrop, (SJL) to model the detailed routing from the lower San Joaquin River near MacDonald Island and Turner Cut through or around the interior Delta to Jersey Point and Chipps Island (Figure 4). Submodel II included the Medford Island detection site (A9), which was omitted from Submodel I because of complex routing in that region.

Reduced Model

Detection data of tagged Chinook Salmon in the interior Delta in 2012 were very sparse. There were very few detections at the downstream Old and Middle river sites (OR4 [model code B3] and MR4

[C2]) and Central Valley Project (model codes E1 and E2) receivers, and no detections in Middle River at its head (C1) or radial gates (D1 and D2) receivers. There were also no detections at False River (H1) used in the survival analysis because all False River detections were followed by detections either at Jersey Point (G1) or Chipps Island (G2). With so few detections in the Old River route and the interior Delta portions of the San Joaquin River route, it was not possible to fit the full release-recapture model to the 2012 Chinook Salmon data set. Instead, it was necessary to omit all detection sites in the Old River route other than the first two sites in that route: ORE (B1) and ORS (B2). The simplified submodel I (Figure 5) includes the overall probability of surviving from the Old River receivers near the head of Middle River (ORS) to Chipps Island, $S_{B2,G2}$. This parameter includes all ways of getting from ORS (site B2) to Chipps Island (site G2), and is interpreted as the sum of products of the $\phi_{kj,hi}$ parameters from the full Submodel I:

$$S_{B2,G2} = \phi_{B2,D1}\phi_{D1,D2}\phi_{D2,G2} + \phi_{B2,E1}\phi_{E1,E2}\phi_{E2,G2} + \left(\phi_{B2,B3}\phi_{B3,GH} + \phi_{B2,C2}\phi_{C2,GH}\right)\psi_{G1}\phi_{G1,G2}.$$

The reduced Submodel I does not decompose $S_{B2,G2}$ into its route-specific components because of sparse data.

The reduced Submodel II focuses on transitions in and from the lower portions of the San Joaquin River, and omits transitions from this region to the interior Delta or water export facilities (Figure 6). While the full Submodel II included transitions from MacDonald Island, Medford Island, and Turner Cut to the interior Delta and water export facilities, insufficient observations of tags making these transitions made it necessary to omit these pathways from the reduced model. Thus, the reduced Submodel II models transitions only to the Jersey Point/False River junction from the MacDonald Island/Medford Island/Turner Cut region. In fact, because no tags were observed exiting the system at False River, it was not possible to separate the probability of getting to the Jersey Point/False River junction $\left(\phi_{hi,GH}\right)$ from the probability of turning toward Jersey Point $\left(\psi_{G1}\right)$; instead, only the product was estimable: $\phi_{hi,G1} = \phi_{hi,GH}\psi_{G1}$, for transitions from site i in route h. Thus, the reduced Submodel II used parameters $\phi_{A8,G1}$, $\phi_{A9,G1}$, and $\phi_{F1,G1}$, which jointly include all routes from the lower San Joaquin River receivers to Jersey Point, including those past the interior Delta receivers in northern Old and Middle rivers (B3 and C2). Likewise, without detections at the head of Middle River receiver (MRH, code C1), it was not possible to separately estimate the probability of surviving from the head of Old River to the head of Middle River $\left(S_{B1}\right)$ from the probability of remaining in Old River at the head of Middle River $\left(\psi_{B2}\right)$. Only the product was estimate: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. Finally, there were insufficient detections at the receivers upstream of the Durham Ferry release site (DFU, code A0), so the A0 site was removed from the simplified submodel I (Figure 5).

The two simplified submodels I and II were fit concurrently using unique detection and transitions probabilities at shared receivers: SJG (A6), SJNB (A7), MAC (A8), TCE/TCW (F1), and MAE/MAW (G2). Parameters at these sites were estimated separately for the two submodels to avoid “double-counting” tags used in both submodels.

In addition to the model parameters, derived performance metrics measuring migration route probabilities and survival were estimated as functions of the model parameters. Both route entrainment and route-specific survival were estimated for the two primary routes determined by routing at the head of Old River (routes A and B). Route entrainment and route-specific survival were also estimated for the major subroutes of route A; subroutes were not distinguishable for route B. These subroutes were identified by a two-letter code, where the first letter indicates routing used at the head of Old River (i.e., A), and the second letter indicates routing used at the Turner Cut junction: A or F. Thus, the route entrainment probabilities for the route A subroutes were:

$\psi_{AA} = \psi_{A1}\psi_{A2}$: probability of remaining in the San Joaquin River past both the head of Old River and the Turner Cut Junction, and

$\psi_{AF} = \psi_{A1}\psi_{F2}$: probability of remaining in the San Joaquin River past the head of Old River, and exiting to the interior Delta at Turner Cut, where $\psi_{F2} = 1 - \psi_{A2}$.

Route entrainment probabilities were estimated on the large routing scale, as well, focusing on routing only at the head of Old River. The route entrainment parameters were defined as:

$\psi_A = \psi_{A1}$: probability of remaining in the San Joaquin River at the head of Old River

$\psi_B = \psi_{B1}$: probability of entering Old River at the head of Old River.

The probability of surviving from the entrance of the Delta near Mossdale Bridge (site A4, MOS) through an entire migration pathway to Chipps Island was estimated as the product of survival probabilities that trace that pathway:

$S_{AA} = S_{A4}S_{A5}S_{A6}S_{A7}S_{A8,G2}$: Delta survival for fish that remained in the San Joaquin River past the head of Old River and Turner Cut,

$S_{AF} = S_{A4}S_{A5}S_{A6}S_{A7}S_{F1,G2}$: Delta survival for fish that entered Turner Cut from the San Joaquin River, and

$S_B = S_{A4}\phi_{B1,B2}S_{B2,G2}$: Delta survival for fish that entered Old River at its head.

The overall probability of surviving through the Delta in the San Joaquin River route was defined using the subroute-specific survival probabilities and the probabilities of taking each subroute:

$S_A = \psi_{A2}S_{AA} + \psi_{F2}S_{AF}$: Delta survival (from Mossdale to Chipps Island) for fish that remained in the San Joaquin River at the head of Old River.

The parameters $S_{A8,G2}$ and $S_{F1,G2}$ used in S_{AA} and S_{AF} represent the probability of getting to Chipps Island (i.e., Mallard Island, site MAE/MAW) from A8 and F1, respectively. Both parameters represent multiple pathways around or through the Delta to Chipps Island (Figure 2). Fish that were detected at the A8 receivers (MacDonald Island) may have remained in the San Joaquin River all the way to Chipps Island, or they may have entered the interior Delta downstream of Turner Cut. Fish that entered the interior Delta either at Turner Cut or farther downstream may have migrated through the interior Delta to Chipps Island via Frank's Tract or Fisherman's Cut, False River, and Jersey Point; returned to the San Joaquin River via its downstream confluence with either Old or Middle River at Mandeville Island; or gone through salvage and trucking from the water export facilities. All such routes are represented in the $S_{A8,G2}$ and $S_{F1,G2}$ parameters, which were estimated directly using Submodel I.

The route-specific survival probability for the Old River route, S_B, includes a transition probability, $\phi_{B1,B2}$, as a factor. As indicated above, $\phi_{B1,B2}$ is the product of a survival probability and a route entrainment probability: $\phi_{B1,B2} = S_{B1}\psi_{B2}$. No tags were detected on the Middle River receivers near the head of Middle River (site C1). However, if some tags actually had entered Middle River at its head without detection, then $\psi_{B2} < 1$ and $\phi_{B1,B2} < S_{B1}$, resulting in S_B being a minimum estimate of true Delta survival in the Old River route.

Using the estimated migration route probabilities and route-specific survival for these two primary routes (A and B), survival of the population from A4 (Mossdale) to Chipps Island was estimated as:

$$S_{Total} = \psi_A S_A + \psi_B S_B .$$

Survival was also estimated from Mossdale to Jersey Point, although this was estimable only for fish in the San Joaquin River route. Survival through this region ("Mid-Delta" or MD) was defined as follows:

$S_{A(MD)} = \psi_{A2} S_{AA(MD)} + \psi_{F2} S_{AF(MD)}$: Mid-Delta survival for fish that remained in the San Joaquin River past the head of Old River,

where

$$S_{AA(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \left(\phi_{A8,G1} + \phi_{A8,A9} \phi_{A9,G1} \right), \text{ and}$$

$$S_{AF(MD)} = S_{A4} S_{A5} S_{A6} S_{A7} \phi_{F1,G1} .$$

Survival was also estimated through the southern portions of the Delta ("Southern Delta" or SD), although once again this was estimable only for fish in the San Joaquin River route:

$$S_{A(SD)} = S_{A4} S_{A5} S_{A6} S_{A7} .$$

The probability of reaching Mossdale from the release point at Durham Ferry, ϕ_{A1A4}, was defined as the product of the intervening reach survival probabilities:

$$\phi_{A1,A4} = \phi_{A1,A2} S_{A2} S_{A3} .$$

This measure reflects a combination of mortality and possible residualization upstream of Old River, although the Chinook Salmon in this study were assumed to be migrating (i.e., no residualization). In cases where the first detection site A2 (DFD) had to be removed from analysis, the alternative model parameter $\phi_{A1,A3} = \phi_{A1,A2} S_{A2}$ was used:

$$\phi_{A1,A4} = \phi_{A1,A3} S_{A3} .$$

Individual detection histories (i.e., capture histories) were constructed for each tag as described above. Each detection history consisted of one or more fields representing initial release (field 1) and the sites where the tag was detected, in chronological order. Detection on both receivers in a dual array was denoted by the code “ab”, detection on only the upstream receiver was denoted “a0”, and detection on only the downstream receiver was denoted “b0”. For example, the detection history DF A2a0 A5 A7 A8ab A9b0 G1a0 G2ab represented a tag that was released at Durham Ferry and detected at the first (but not the second) receiver just downstream of the release site (A2a0), at one or both of the receivers near Lathrop (A5), at the single receiver in the San Joaquin River near the Navy Drive Bridge (A7), both receivers at MacDonald Island (A8ab), the downstream receiver at Medford Island (A9b0), the upstream receiver at Jersey Point (G1a0), and both receivers at Chipps Island (G2ab). A tag with this detection history can be assumed to have passed by certain receivers without detection: A2b, A3, A4, A6, A9a, and G1b. In Submodel I, the detections at A9 and G1 were not modeled, yielding Submodel I parameterization:

$$\phi_{A1,A2} P_{A2a} \left(1 - P_{A2b}\right) S_{A2} \left(1 - P_{A3}\right) S_{A3} \left(1 - P_{A4}\right) S_{A4} \psi_{A1} P_{A5} S_{A5} \left(1 - P_{A6}\right) S_{A6} P_{A7} S_{A7} \psi_{A2} P_{A8a} P_{A8b} S_{A8,G2} P_{G2a} P_{G2b} .$$

In Submodel II, this detection history was parameterized starting at the virtual release at site A5 and included detections at A8, A9, and G1:

$$S_{A5} \left(1 - P_{A6}\right) S_{A6} P_{A7} S_{A7} \psi_{A2} P_{A8a} P_{A8b} \phi_{A8,A9} \left(1 - P_{A9a}\right) P_{A9b} \phi_{A9,G1} P_{G1a} \left(1 - P_{G1b}\right) \phi_{G1,G2} P_{G2a} P_{G2b} .$$

Another example is the detection history DF A2ab A4 A5 A6 A7 G2b0. A fish with this detection history was released at Durham Ferry, migrated downstream in the San Joaquin River past the head of Old River with detections at the receivers just downstream of the release site (A2ab), as well as at the Mossdale Bridge (A4), Lathrop (A5), Garwood Bridge (A6), and Navy Drive Bridge (A7) before being detected on the second Chipps Island receiver (G2b0). This fish passed the Turner Cut junction but we have no information on which route it took there, so both routes must be parameterized in both submodels. This fish presumably passed Jersey Point without being detected on either receiver there.

This detection history is modeled partially in Submodel I and partially in Submodel II. In Submodel I, the probability of this detection history is

$$\phi_{A1,A2}P_{A2a}P_{A2b}S_{A2}\left(1-P_{A3}\right)S_{A3}P_{A4}S_{A4}\psi_{A1}P_{A5}S_{A5}P_{A6}S_{A6}P_{A7}S_{A7}\theta P_{G2a}P_{G2b},$$

where $\theta=\psi_{A2}\left(1-P_{A8}\right)S_{A8,G2}+\psi_{F2}\left(1-P_{F1}\right)S_{F1,G2}$, $1-P_{A8}=\left(1-P_{A8a}\right)\left(1-P_{A8b}\right)$, and $1-P_{F1}=\left(1-P_{F1a}\right)\left(1-P_{F1b}\right)$.

In Submodel II, this detection history is parameterized

$$S_{A5}P_{A6}S_{A6}P_{A7}S_{A7}\left[\psi_{A2}\left(1-P_{A8}\right)\left(\phi_{A8,G1}+\phi_{A8,A9}\phi_{A9,G1}\right)+\psi_{F2}\left(1-P_{F1}\right)\phi_{F1,G1}\right]\left(1-P_{G1}\right)\phi_{G1,G2}\left(1-P_{G2a}\right)P_{G2b},$$

where $1-P_{G1}=\left(1-P_{G1a}\right)\left(1-P_{G1b}\right)$.

A final example is the detection history DF A3 A4 B1 B2a0. A fish with this detection history was released at Durham Ferry, passed the first receivers without detection, passed the receivers at Banta Carbona (A3) and Mossdale Bridge (A4) with detection, entered Old River through the barrier and was detected on at least one receiver at the first Old River site (B1) and on the upstream receiver at the Old River South site (B2a0). The fish was not detected again after passing the Old River South site. It may have died between that site and Chipps Island (the next site modeled), or it may have reached Chipps Island but evaded detection there. Both possibilities must be included in the model parameterization. This detection history is parameterized only in Submodel I:

$$\phi_{A1,A2}\left(1-P_{A2}\right)S_{A2}P_{A3}S_{A3}P_{A4}S_{A4}\left(1-\psi_{A1}\right)P_{B1}\phi_{B1,B2}P_{B2a}\left(1-P_{B2b}\right)\left[1-S_{B2,G2}P_{G2}\right],$$

where $1-P_{A2}=\left(1-P_{A2a}\right)\left(1-P_{A2b}\right)$ and $P_{G2}=1-\left(1-P_{G2a}\right)\left(1-P_{G2b}\right)$.

Under the assumptions of common survival, route entrainment, and detection probabilities and independent detections among the tagged fish in each release group, the likelihood function for the survival model for each release group is a multinomial likelihood with individual cells denoting each possible capture history.

Parameter Estimation

The multinomial likelihood model described above was fit numerically to the observed set of detection histories according to the principle of maximum likelihood using Program USER software, developed at the UW (Lady et al. 2009). Point estimates and standard errors were computed for each parameter. Standard errors of derived performance measures were estimated using the delta method (Seber 2002: 7-9). Sparse data prevented some parameters from being freely estimated for some release groups. Transition, survival, and detection probabilities were fixed to 1.0 or 0.0 in the USER model as appropriate, based on the observed detections. The model was fit separately for each release.

For each release, the complete data set that included possible detections from predatory fish was analyzed separately from the reduced data set restricted to detections classified as Chinook Salmon smolt detections. Population-level estimates of parameters and performance measures, representing both release groups, were estimated by fitting the model to the pooled detection data from both release groups. For each model fit, goodness-of-fit was assessed visually using Anscombe residuals (McCullagh and Nelder 1989). The sensitivity of parameter and performance metric estimates to inclusion of detection histories with large absolute values of Anscombe residuals was examined for each release group individually.

For each release group and for the pooled data set, the effect of primary route (San Joaquin River or Old River) on estimates of survival to Chipps Island was tested with a two-sided *Z*-test on the log scale:

$$Z = \frac{\ln\left(\hat{S}_A\right) - \ln\left(\hat{S}_B\right)}{\sqrt{\hat{V}}},$$

where

$$V = \frac{Var\left(\hat{S}_A\right)}{\hat{S}_A} + \frac{Var\left(\hat{S}_B\right)}{\hat{S}_B} - \frac{2Cov\left(\hat{S}_A, \hat{S}_B\right)}{\hat{S}_A \hat{S}_B}.$$

The parameter *V* was estimated using Program USER. Also tested was whether tagged Chinook Salmon smolts showed a preference for the San Joaquin River route using a one-sided *Z*-test with the test statistic:

$$Z = \frac{\hat{\psi}_A - 0.5}{SE\left(\hat{\psi}_A\right)}.$$

Statistical significance was tested at the 5% level (α=0.05).

Analysis of Tag Failure

The first of two tag-life studies began on May 16 with 43 tags; the last tag failure was recorded on July 6. The second tag-life study began on May 24 with 40 tags, and the last tag failure was recorded on July 12. Observed tag survival was modeled using the 4-parameter vitality curve (Li and Anderson 2009). Stratifying by tag-life study (mid-May or late May) versus pooling across studies was assessed using the Akaike Information Criterion (AIC; Burnham and Anderson 2002).

The fitted tag survival model was used to adjust estimated fish survival and transition probabilities for premature tag failure using methods adapted from Townsend et al. (2006). In Townsend et al. (2006), the probability of tag survival through a reach is estimated based on the average observed travel time of tagged fish through that reach. For this study, travel time and the probability of tag survival to Chipps Island were estimated separately for the different routes (e.g., San Joaquin route vs. Old River route). Standard errors of the tag-adjusted fish survival and transition probabilities were estimated using the inverse Hessian matrix of the fitted joint fish-tag survival model. The additional uncertainty introduced by variability in tag survival parameters was not estimated, with the result that standard errors may have been slightly low. In previous studies, however, variability in tag-survival parameters has been observed to contribute little to the uncertainty in the fish survival estimates when compared with other, modeled sources of variability (Townsend et al. 2006); thus, the resulting bias in the standard errors was expected to be small.

Analysis of Tagger Effects

Tagger effects were analyzed in several ways. The simplest method used contingency tests of independence on the number of tag detections at key detection sites throughout the study area. Specifically, a lack of independence (i.e., heterogeneity) between the detections distribution and tagger was tested using a chi-squared test (α=0.05; Sokal and Rohlf 1995). Detections from downstream sites were pooled for this test in order to achieve adequate cell counts, and the chi-squared test was performed via Monte Carlo simulations to accommodate remaining low cell counts.

Lack of independence may be caused by differences in survival, route entrainment, or detection probabilities. A second method visually compared estimates of cumulative survival throughout the study area among taggers. Sparse detection data in the Old River route for individual taggers prevented estimating reach survival within the Old River route by tagger, so only the overall survival to Chipps Island was estimated for route B for this analysis. A third method used Analysis of Variance to test for a tagger effect on individual reach survival estimates, and an F-test to test for a tagger effect on cumulative survival throughout each major route (routes A and B). Tagger effects on estimates of individual parameters were also assessed using an F-test. Finally, the nonparametric Kruskal-Wallis rank sum test (Sokal and Rohlf 1995, ch. 13) was used to test for whether one or more taggers performed consistently poorer than others, based on individual reach survival or transition probabilities through key reaches. In the event that survival was different for a particular tagger, the model was refit to the pooled release groups without tags from the tagger in question, and the difference in survival estimates due to the tagger was tested using a two-sided Z-test on the lognormal scale. The reduced data set (without predator-type detections), pooled over release groups, was used for these analyses.

Testing Effect of Release Group on Parameter Estimates

The effect of release group on the values of the model survival and transition probability parameters was examined by testing for a statistically significant decrease in parameter estimates for the second release group. For each model survival and transition probability parameter θ, where $\theta = \phi_{kj,hi}$ or $\theta = S_{hi}$, the difference in parameter values between the first and second release groups was defined as

$$\Delta_\theta = \theta_1 - \theta_2 \ ,$$

for model parameter θ_R for release group R ($R = 1, 2$). The difference was estimated by $\hat{\Delta}_\theta = \theta_1 - \theta_2$. The null hypothesis of no difference was tested against the alternative of a positive difference (i.e., higher parameter value for the first release group):

$$H_{0\theta} : \Delta_\theta = 0$$

vs

$$H_{A\theta} : \Delta_\theta > 0 .$$

A family-wise significance level of α=0.10 was selected, and the Bonferroni multiple comparison correction was used, resulting in a test-wise significance level of 0.0071 for 14 tests (Sokal and Rohlf 1995).

Analysis of Travel Time

Travel time was measured from release at Durham Ferry to each detection site. Travel time was also measured through each reach for tags detected at the beginning and end of the reach, and summarized across all tags with observations. Travel time between two sites was defined as the time delay between the last detection at the first site and the first detection at the second site. In cases where the tagged fish was observed to make multiple visits to a site, the final visit was used for travel time calculations. When possible, travel times were measured separately for different routes through the study area. The harmonic mean was used to summarize travel times.

To evaluate our hypotheses that reduced travel times increased survival, we compared average travel time and survival for the different reaches to see if they were different ($p<0.05$) for the two release groups. Given that the lengths of the reaches were different we also standardized the length of each reach and survival in the reach by the distance of each reach (in km) prior to comparing average travel time per km to survival per km (S^(1/km)) across reaches.

Route Entrainment Analysis

A physical barrier was installed at the head of Old River in 2012. The barrier was designed to keep fish from entering Old River, but included culverts that allowed limited fish passage. Only 11 of the 959 (1%) tags released in juvenile Chinook Salmon in 2012 were detected entering the Old River route in 2012, while 449 (47% of 959) were detected in the San Joaquin River route. Because of the barrier and the low number of tags detected in the Old River route, no effort was made to relate route entrainment at the head of Old River to hydrologic conditions in 2012. A route entrainment analysis was performed for the Turner Cut junction instead.

The effects of variability in hydrologic conditions on route entrainment at the junction of Turner Cut with the San Joaquin River were explored using statistical generalized linear models (GLMs) with a binomial error structure and logit link (McCullagh and Nelder 1989). The acoustic tags used in this analysis were restricted to those detected at either of the acoustic receiver dual arrays located just downstream of the Turner Cut junction: site MAC (model code A8) or site TCE/TCW (code F1). Tags were further restricted to those whose final pass of the Turner Cut junction came from either upstream sites or from the opposite leg of the junction; tags whose final pass of the junction came either from downstream sites (e.g., MFE/MFW) or from a previous visit to the same receivers (e.g., multiple visits to the MAC receivers) were excluded from this analysis. Tags were restricted in this way in order to limit the delay between initial arrival at the junction, when hydrologic covariates were measured, and the tagged fish's final route selection at the junction. No Chinook Salmon tags were observed moving from one junction leg to the other, so in fact only tags that came from upstream were used in this analysis. Predator-type detections were also excluded. Detections from a total of 89 tags were used in this analysis: 79 from release group 1, and 10 from release group 2.

Hydrologic conditions were represented in several ways, primarily total river flow (discharge), water velocity, and river stage. These measures were available at 15-minute intervals from the TRN gaging station in Turner Cut, maintained by the USGS (Table 4). The Turner Cut acoustic receivers (TCE and TCW) were located 0.15 – 0.30 km past the TRN station in Turner Cut. No gaging station was available in the San Joaquin River close to the MAC receivers. The closest stations were PRI (13 km downstream from the junction), and SJG (18 km upstream from the junction) (Table 4). These stations were considered too far distant from the MAC receivers to provide measures of flow, velocity, and river stage sufficiently accurate for describing localized conditions at the Turner Cut junction for the route entrainment analysis. Thus, while measures of hydrologic conditions were available in Turner Cut, measures of flow proportion into Turner Cut were not available.

Additionally, there was no measure of river conditions available just upstream of the junction that might inform about the environment as the fish approached the junction. Instead, gaging data from the SJG gaging station (18 km upstream of the junction) were used as a surrogate for conditions upstream of the junction. Because of the distance between the SJG station and the Turner Cut junction, and the fact that the San Joaquin River becomes considerably wider between the SJG station and the junction, conditions at SJG were used only as an index of average conditions during the time when the fish was in this reach. In particular, no measure of tidal stage or flow direction was used at SJG. Instead, the analysis used the average magnitude (measured as the root mean square, RMS) of flow and velocity at SJG during the tag transition from the time of tag departure from the SJG acoustic receiver (model code A6) to the time of estimated arrival at the Turner Cut junction.

Conditions at the TRN gaging station were measured at the estimated time of arrival at the Turner Cut junction. The location (named TCJ for Turner Cut Junction) used to indicate arrival at the junction was located in the San Joaquin River 1.23 km from the TCE receiver and 2.89 km upstream of the MACU receiver. Time of arrival at TCJ $\left(t_i\right)$ was estimated for tag i by a linear interpolation from the observed travel time from the SJNB or SJG acoustic receivers upstream to detection on either the MAC or TCE/TCW receivers just downstream of the junction. Linear interpolation is based on the first-order assumption of constant movement during the transition from the previous site. In a tidal area, it is likely that movement was not actually constant during the transition, but in the absence of more precise spatiotemporal tag detection data, the linear interpolation may nevertheless provide the best estimate of arrival time.

The TRN gaging station typically recorded flow, velocity, and river stage measurements every 15 minutes. Linear interpolation was used to estimate the flow, velocity, and river stage conditions at the estimated time of tag arrival at TCJ:

$$x_i = w_i x_{t_{1(i)}} + (1 - w_i) x_{t_{2(i)}}$$

where $x_{t_{1(i)}}$ and $x_{t_{2(i)}}$ are the two observations of metric x (x = Q [flow], V [velocity], or C [stage]) at the TRN gaging station nearest in time to the time t_i of tag i arrival such that $t_{1(i)} \le t_i \le t_{2(i)}$. The weights w_i were defined as

$$w_i = \frac{t_{2(i)} - t_i}{t_{2(i)} - t_{1(i)}},$$

and resulted in weighting x_i toward the closest flow, velocity, or stage observation.

In cases with a short time delay between consecutive flow and velocity observations (i.e., $t_{2(i)} - t_{1(i)} \le 60$ minutes), the change in conditions between the two time points was used to represent the tidal stage (Perry 2010):

$$\Delta x_i = x_{t_{2(i)}} - x_{t_{1(i)}}$$

for $x = Q, V, \text{ or } C$, and tag i.

Negative flow measured at the TRN gaging station was interpreted as river flow being directed into the interior Delta, away from the San Joaquin River (Cavallo et al. 2013). Flow reversal (i.e., negative flow at TRN) was represented by the indicator variable U (Perry 2010):

$$U_i = \begin{cases} 1, & for\ Q_i < 0 \\ 0, & for\ Q_i \ge 0 \end{cases}$$

Prevailing flow and velocity conditions in the reach from the SJG acoustic receiver to arrival at the Turner Cut junction were represented by the root mean square (RMS) of the time series of observed conditions measured at the SJG gaging station during the estimated duration of the transition:

$$x_{RMS(i)} = \sqrt{\frac{1}{n_i} \sum_{j=T_{1(i)}}^{T_{2(i)}} x_j^2}$$

where x_j = observed covariate x at time j at the SJG gaging station $(x = Q \text{ or } V)$, $T_{1(i)}$ = closest observation time of covariate x to the final detection of tag i on the SJG acoustic receivers, and $T_{2(i)}$ =

closest observation time of covariate x to the estimated time of arrival of tag i at TCJ. If the time delay between either $T_{1(i)}$ and final detection of tag i on the SJG acoustic receivers, or $T_{2(i)}$ and estimated time of arrival of tag i at TCJ, was greater than 1 hour, then no measure of covariate x from the SJG gaging station was used for tag i.

Daily export rate for day of arrival of tag i at TCJ was measured at the Central Valley Project $\left(E_{iCVP}\right)$ and State Water Project $\left(E_{iSWP}\right)$ (data downloaded from DayFlow on November 5, 2013). Fork length at tagging L_i and release group RG_i were also considered. Finally, arrival time (day vs. night) at the Turner Cut Junction site (TCJ) was measured based on whether the tagged Chinook Salmon first arrived at TCJ between sunrise and sunset $\left(day_i\right)$.

All continuous covariates were standardized, i.e.,

$$\tilde{x}_{ij} = \frac{x_{ij} - \overline{x}_j}{s(x_j)}$$

for the observation x of covariate j from tag i. The indicator variables U, RG, and day were not standardized.

The form of the generalized linear model was

$$\ln\left(\frac{\psi_{iA}}{\psi_{iF}}\right) = \beta_0 + \beta_1\left(\tilde{x}_{i1}\right) + \beta_2\left(\tilde{x}_{i2}\right) + \cdots + \beta_p\left(\tilde{x}_{ip}\right)$$

where $\tilde{x}_{i1}, \tilde{x}_{i2}, \ldots, \tilde{x}_{ip}$ are the observed values of standardized covariates for tag i (covariates 1, 2, …, p, see below), ψ_{iA} is the predicted probability that the fish with tag i selected route A (San Joaquin River route), and $\psi_{iF} = 1 - \psi_{iA}$ (F = Turner Cut route). Route choice for tag i was determined based on detection of tag i at either site A8 (route A) or site F1 (route F). Estimated detection probabilities for the two release groups were 0.97 – 1.00 for site A8 and 1.00 for site F1 (Appendix 5, Table 5A-2), so no groups were omitted because of low detection probability.

Single-variate regression was performed first, and covariates were ranked by P-values from the appropriate F-test (if the model was overdispersed) or x^2 test (McCullagh and Nelder 1989). Covariates found to be significant alone (α=0.05) were then analyzed together in a series of multivariate regression models. Because of high correlation between flow and velocity measured from the same site, and to a lesser extent, correlation between flow or velocity and river stage, the covariates flow, velocity, and river stage were analyzed in separate models. The exception was that the flow index in the reach from SJG to TCJ $\left(Q_{SJG}\right)$ was included in the river stage model. Exports at CVP and SWP had low correlation over the time period in question, so CVP and SWP exports were considered in the same models. The general forms of the three multivariate models were:

Flow model: $Q_{TRN} + Q_{SJG} + \Delta Q_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG$

Velocity model: $V_{TRN} + V_{SJG} + \Delta V_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG$

Stage model: $C_{TRN} + Q_{SJG} + \Delta C_{TRN} + U + day + E_{CVP} + E_{SWP} + L + RG.$

In general, only terms that were significant in the single-variate models were included as candidates in the flow, velocity, and stage models. However, the flow, velocity, and stage metrics from the TRN gaging station were included as candidates in their respective models, regardless of their significance in the single-variate models. Backwards selection with F-tests was used to find the most parsimonious model in each category (flow, velocity, and stage) that explained the most variation in the data (McCullagh and Nelder 1989). Main effects and two-way interaction effects were considered. The model that resulted from the backwards selection process in each category (flow, velocity, or stage) was compared using an F-test to the full model from that category to ensure that all significant main effects were included. AIC was used to select among the flow, velocity, and stage models. Model fit was assessed by grouping data into discrete classes according to the independent covariate, and comparing predicted and observed frequencies of route entrainment into the San Joaquin using the Pearson chi-squared test (Sokal and Rohlf 1995).

Comparison of survival between Mossdale and Jersey Point in 2012 compared to past years.

A multiple regression was run on the combined data set of survival estimates from Mossdale to Jersey Point with the HORB using CWT's in 1994, 1997, 2000-2004 (SJRGA 2013) and using acoustic tags for the two releases in 2012 to determine if tag type (acoustic tag or coded wire tag) was a significant factor in addition to flow for predicting survival. We also compared the results observed in 2012 to those predicted from the CWT relationship with flow at the same flow levels as those experienced by tagged fish in the two 2012 releases. The data were also plotted and the two regression lines were compared; CWT data only and the CWT data combined with the 2012 acoustic tag data.

Results

Transport to Release Site

No mortalities were observed after transport to the release site. Water temperatures ranged from 16.8°C to 20.3° C after loading, prior to transport. Water temperatures ranged from 16.5°C to 20.5°C after transport and before unloading at the release site. Water temperature in the river at the release site ranged from 17.5°C to 20.7°C, with the average during the first week being lower (18.3°C) than for the second week (19.7°C) (Table 6). By adding ice, water temperatures did not change substantially during transport (Table 6 and Appendix 3) and water temperatures in the transport tanks when arriving at the release site were usually within a degree C of the water temperature in the river (Table 6). During transport water temperatures did not rise or lower more than 0.5°C, and transport tank temperatures were similar between tanks within about 0.5 °C (Appendix 3). Dissolved oxygen levels ranged between 8.73 and 11.89 mg/l for all measurements in the transport tanks or in the river (Table 6).

Fish Releases

No mortalities occurred after holding and prior to release in the 2012 Chinook Salmon study (Table 6).

Dummy Tagged fish

None of the 60 dummy-tagged Chinook Salmon were found dead when evaluated after being held for 48 hours (Table 7). Three fish from the May 20 group had abnormal gill coloration. All remaining fish were found swimming vigorously, had normal gill coloration, normal eye quality, normal body coloration and no fin hemorrhaging. Mean scale loss for all fish assessed ranged from 2.3 to 5.5%. Eight of the 60 examined fish were found to have stitched organs. Mean FL of the four groups of dummy tagged fish ranged from 108.2 to 112.0 mm. These data indicate that the fish used for the Chinook Salmon study in 2012 appeared to be in generally good condition (Table 7).

Fish Health

Pathogen testing conducted on dummy-tag cohorts of acoustic tagged MRH juvenile Chinook Salmon used in studies corresponding to May 7 and May 23 releases showed no virus or *Renibacterium salmoninarum* infection detected in the fish. The May 23 group had 37% prevalence of both suture abnormalities and A*eromonas – Pseudomonas* sp. infection however there was little correlation between the two findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent ($\geq$ 97%) and the associated Proliferative Kidney Disease became more pronounced in the May 23 sample. No mortality occurred to these fish prior to assessment after they had been held for 48 hours for either sample date. Gill Na-K-ATPase data was not reported due to a problem with a key assay reagent. The combination of kidney impairment and poor suture condition of the May 23 salmon indicates that health of the two release groups was not equivalent. See Appendix 4 for more detail on the results of the fish health evaluations.

Tag retention test

Of the 39 dummy tagged fish held for 30 days, 3 died within the first 5 days after tagging. No other mortality was observed during the 30 day period. This suggests that the tagging process alone may have caused some (less than 10%) of the mortality observed during the study. None expelled their tag.

Detections of Acoustic-Tagged Fish

There were 960 acoustic tags released in juvenile Chinook Salmon at Durham Ferry in 2012, but one was removed from the analyses due to the tag “looking odd” resulting in data from only 959 being analyzed. Of these, 713 (74%) were detected on one or more receivers either upstream or downstream of the release site (Table 8), including any predator detections. A total of 707 tags (74%) were detected at least once downstream of the release site, and 482 (50%) were detected in the study area from

Mossdale to Chipps Island (Table 8). Although more tags from the second release group were detected between the release site and the upstream boundary of the study area (Mossdale), considerably more tags from the first release group were detected in the study area than from the second release group (301 vs. 181) (Table 8).

The large majority of the tags detected in the study area were detected in the San Joaquin River route (449 of 482), while only 11 tags were detected in the Old River route (Table 8). Additionally, some tags were detected in the study area near Mossdale Bridge but not downstream of the head of Old River. In general, tag detection counts in the San Joaquin River route decreased as distance from the release point increased. Of the 449 tags observed in the San Joaquin River route, 449 were detected on the receivers near Lathrop; 310 were detected on one or both of the receivers near Stockton (SJG or SJNB); 111 were detected on the receivers in the San Joaquin River near MacDonald Island or in Turner Cut; and 47 were detected at Medford Island (Table 9).

Some of the 449 tags detected in the San Joaquin River downstream of the head of Old River were not assigned to that route for survival analysis because they were subsequently observed upstream of Old River and had no later downstream detections (Table 8). Overall, 446 of the 449 tags observed in the San Joaquin River downstream of Old River were assigned to that route for survival analysis. Of these, 13 tags were observed exiting the San Joaquin River at Turner Cut, three were observed at the Old or Middle River receivers near of Empire Cut, one was observed at the Old and Middle River receivers near Highway 4, one was observed at the CVP trashrack, and none were observed at the radial gates at the entrance to the Clifton Court Forebay (Table 9). A total of 28 San Joaquin River route tags were detected at the Jersey Point/False River receivers, including seven detections on the False River receivers (Table 9). However, all of the tags detected at False River were later detected either at Jersey Point or at Chipps Island, and so no San Joaquin River route tags were used in the survival model at False River (Table10). A total of 14 San Joaquin River route tags were eventually detected at Chipps Island, including predator-type detections (Table 9).

Only 11 tags were detected in the Old River route, and all but one, were assigned to that route for survival analysis (Table 8). Nine (9) tags were detected both at the Old River East receivers near the head of Old River (ORE) and the Old River receivers near the head of Middle River (ORS). Four tags were detected at the CVP trashracks, and none at the radial gates at the entrance to the Clifton Court Forebay (Table 9). One tag from the Old River route was detected at both the Old River sites near Highway 4 and near Empire Cut; it was last detected at Empire Cut. No tags from the Old River route were detected at any of the Middle River sites (Table 9). One of the 11 tags in the Old River route was observed at Chipps Island, and it passed through the holding tank at the Central Valley Project (Tables 9 and 10).

In addition to the Old and Middle receivers located near Empire Cut, the Threemile Slough receivers recorded detections of tags but were purposely omitted from the full survival model. Six tags were detected on the Threemile Slough receivers: four came directly from the San Joaquin River receivers at Medford Island and MacDonald Island, and two were last detected at Jersey Point before being detected at Threemile Slough (Table 9). Those that had come from Medford Island and MacDonald Island continued on to either Jersey Point or Chipps Island, while those that came upriver to Threemile Slough from Jersey Point had no subsequent detections.

The predator filter used to distinguish between detections of juvenile Chinook Salmon and detections of predatory fish that had eaten tagged smolts classified 130 of the 959 tags released (14%) as being detected in a predator at some point during the study (Table 11). Of the 482 tags detected in the study area (i.e., at Mossdale or points downstream), 95 tags (20% of 482) were classified as being in a predator, and the majority (94 of 95) were first classified as being in a predator within the study area. The remaining tag was classified as a predator at Banta Carbona (upstream of the study area) but was later detected in the San Joaquin River at the Lathrop receiver (SJL). Approximately 7% (36 of 535) of the tags detected upstream of Mossdale were classified as being in a predator in that region (Table 11). Two of the tags that were first classified as predators in the study area were subsequently detected upstream of Mossdale. Two of the nine tags detected at upstream Old River sites (ORE and ORS) were classified as in a predator (Table 11).

Within the study area, the detection sites with the largest number of first-time predator-type detections were Lathrop (14 of 449, 3%), Garwood Bridge (18 of 310, 6%), Navy Drive Bridge (23 of 241, 10%), and MacDonald Island (18 of 100, 18%) (Tables 9 and 11). The majority of predator classifications at these four sites were assigned on tag departure from the detection site in question because of long residence times and movements against the flow. Because those detections that are assigned the predator classification only on departure are not removed from analysis in the survival model, only a few detections were actually removed from these sites.

When the predator-type detections were removed, slightly fewer detections were available for the survival analysis (Tables 12-14). With the predator-type detections removed, 697 of the 959 (73%) tags released were detected downstream of the release site, and 480 (50% of those released) were detected in the study area from Mossdale to Chipps Island (Table 12). A similar percentage of the tags from each release group were detected anywhere as a smolt (73% and 72% for the two release groups). Considerably more tags from the first release group were detected in the study area than from the second release group (63% vs. 37%) (Table 12).

Removing predator-type detections did not appreciably change the spatial patterns in the detection counts. The large majority of the tags detected in the study area were detected in the San Joaquin River route (444 of 480, 93%) and assigned to that route for the survival analysis. Only 11 tags were observed in the Old River route (Table 12). Another 25 tags were detected at the Mossdale receivers, but not downstream of the head of Old River (Table 12). Most of the changes to detection counts introduced by removing predator-type detections occurred at receivers in the San Joaquin River, both upstream and downstream of the head of Old River (Tables 9 and 13). There was no change in tag counts at Jersey Point, False River, and Chipps Island. There were very few detections at receivers throughout the western and northern regions of the interior Delta (Table 13), and somewhat fewer once detections were formatted for survival analysis (Table 14). Whether predator-type detections were included or not, detections from those sites had to be omitted from the survival model (Tables 10 and 14) (See *Statistical Methods: Survival Model – Reduced Model*).

Tag-Survival Model and Tag-Life Adjustments

The Akaike Information Criterion (AIC) indicated that pooling data from both tag-life studies (AIC = 18.1) was preferable to stratifying by study month (AIC = 33.4). Thus, a single tag survival model was fitted and used to adjust fish survival estimates for premature tag failure. The estimated mean time to failure from the pooled data was 41.7 days ($SE = 7.5$ days) (Figure 7).

The complete set of detection data, including predator-type detections, contained some detections that occurred after the tags began dying (Figures 8 and 9). The sites with the latest detections were Banta Carbona and the San Joaquin River receivers near the Lathrop, Garwood Bridge, Navy Bridge and MacDonald Island. Some of these late-arriving detections may have come from predators. Tag-life corrections were made to survival estimates to account for the premature tag failure observed in the tag-life studies. All estimates of reach survival for the acoustic tags were greater than 0.99 (out of a possible range of 0 – 1). Thus, there was very little effect of either premature tag failure or corrections for tag failure on the estimates of salmon reach survival in 2012.

Tagger Effects

Fish in the release groups were evenly distributed across tagger (Table 15). For each tagger, the number tagged was distributed evenly across the two release groups. A chi-squared test found no evidence of lack of independence of tagger across the release groups (χ^2 =0.0279, df=3, P=0.9988). The distribution of tags detected at various key detection sites or regions of the study area was well-distributed across taggers, showing no evidence of a tagger effect on survival, route entrainment, or detection probabilities at these sites (χ^2 =16.8759, simulated P-value = 0.5372; Table 16).

Estimates of cumulative survival throughout the San Joaquin River route to Chipps Island showed generally small, non-significant effects of tagger through the system (Figure10). Tagger C had consistently higher point estimates of cumulative survival through the receiver at Navy Drive Bridge, after which cumulative survival from this tagger were no greater than from the other taggers. Despite the higher point estimates of survival observed for Tagger C, the differences were not statistically significant (ANOVA, P = 0.1944). Furthermore, rank tests found no evidence of consistent differences in reach survival across fish from different taggers either upstream of the head of Old River (P=0.9217) or in the San Joaquin River route (P=0.9704). Fish tagged by Tagger B had significantly lower survival estimates through the San Joaquin River reach from the Navy Bridge to the Turner Cut junction (i.e., MacDonald Island and Turner Cut) (F-test: P = 0.0078); however, fish from Tagger B showed no difference in survival estimates in other reaches or to Chipps Island overall compared to the other taggers (Figure 10).

In particular, there was no difference in overall survival to Chipps Island among taggers through the San Joaquin River route (P=0.4655). Only one fish was observed to arrive at Chipps Island via the Old River route, so no tagger effects could be explored for that route. The survival model was fit to the data pooled from all taggers without Tagger B, and estimates of four key performance measures were compared to results found with Tagger B: S_{Total}, S_A, S_B, and $\phi_{A1,A4}$. Statistical Z-tests on the log-scale found no significant difference between estimates of these parameters with and without data from fish tagged by Tagger B (P≥ 0.5835).

Survival and Route Entrainment Probabilities

As described above, detections from the receivers at the entrances to the water export facilities and in the holding tank at the Central Valley Project were removed from the survival model because of sparse data, as were detections from the Old and Middle River receivers near Highway 4. In some cases, there were too few detections at the dual array just downstream of Durham Ferry (DFD, site A2) to include this site in the model. In these cases, the model used the composite parameter $\phi_{A1,A3} = \phi_{A1,A2} S_{A2}$ in place of $\phi_{A1,A2}$ and S_{A2}. Also, in several cases analysis of model residuals showed that incorporating the full dual receiver array at some detection sites reduced the quality of the model fit to the data. In such cases when it was possible to simplify the data structure and still attain useful and valid parameter estimates, detections from the dual array in question were pooled to create a redundant array for better model fit. This occurred at the downstream Durham Ferry site (A2), MacDonald Island (A8), Old River South (near the head of Middle River, B2), and Jersey Point (G1).

No tags from the second release group (released in mid-May) were detected at Chipps Island in 2012, yielding a total Delta survival estimate of 0 ($SE = 0$) for that group whether or not predator-type detections were included. The first release group (released in early May) had positive survival ($S_{total} =$ 0.05; $SE = 0.01$), yielding a population estimate for all fish in the tagging study of 0.03 ($SE = 0.01$) (Table 17). Using only those detections classified as coming from juvenile Chinook Salmon and excluding the predator-type detections, the estimated probability of remaining in the San Joaquin River at the junction with Old River $\left(\psi_A = \psi_{A1}\right)$ was 0.98 ($SE = 0.01$) for both release groups (Table 17), and both release groups demonstrated a significant preference for the San Joaquin River route (P<0.0001 for each group). The estimated survival from Mossdale to Chipps Island via the San Joaquin River route $\left(S_A\right)$ was 0.05 ($SE = 0.01$) for the first release group, and 0 ($SE = 0$) for the second group; the overall population estimate was 0.03 ($SE = 0.01$)(Table 17). Very few fish took the Old River route (11 overall). Although the point estimate of survival to Chipps Island via this route ($S_B = 0.16$) was relatively high compared to the estimated survival via the San Joaquin River route ($S_A = 0.05$), the small number of fish observed taking the Old River route resulted in very high uncertainty in the Old River route survival estimate ($SE = 0.15$ for S_B); thus no significant difference in route-specific survival was detected for the first release group (P=0.1977). The estimated route-specific survival to Chipps Island via the Old River route was 0 for the second release group, yielding a population estimate of $S_B = 0.11$ ($SE = 0.10$); again, there was no significant difference in population survival estimates between the two routes (P=0.1999) (Table 17).

Survival in the Old River route used the parameter $\phi_{B1,B2}$ in place of S_{B1} because there were no detections at site C1 (MRH) (see *Statistical Methods*). The transition parameter $\phi_{B1,B2} = S_{B1}\psi_{B2}$, so if $\psi_{B2} < 1$, then S_B is underestimated using this formulation. For the first release group, $\phi_{B1,B2}$ = 1 ($SE =$

0), so both $S_{B1} = 1$ and $\psi_{B2} = 1$, and S_B is not underestimated (Table A5-2). For the second release group, $\phi_{B1,B2}$=0.67 ($SE = 0.27$), implying that either $S_{B1} < 1$ or $\psi_{B2} < 1$, or both (Table A5-2). However, there was only a single tag detected at site B1 (ORE) that was not later detected as a smolt at site B2 (ORS), and this tag was actually detected at B2 with a predator classification at that site. Thus, there is no evidence that $\psi_{B2} < 1$ for either release group, and so it reasonable to interpret estimates of S_B as unbiased rather than as minima. Furthermore, the lack of detections of tags from the second release group at Chipps Island would yield $S_B = 0$ for that release group in any event. Thus, there is no reason to assume that survival to Chipps Island via the Old River route is underestimated.

Survival was estimated to Jersey Point for fish that used the San Joaquin River route. This survival measure $\left(S_{A(MD)}\right)$ was estimated at 0. 09 (SE =0.02) for the first release group, 0.01 (SE =0.01) for the second release group, and 0.06 (SE =0.01) overall (Table 17). No estimates were available for the Old River route. Survival $\left(S_{A(SD)}\right)$ to the receivers just downstream of the Turner Cut junction on the San Joaquin River (i.e., MacDonald Island and Turner Cut receivers) was estimated at 0.33 ($SE = 0.03$) for the first release group, 0.07 ($SE = 0.02$) for the second release group, and 0.23 ($SE = 0.02$) overall (Table 17). Thus it is apparent that survival was low both to the Turner Cut junction and from that junction to Jersey Point, especially for fish from the second release group.

Survival was lower for the second release group than for the first group throughout the San Joaquin River. Estimated survival from the release site to Mossdale ($\phi_{A1,A4}$) was considerably lower (p<0.0001) for the second release group (0.37 for the second group vs. 0.63 for the first group), as was survival through the Southern Delta (0.07 vs. 0.33; p<0.0001), Middle Delta to Jersey Point (0.01 vs. 0.09; p<0.0001), and the entire Delta to Chipps Island (0 vs. 0.05; p<0.0001)(Table 17). Estimated survival was also lower through the modeled portions of the Old River route, i.e., from the head of Old River to the head of Middle River for the second release group. For the first release group, estimated survival through this reach was 1.0; for the second release group, it was 0.67 ($SE = 0.27$); however, the difference was not statistically significant (p= 0.1106) (Table A5-2). Although the estimate for this reach for the second release group had high uncertainty, the point estimate fits the pattern observed in the San Joaquin River of lower survival for the second release group relative to the first release group.

Including predator-type detections in the analysis produced very similar results on all spatial scales, including survival to Chipps Island, Jersey Point, and the Turner Cut junction (Table 18). The largest difference was in estimates of San Joaquin River survival through the Southern Delta to the Turner Cut junction $\left(S_{A(SD)}\right)$, which increased by 0.01 for both release groups and overall (overall estimate = 0.24, $SE = 0.02$) (Table 18). Including predator detections did not alter the comparisons between release groups; estimated survival was lower for the second release group throughout the various San Joaquin River regions (Table 18; P<0.0001).

Parameter estimates were significantly (family-wise α=0.10) higher for the first release group compared to the second release group for parameters S_{A2}, S_{A3}, S_{A4}, S_{A5}, S_{A7}, $\phi_{A8,G1}$, and $\phi_{G1,G2}$ (Table 19).

Travel Time

Average travel time through the system from release at Durham Ferry to Chipps Island was 5.75 days based on 11 detections ($SE = 0.41$ days) (Table 20a). Travel time to Chipps Island ranged from 4.1 days to 10.4 days, all from the first release group. The large majority of tags that reached Chipps Island came via the San Joaquin River route; the single tag that arrived at Chipps Island via the Old River route had a total travel time of 4.12 days, which was faster than any of the 14 tags that arrived via the San Joaquin River route. All tags observed at Jersey Point arrived via the San Joaquin River route in 3 – 9 days, with an average of approximately 6 days (Table 20a).

Travel time from release to the Mossdale Bridge receivers ranged from 0.3 to 3.9 days, and averaged 0.53 days (harmonic mean; $SE = 0.01$ days) (Table 20a). Fish with the longer travel times to Mossdale tended to come from the second release group, although both release groups included fish that arrived in under 8 hours. Travel time from release to the Turner Cut junction receivers (i.e., to Turner Cut or MacDonald Island) ranged from 1.5 days to 8.2 days, and averaged between 2 and 4 days (Table 20a). Fish with the longer travel times to Mossdale tended to come from the second release group, although both release groups included fish that arrived in under 8 hours. Travel time from release to the Turner Cut junction receivers (i.e., to Turner Cut or MacDonald Island) ranged from 1.5 days to 8.2 days, and averaged between 2 and 4 days (Table 20a).

Only 2 tags were detected at the Old River receivers near Highway 4 (OR4). One of these tags came via the Old River route and arrived 4.3 days after release, while the other tag arrived via Turner Cut from the San Joaquin River route 5.1 days after release. For the few tags that were detected at the entrance to the Central Valley Project, tags that came via the Old River route tended to have shorter travel times than tags that arrived via the San Joaquin River route (Table 20a). Sample sizes were too small to draw definitive conclusions, but these observations may have been expected because of the longer route to the interior and western receivers via the San Joaquin River route.

Including predator-type detections had only a small effect on average travel times through the system (Table 20b). Travel times to the San Joaquin River receivers at MacDonald Island and Turner Cut were generally slightly longer when predator-type detections were included. This was because travel times were measured to the beginning of the tag's final visit to each site, and many tags classified as being in predators at those sites were observed making multiple visits to those sites. The longer travel times observed for the data set that includes the predator-type detections reflect the assumption used in the predator filter that predators are more likely than smolts to exhibit long travel times.

Average travel time through reaches for tags classified as being in smolts ranged from 0.01 days (approximately 20 minutes) for the single tag observed moving from the Central Valley Project trashracks to the holding tank, to over 2 days for tags moving from MacDonald Island to Jersey Point, and over 3 days for tags moving from MacDonald Island and Medford Island to Chipps Island (Table 21a). While there were several tags that moved from MacDonald Island to Jersey Point in under 2 days, there were also several tags that took over 5 days to make the journey. Similar travel times were observed from the Medford Island receivers to the Jersey Point receivers, although the average travel time was somewhat lower from Medford Island (approximately 1.54 days over both release groups) (Table 21a). The reach from MacDonald Island to Jersey Point was one of the longer reaches in the study area (approximately 26 rkm), so it not surprising that it had some of the longer observed travel times. However, the reach from Jersey Point to Chipps Island was also approximately 26 rkm in length, and travel time through this reached tended to be shorter, ranging from 16 hours to 2.1 days and averaging 1.21 days ($SE = 0.14$ days) (Table 21a). The region between Jersey Point and Chipps Island is strongly affected by tides, which may delay migrating fish, but it is nevertheless channelized. The region between MacDonald Island and Jersey Point, on the other hand, includes Frank's Tract, and it is possible that migrating Chinook Salmon smolts are delayed there for a considerable time. In general, there were too few detections in the interior Delta to make comparisons of travel time through reaches in that region with travel time through reaches contained within the San Joaquin River route. Including predator-type detections did not greatly affect the pattern of observed travel times through the various reaches (Table 21b).

There was a significant negative relationship ($p<0.05$) between travel time per km and survival per km in river reaches upstream of the Lathrop/Old River junction for the second release group, suggesting as travel time per km increased, survival per km decreased (Figure 11, Table 22). Survival also decreased as travel time increased in reaches between Durham Ferry and Lathrop/Old River junction for the first release group, but the regression line was not significant at the $p<0.05$ level. Survival was higher for the first release group, than for the second release group in these three reaches of the river (Figure 11, Table 19). Also there appeared to be a slight increase in travel time (slower migration rate) between Mossdale and Lathrop/Old River junction and between Banta Carbona and Mossdale for the second release group relative to the first release group (Figure 11, Table 22).

In contrast, there did not appear to be a relationship between travel time per km and survival per km for reaches between the Lathrop/Old River junction and Jersey Point (tidal reaches) for either of the release groups in 2012 (Figure 12). While survival through the reach (or joint probability of moving to and surviving to the downstream location) was significantly higher (Table 19) for the first release group for three of these reaches in the San Joaquin River downstream of Lathrop (Lathrop to Garwood Bridge, S_{A5} ; Navy Drive Bridge to MacDonald Island or Turner Cut, S_{A7} ; and the reach between MacDonald Island to Jersey Point, $\phi_{A8,G1}$ [not shown on Figure 12]0, others were not significantly higher (e.g. Garwood Bridge to Navy Bridge Drive [S_{A6}], MacDonald Island to Medford Island [$\phi_{A8,A9}$], and Medford Island to Jersey Point [$\phi_{,A9,G1}$]) (Table 19). Travel times in these reaches were similar for the two release groups (Figure 12).

Route Entrainment Analysis

River flow (discharge) at the TRN gaging station in Turner Cut ranged from -4,402 cfs to 3,361 cfs (average = -1070 cfs) during the estimated arrival time of the tagged Chinook Salmon at the Turner Cut junction location (TCJ) in 2012. Water velocity in Turner Cut was highly correlated with river flow ($r=0.999$), and velocity values ranged from -0.8 ft/s to 0.6 ft/s (average = -0.1 ft/s). The flow in Turner

Cut was negative (i.e., directed to the interior Delta) upon arrival at TCJ of approximately 61% (54 of 89) tags in this analysis. River stage measured in Turner Cut was moderately correlated with both river flow and velocity (r=-0.70), and ranged from 6.7 ft to 10.9 ft (average = 9.1 ft). Changes in river stage in the 15-minute observation period containing the arrival of the tagged Chinook Salmon to the TCJ ranged from -0.2 ft to 0.2 ft (average = 0 ft). Changes in river stage were not correlated with stage (r=-0.13). The index of river flow in the reach from Stockton to Turner Cut was uncorrelated with flow and velocity in Turner Cut upon arrival at TCJ (r= 0.01), and only moderately correlated with river stage at Turner Cut (r= -0.29). The flow index in the Stockton-Turner Cut reach ranged from 2,324 cfs to 3,400 cfs (average = 2,785 cfs).

The daily export rate at CVP ranged from 821 cfs to 1,016 cfs (average = 960 cfs); exports at CVP were generally low in both early and late May, and was greatest in mid-May. The daily export rate at the State Water Project (SWP) ranged from 507 cfs to 3,698 cfs (average = 1,908 cfs). SWP exports were more variable than CVP exports but also peaked in the third week of May. Exports from CVP and SWP were uncorrelated (r= -0.01). Neither CVP nor SWP exports was correlated with either flow (r=0.09 for CVP, r=-0.03 for SWP) or river stage (r=0.00 for CVP, r=-0.14 for SWP) in Turner Cut. The majority of tags (66 of 89, 74%) arrived at the Turner Cut junction during daylight hours.

The single-variate analyses found no significant effects (α=0.05) of any of the covariates considered (P>0.40 for all covariates; Table 23). This negative result may reflect the true lack of a relationship between environmental variables and route selection at Turner Cut, or it may be an artifact of the low degrees of freedom available and the resulting low statistical power; because only 11 fish were observed entering Turner Cut (out of 89), there were only 11 degrees of freedom total. A study with a larger sample size and more fish observed using Turner Cut may provide evidence of a relationship between one or more of the covariates and route selection at this junction in future.

Comparison of Delta Survival to Past Years

In a multiple regression, tag type (acoustic or CWT) did not come out as an important variable affecting survival, whereas flow did (Table 24). Using the relationship developed from the CWT data (Figure 13), we calculated what survival from Mossdale to Jersey Point was expected to be at the two flow levels in 2012: predicted survival was 0.12 at flows of 3543 cfs and 0 at flows of 2327cfs, very close to what we observed (0.09, $SE = 0.02$, at the higher flow and 0.01, $SE = 0.01$, at the lower flow). The relationships between flow at Vernalis and survival from Mossdale to Jersey Point with the HORB, developed from the historical CWT data and from all of the data (historic CWT data and acoustic tag data added from 2012), were similar (Figure 13). The slopes of the two linear regression lines were the same (0.0001), and the intercepts were similar (-0.2345 for the CWT data only and -0.2295 for the combined data (Figure 13)) . Both relationships were statistically significant (p <0.01).

Discussion

The similarity between parameter estimates with and without predator-type detections raises questions about the predator filter. One possible explanation for the similar estimates is that the majority of the mortality was not directly caused by the predatory fish used to build the predator filter, or that many of the predatory fish feeding on the tagged salmon merely evaded detection. Chinook Salmon smolts may have been eaten by sedentary predators, birds, or mammals (e.g., otters), or by predatory fish that moved about the Delta but evaded the acoustic receivers. Alternatively, Chinook Salmon smolts may have died due to disease or habitat quality. In either case, the tags of the deceased salmon smolts may have settled on the river bottom away from the acoustic receivers; in these cases, the predator filter would correctly identify existing detections of these tags as in smolts rather than predators, and the survival model estimates would be unbiased.

Another possibility is that the filter missed detections of predators, and thus the resulting filtered data set (which supposedly has no detections from predators) is only artificially similar to the unfiltered data set (which includes detections from predators). If this is the case, then survival estimates for the (presumed) smolt-only data set would be biased because they would be based partially on predator detections. The type of bias depends on where the predator filter failed. For example, none of the tags detected at Chipps Island were classified as being in predators by the existing filter. A filter that recategorizes some of those detections as predator detections may yield survival estimates to Chipps Island that are lower than that estimated in this study (0.03). This would happen as long as the revised filter agreed with the original filter in upstream regions. On the other hand, if the predator filter was inefficient (i.e., wrong) upriver of Mossdale such that detections passed by the filter as smolts were actually detections of predators, then it is possible that true survival to Chipps Island was actually higher than estimated (0.03); this may happen if there were fewer actual smolts starting at Mossdale than appeared from the original filter. Of the 959 tags released at Durham Ferry, only 480 (50%) were detected at Mossdale, and 478 of them were classified as in smolts upon arrival at Mossdale (Tables 9 and 13). Only 15 of these tags were detected at Chipps Island. Adjusting the predator filter cannot add more detections at Chipps Island, but it may remove detections at Mossdale. A revised filter that used more stringent criteria upstream of Mossdale was constructed and implemented on the detection data. The revisions to the filter were:

- no upstream-directed transitions allowed upstream of Mossdale
- no repeat visits to sites upstream of Mossdale
- maximum residence time of 2 hours at any site upstream of Mossdale
- maximum regional residence time of 15 hours upstream of Mossdale
- minimum migration rate of 0.2 km/hr for all transitions upstream of Mossdale

This stricter filter resulted in 477 of the 480 detections at Mossdale being classified as in smolts, compared to 478 classified as in smolts using the original predator filter. The Delta survival estimate from the stricter predator filter was 0.03 for the population (i.e., both release groups pooled), unchanged from the estimate using the original filter. Thus, it is unlikely that errors in the predator filter resulted in the similar results with and without the predator-type detections.

Our first objective of the 2012 study was to determine survival of emigrating salmon smolts from Mossdale to Chipps Island during two time periods (prior to May 15 and after May 15) in the presence of the HORB to determine if there was a benefit from the flow augmentation from the Merced

River in 2012. Average river flow measured at the Vernalis gaging station when fish from the first release group were traveling through the Delta to Chipps Island (from release through approximately 10 days after the end of release period) was 3,543 cfs, while for the period of comparable length for the second release group was 2,327 cfs (Figure 14). Survival was higher ($p < 0.0001$) through the Delta (S_{Total}) for the first release group (0.05) relative to the second release group (0.00) (Table 17). Thus these findings appear to support our hypothesis that the increased flow from the Merced River flow augmentation increased survival through the Delta.

Our second objective was to assess whether the higher flows from the Merced River flow augmentation resulted in a reduction in travel time and higher survival, specifically in the riverine reaches of the Delta, and resulted in higher through-Delta survival. Shorter travel times would reduce the time tagged fish were exposed to mortality factors such as predation, high water temperatures, and toxics. Travel times in reaches of the Delta between Durham Ferry and a series of downstream locations (Mossdale, Lathrop, Garwood Bridge, Navy Drive Bridge, and MacDonald Island) were all significantly less (i.e. faster migration) for the first release group than the second release group (Table 20a; $p < 0.05$). The travel times in these reaches appeared to be strongly influenced by the travel time for the reach between Lathrop (SJL) and Garwood Bridge (SJG). Travel time between SJL and SJG was significantly less ($p < 0.05$) for the first release group (0.60; $SE =$ 0.02) which experienced the higher flows, than for the second release group (0.86; $SE =$ 0.05) which experienced the lower flows (Table 21a). Survival through this reach was also higher for the first release group (0.81; $SE =$0.02) relative to the second release group (0.48; $SE =$0.04)($p < 0.0001$) (S_{A5}; Table A5-2). Thus, the data in this specific, partly riverine, reach of the Delta are consistent with our hypothesis that an increase in flow would reduce travel time and be associated with higher survival.

To further evaluate the possible relationship between travel time and survival in the remaining reaches, travel time and survival were standardized to a per-km basis. With this standardization, we found that as travel time per km increased, survival decreased for both release groups in the three riverine reaches between Durham Ferry and the Lathrop/Old River junction (Figure 11). Travel time per km was greater for the second group relative to the first group for two of the three reaches; (Banta Carbona to Mossdale and Mossdale to Lathrop/Old River, but not Durham Ferry to Banta Carbona) whereas survival was always lower for the second release group (lower flows) relative to the first group (higher flows) for these three reaches (Figure 11, Table 22). Thus the difference in travel time per km for the first group relative to the second did not always support our hypotheses that the higher survival per km resulted from a decrease in travel time per km from the higher flows in these riverine reaches.

Travel time per km was somewhat less and survival greater for the first release group relative to the second release group in two reaches: 1) between Lathrop and Garwood Bridge (discussed above) and 2) between Garwood Bridge and Navy Bridge Drive (Figure 12, Table 22); the shorter travel time from the increased flow may partially explain the higher point estimate of survival for release 1 compared to release 2 between Garwood Bridge and Navy Bridge, although the increase in survival is not statistically significant at the 5% level (Table 19); however, it is not possible to determine causation from this study.

Once fish enter the interior Delta or into the strongly tidally influenced San Joaquin River, travel times were expected to increase and survival was expected to decrease. While we did generally see longer travel times per km in the tidal reaches (reaches downstream of Navy Bridge Drive), it was not always greater (Table 22; e.g. travel time per km was shorter from MacDonald Island to Medford Island than it was from Lathrop to Garwood Bridge). Travel time per km was also less for the second release group than for the first, even though survival was generally higher for the first group relative to the second in all reaches downstream of Navy Bridge Drive, except between MacDonald Island and Medford Island, when survival per km was higher for the second group (Table 22). Since the increased flow probably was not enough to change velocities significantly in the downstream tidal reaches, the increased survival of the first group relative to the second in most of these tidal reaches suggests there are other mechanisms either associated with flow or other factors that resulted in the increases in survival in these tidal reaches of the Delta.

Once fish move into the interior Delta, they are exposed to flows moving toward the export facilities, which may increase their travel time and reduce their survival to Jersey Point or Chipps Island. While many of the tagged fish may have been diverted from the San Joaquin River into the interior Delta downstream of Turner Cut, we were only able to identify those entering the interior Delta through Turner Cut. We had hypothesized that tagged fish moving into the interior Delta (e.g. Turner Cut) would have increased travel times over those not being diverted into Turner Cut. Since none of the tagged fish that entered Turner Cut survived to Chipps Island for either the first or second release group, we could not compare travel times between release groups or for the Turner Cut route relative to the other routes. One fish that entered Turner Cut from the first release group was observed in the CVP holding tank, but did not survive to reach Chipps Island. We were also not able to assess the impact on survival of tagged fish being routed to the SWP and CVP as detections from the receivers at the entrances to the water export facilities and in the holding tank at the Central Valley Project were removed from the survival model because of sparse data due to the presence of the HORB.

The results of comparing travel time to survival suggests that the increased flow during the first release did not always result in decreased travel times, although it did coincide with an increase in survival in more of the riverine reaches. It was the higher survival in the majority of the reaches (both riverine and tidal) during the first release that resulted in a higher overall survival through the Delta for the first release group relative to the second release group.

However, there are other possible hypotheses for the lower survival in the second release group compared to the first release group, including differences in fish condition, tagging and release procedures, and other environmental conditions. The same tagging and release procedures were used for both release groups, including the same taggers, presumably with the same skill set, so that does not appear to be responsible for the differences in survival we observed. Fish from the second release group were slightly larger on average than fish from the first release group (mean FL = 109.9 mm and 115.7 mm for the first and second release groups, respectively), so it was reasonable to expect higher survival for the second release group rather than lower survival, but we did not observe this. Although the two release groups were released only two weeks apart, they experienced different environmental conditions other than flow. During the same two time periods, combined exports at CVP and SWP varied from 1,513 cfs to 5,054 (mean = 3,200 cfs), with similar means in the two periods. However, exports tended to be high toward the end of the first period, when relatively few fish from the first release were still migrating, and also high near the beginning of the second period, when the majority of fish from the second release group were migrating (Figure 15).

It is also possible that the difference in flow conditions may have resulted in the different survival rates via a mechanism other than travel time, such as temperature, increased predation or toxicity. We had hypothesized that the higher inflow from the Merced flow augmentation would potentially reduce the effects of these mortality factors by reducing temperature stress, diluting toxics or reducing predator metabolic demands from the lower water temperatures. Water temperature measured at the San Joaquin River gage near Lathrop was almost 2 degrees higher on average for the second release group (67.5 °F [19.7°C]) than for the first group (65.6 °F [18.7°C]), which may have negatively affected the survival of the second release group, and been a consequence of the lower flows experienced by the second release group (Figure 16). We were unable to assess the hypothesis that increased metabolic demands from predators due to the warmer water temperatures was the cause for the increased mortality for the second release group relative to the first release group.

To assess the hypothesis that the increased flow from the Merced River flow augmentation may have diluted toxicity in the Delta, we observed that survival was significantly higher for the first group relative to the second group in the reach between SJL and SJG (Table 19). This reach from SJL to the SJG is one of the longer reaches of the Delta at 18 km (Table 22), and it includes a variety of habitats. It is not entirely riverine, but includes the transition to tidal habitat, depending on inflow. The reach is more riverine at higher inflows, and more tidal at lower inflows. The Stockton Wastewater treatment plant releases its effluent in the lower part of this reach which may have an effect on survival, especially during periods of low flow. During periods of low flow the movement of the tidal prism upstream may result in concentration of the effluent in this reach and dilution from flow would be less. There is also the possibility that increased temperatures exacerbate the toxicity effects of the effluent on juvenile salmon survival. Further evaluation of water quality in this reach may be warranted, building on studies conducted near there in 2008 (SJRGA 2009) after a significant die-off of acoustic tags near this location in 2007 – a low flow year (SJRGA 2008).

In addition, it is possible that the higher incidence of PKD infection for the second release group reduced their survival to Chipps Island relative to the first release group. Infection does not necessarily lead to death but would reduce fitness from anemia, kidney dysfunction, and immune suppression even if the fish survived the disease (Angelidis et al 1987, Hedrick and Aronstien 1987 as cited in Nichols et al 2012). The increase in water temperature may have contributed to the higher incidence of PKD infection for the second release group relative to the first as PKD is a progressive disease at water temperatures greater than 15°C (Okamura and Wood 2002 as cited in SJRGA 2013).

Unfortunately, PKD infection is not just a problem for the experimental fish we used in 2012, but was noted as a problem in monitoring on the Merced River. Smolts caught in the Hopeton rotary screw trap on the Merced River (presumably wild stock) also had high levels of PKD infection in 2012 (Nichols et al. 2012). This is also not new, as 90-100% of naturally produced fish in a 2001 survey of Merced outmigrant salmonid health were observed to be infected with PKD (Nichols and Foott 2002 as cited in Nichols et al. 2012). Even some of salmon transferred from MRH to the lab at the Fish Health Center soon after ponding in February of 2012, developed light infections of PKD (Nichols et al 2012).

However, the worst infections identified in the 2012 study were later in the season, with gross clinical signs of PKD (anemia and swollen kidney) observed for naturally produced fish on May 9 (2 out of 24), and high numbers of parasites observed for both naturally produced (May 9 and May 15) and hatchery fish (May 15) (Nichols et al. 2012).

PKD is caused by infection by the endoparasitic myxozoan, *Tetracapsuloides bryosalmonae*. Reducing byrozoan habitat directly upstream of the hatchery and in the Merced River could be a viable disease management strategy (Foott et al. 2007). Increasing flows, if they result in decreasing water temperatures, would serve to reduce the severity of PKD for both experimental and wild fish emigrating from the San Joaquin basin. Higher water temperatures in the river and at the hatchery may have increased the severity of the PKD infection for the second group of tagged fish in 2012, relative to the first group; this may account for some of the increased mortality observed in the second group. Higher water temperatures are affected by both flow and air temperature upstream of the Delta. Cold water releases from the upstream reservoir on the Merced River may have reduced the water temperatures for the first release group over what they would have been without the water release.

Our third objective of the 2012 study was to identify route selection at HOR and at Turner Cut under the two different periods with varying flows and exports. Since the physical HORB was in place in 2012, route selection into the San Joaquin River was high for both groups (0.98; $SE = 0.02$) and did not vary between release groups (Table 17) or when predator type detections were included (Table 18). Route selection at Turner Cut was 0.11 ($SE = 0.03$) for the first release group, and 0.16 ($SE = 0.11$) for the second release group (Table 17) when predator-type detections were removed and similar when predator-type detections were included (0.12; $SE = 0.03$ for the first release group and 0.14; $SE = 0.04$ for the second release group) (Table 18). Differences in the proportion diverted into Turner Cut at the TCJ between release groups were not statistically different: with 11 to 16% of the tagged fish diverted into Turner Cut, none of which survived to Chipps Island ($S_{F1,G2}$; Tables A5-2 and A5-3). Zero probability of survival to Chipps Island for the tagged fish that entered Turner Cut negatively affected total through-Delta survival for both release groups. A study with a larger sample size and more fish observed using Turner Cut may provide evidence of a relationship between one or more covariates (e.g. flow, and tides) and route selection at this junction in future.

It is possible that the lower flows, higher water temperatures, higher toxicity, higher incident of disease (PKD) and possibly higher export rates during the time of peak migration may have combined to negatively affect salmon survival from the second release. Diversion into Turner Cut decreased survival of both groups. With only two release groups and observational data, however, it is not possible to conclude more. Combining these results with those from additional years may shed light on possible causes of mortality in the Delta. The Interagency Ecological Program has funded a multi-year analysis of the data from 2010, 2011, 2012 and 2013 and results will be forthcoming.

Based on the results of this study in 2012, naturally spawned or hatchery juvenile salmonids from the San Joaquin tributaries likely experienced variable survival within the migration period through the Delta, with greater survival during the Merced River flow augmentation period and lower survival during the later remainder period of migration. Higher flows appeared to benefit survival through multiple intertwined mechanisms including shorter travel times, lower water temperatures, and reduced disease impacts.

The comparison of estimates of survival from Mossdale to Jersey Point for the two release groups in 2012, to estimates generated using CWT's with the HORB, suggests that survival observed in 2012 was within that expected based on the past CWT relationship, and that differences in flow between the two releases in 2012 likely increased survival over what it would have been without the flow pulse. However, without direct manipulation and further replication, cause and effect cannot be determined.   While this comparison supports our hypothesis that the increased flow from the flow augmentation in the Merced River during the first release group increased survival, it also shows that survival for both groups in 2012 was relatively low, compared to that measured in other years with the HORB (Figure 13). These data suggest a higher flows of approximately 6,000 cfs with the HORB, are needed to achieve survival through the Delta of approximately 0.40. Additional studies, especially during higher flow periods, with the HORB in place, are needed to confirm these results.

List of References

Adams, N.S., D.W. Rondorf, S.D. Evans, and J.E. Kelly (1998). Effects of surgically and gastrically implanted radio tags on growth and feeding behavior of juvenile Chinook Salmon: Transactions of the American Fisheries Society, v.127, p. 128-136.

Brandes, P.L. and J.S. McLain (2001). Juvenile Chinook Salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Contributions to the Biology of the Central Valley Salmonids, Fish Bulletin 179: Volume 2.

Buchanan, R. (2013). OCAP 2011 Steelhead Tagging Study: Statistical Methods and Results. Prepared for Bureau of Reclamation, Bay Delta Office, Sacramento CA. August 9, 2013. 110 p.

Burnham, K. P., and D. R. Anderson (2002). Model selection and multimodel inference: A practical information-theoretic approach. 2nd edition. Springer. New York, NY. 488 pp.

California Department of Water Resources (2015). Final: An Evaluation of Juvenile Salmonid Routing and Barrier Effectiveness, Predation, and Predatory Fishes at the Head of Old River, 2009-2012. Prepared by AECOM, ICF International and Turnpenny Horsfield Associates. http://baydeltaoffice.water.ca.gov/sdb/tbp/web_pg/tempbar/horbereport.cfm

Cavallo, B., P. Gaskill, and J. Melgo (2013). Investigating the influence of tides, inflows, and exports on sub-daily flow in the Sacramento-San Joaquin Delta. Cramer Fish Sciences Report. 64 pp. Available online at: http://www.fishsciences.net/reports/2013/Cavallo_et_al_Delta_Flow_Report.pdf.

Cormack, R.M. (1964) Estimates of survival from the sighting of marked animals. Biometrika 51, 429-438.

Ferguson, HW. (1981). The effects of water temperature on the development of Proliferative Kidney Disease in rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Disease 4: 175-177

Foott JS, R Stone and K Nichols (2007). Proliferative Kidney Disease (Tetracapsuloides bryosalmonae) in Merced River Hatchery juvenile Chinook Salmon: mortality and performance impairment in 2005 smolts. California Fish and Game 93: 57-76.

Jolly, G.M. (1965) Explicit estimates from capture-recapture data with both death and immigration - Stochastic model. Biometrika 52: 225-247.

Lady, J. M., and J. R. Skalski (2009). USER 4: User-Specified Estimation Routine. School of Aquatic and Fishery Sciences. University of Washington. Available from http://www.cbr.washington.edu/paramest/user/.

Li, T., and J. J. Anderson (2009). The Vitality model: A Way to understand population survival and demographic heterogeneity. Theoretical Population Biology 76: 118-131.

Liedtke, T. (2012). 2012 South Delta Study Tagger Training and QA/QC Summary. Prepared by Theresa Liedtke, U.S. Geological Survey, Western Fishereis Research Center, Columbia River Research Laboratory 5501A Cook-Underwood Road, Cook, WA 98605, for J. Israel, USBR Bay-Delta Office, 801 I Street, Suite 140, Sacramento, CA 95814. 97pgs.

Martinelli, T.L., H.C. Hansel, and R.S. Shively (1998). Growth and physiological responses to surgical and gastric radio tag implantation techniques in subyearling Chinook Salmon: Hydrobiologia, v. 371/372, p. 79-87.

McCullagh, P., and J. Nelder (1989). Generalized linear models. 2nd edition. Chapman and Hall, London.

Nichols, K., A. Bolick and J.Scott Foott (2012). FY2012 Technical Report: Merced River juvenile Chinook Salmon health and physiology assessment, March-May 2012. December 2012. US Fish and Wildlife Service, California-Nevada Fish Health Center, 24411 Coleman Hatchery Road, Anderson CA 96007.

Perry, R. W. (2010). Survival and Migration Dynamics of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin River Delta. University of Washington, Ph.D. dissertation. 2010. 223 p.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane (2010). Estimating survival and migration route probabilities of juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta. North American Journal of Fisheries Management 30: 142-156.

San Joaquin River Group Authority (2007). 2006 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at www.sjrg.org.

San Joaquin River Group Authority (2008). 2007 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at www.sjrg.org.

San Joaquin River Group Authority (2010). 2009 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at www.sjrg.org.

San Joaquin River Group Authority (2011). 2010 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at www.sjrg.org.

San Joaquin River Group Authority (2013). 2011 Annual Technical Report: On Implementation and Monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared for the California Water Resources Control Board. Available at www.sjrg.org.

Seber, G. A. F. (2002). The estimation of animal abundance. Second edition. Blackburn Press, Caldwell, New Jersey.

Seber, G.A. F. (1965) A note on the multiple recapture census. Biometrika 52, 249-259.

Skalski, J. R., R. Townsend, J. Lady, A. E. Giorgi, J. R. Stevenson, and R. D. McDonald (2002). Estimating route-specific passage and survival probabilities at a hydroelectric project from smolt radiotelemetry studies. Canadian Journal of Fisheries and Aquatic Sciences 59: 1385 - 1393

Sokal, R. R., and Rohlf, F. J. (1995). Biometry, 3rd ed. W.H. Freeman and Co., New York, NY, USA.

Townsend, R. L., J. R. Skalski, P. Dillingham, and T. W. Steig (2006). Correcting Bias in Survival Estimation Resulting from Tag Failure in Acoustic and Radiotelemetry Studies. Journal of Agricultural, Biological, and Environmental Statistics 11: 183-196.

US Bureau of Reclamation (2012). San Joaquin River Flow Modification Study. Finding of No Significant Impact. Division of Planning, Mid Pacific Region, Sacramento CA. 3 p.

Vogel, D. A. (2010). Evaluation of acoustic-tagged juvenile Chinook Salmon movements in the Sacramento-San Joaquin delta during the 2009 Vernalis Adaptive Management Program. Technical Report for San Joaquin River Group Authority. 72 p. Available http://www.sjrg.org/technicalreport/ (accessed 13 December 2011).

Vogel, D. A. (2011). Evaluation of acoustic-tagged juvenile Chinook Salmon and predatory fish movements in the Sacramento-San Joaquin Delta during the 2010 Vernalis Adaptive Management Program. Technical report for San Joaquin River Group Authority. Available http://www.sjrg.org/technicalreport/ (accessed 13 December 2011).

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Figures

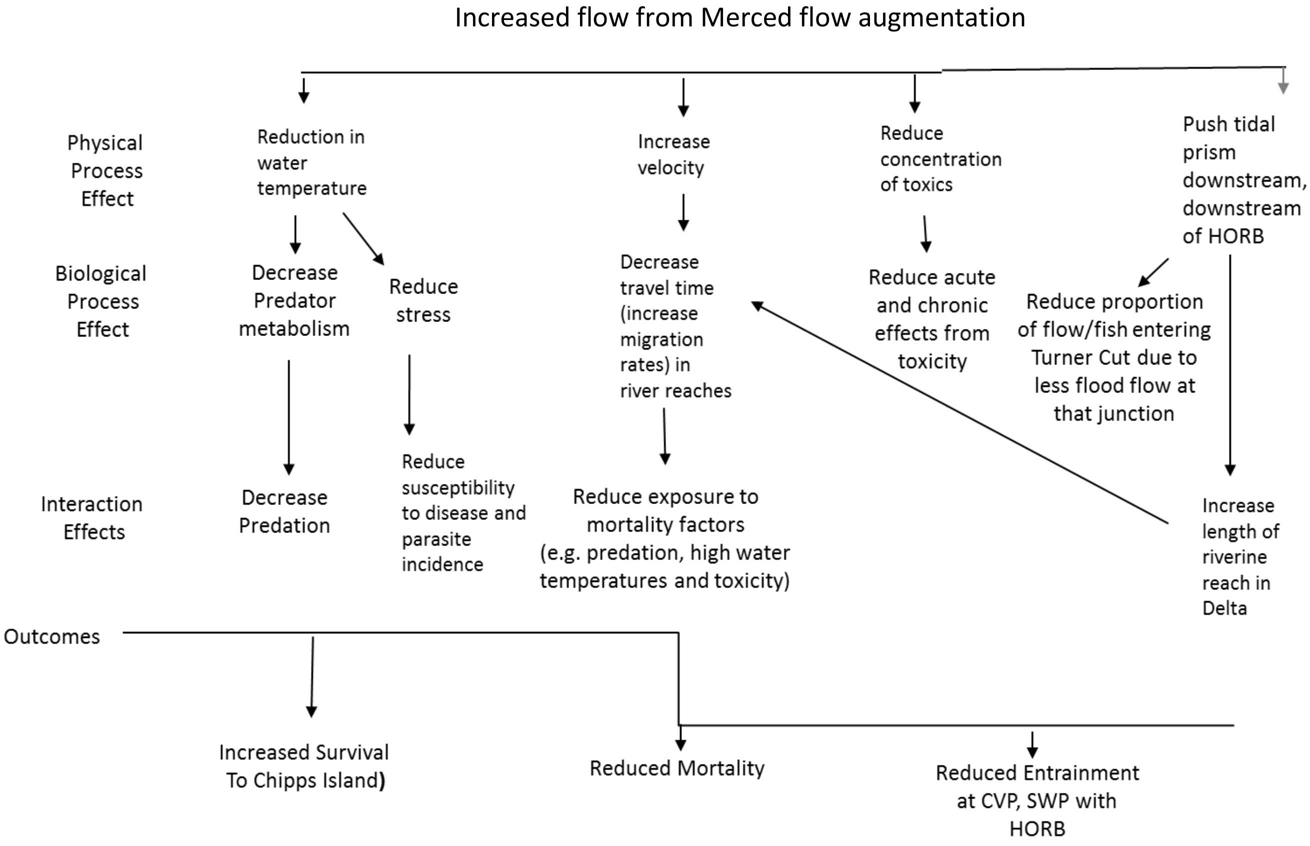


Figure 1: Conceptual model of mechanisms for increased survival from increasing Vernalis Flow with the head of Old River barrier in place.

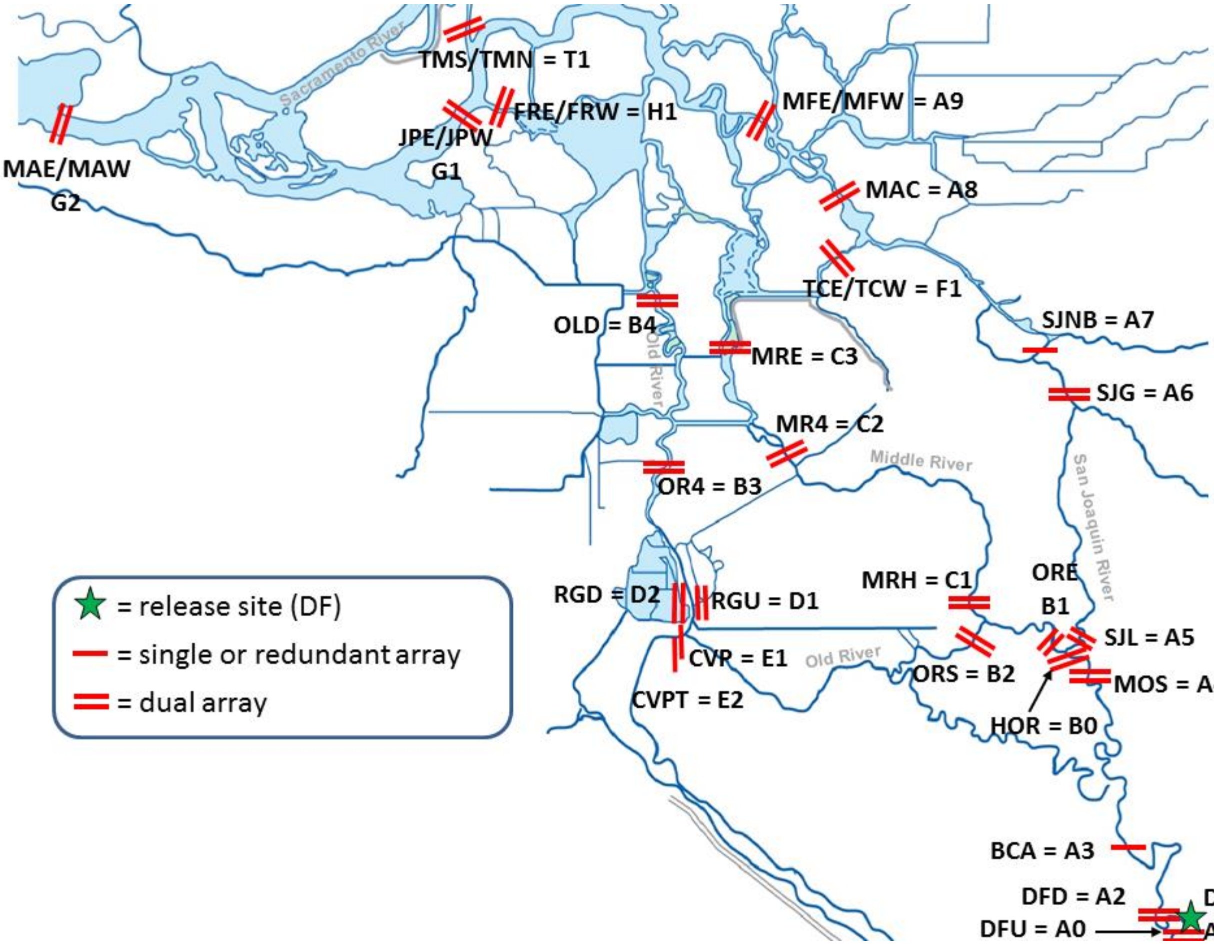


Figure 2. Locations of acoustic receivers and release site used in the 2012 Chinook Salmon study, with site code names (3- or 4-letter code) and model code (letter and number string). Site A1 is the release site at Durham Ferry. Sites B0, B4, C3, and T1 were excluded from the survival model.

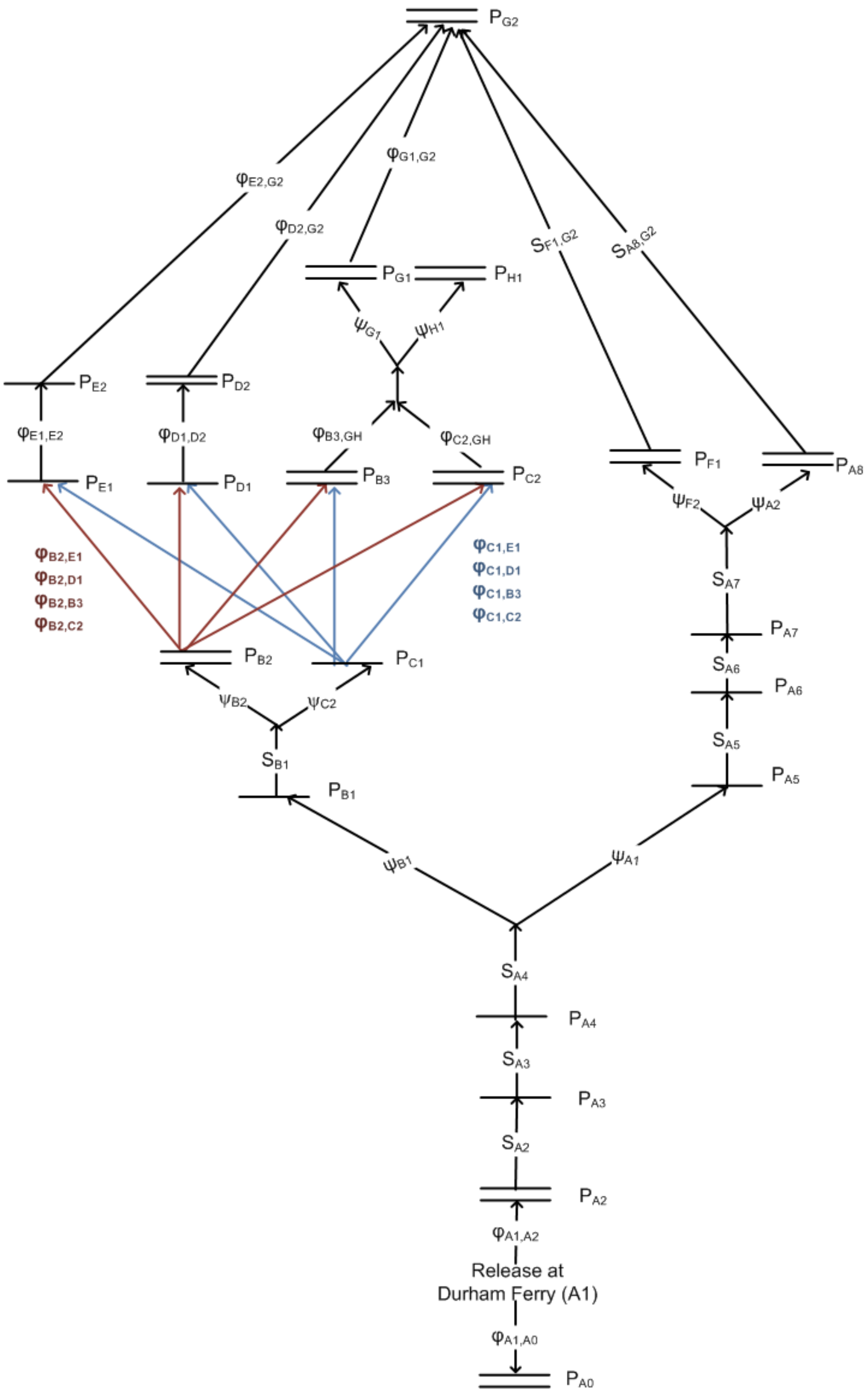


Figure 3. Schematic of 2012 mark-recapture Submodel I. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

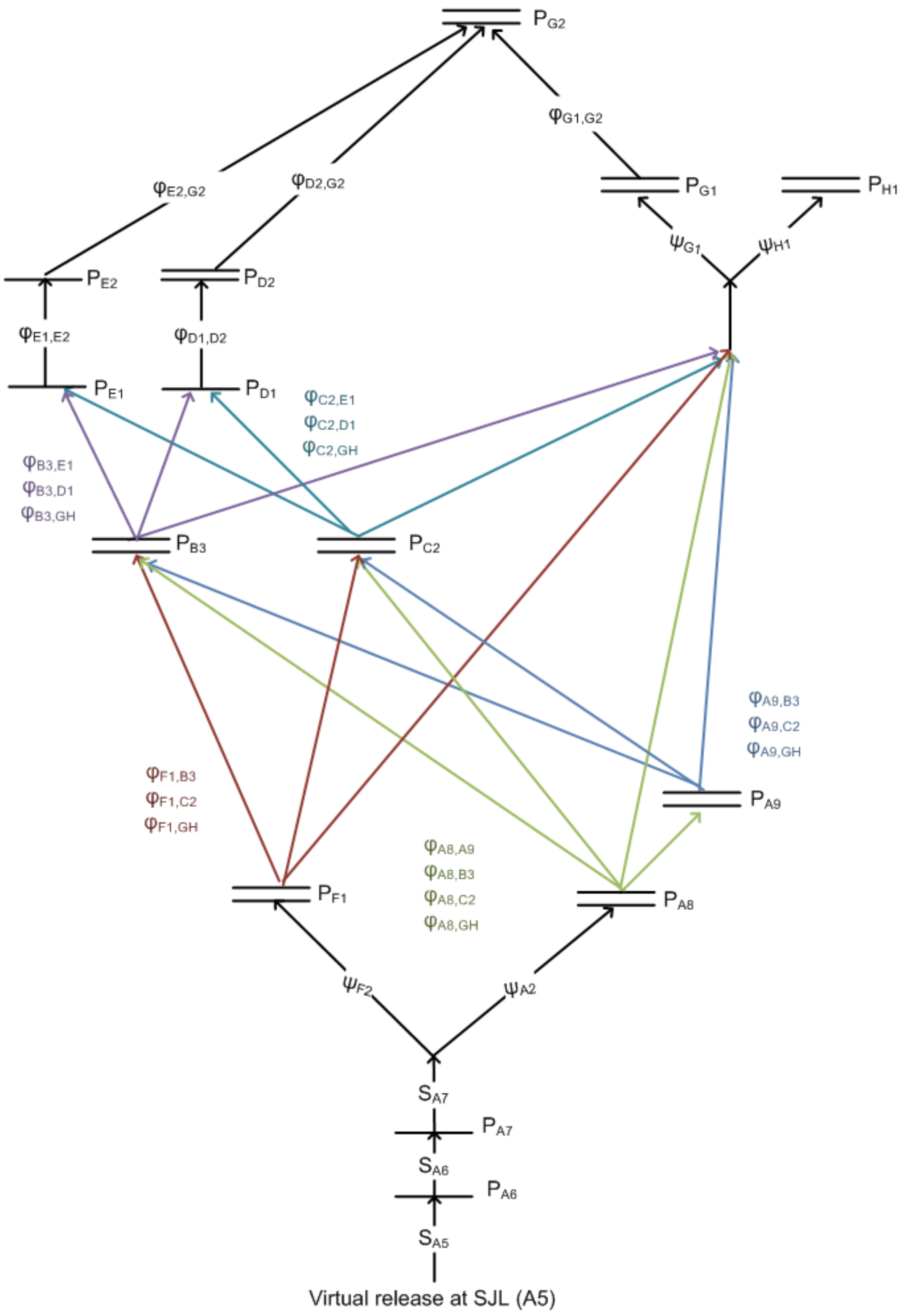


Figure 4. Schematic of 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2. Migration pathways to sites B3 (OR4), C2 (MR4), D1 (RGU), and E1 (CVP) are color-coded by departure site.

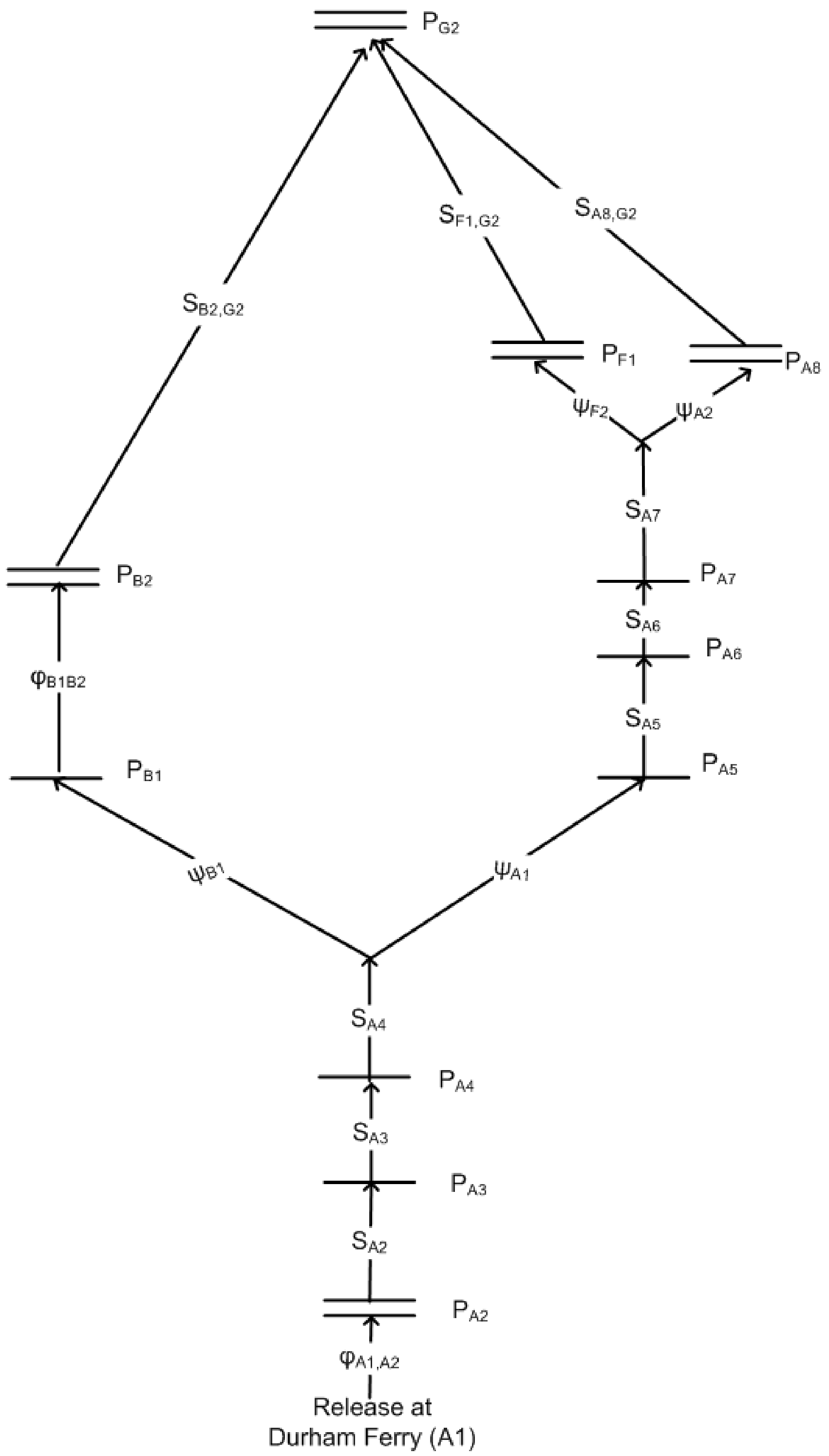


Figure 5. Schematic of reduced 2012 mark-recapture Submodel I with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

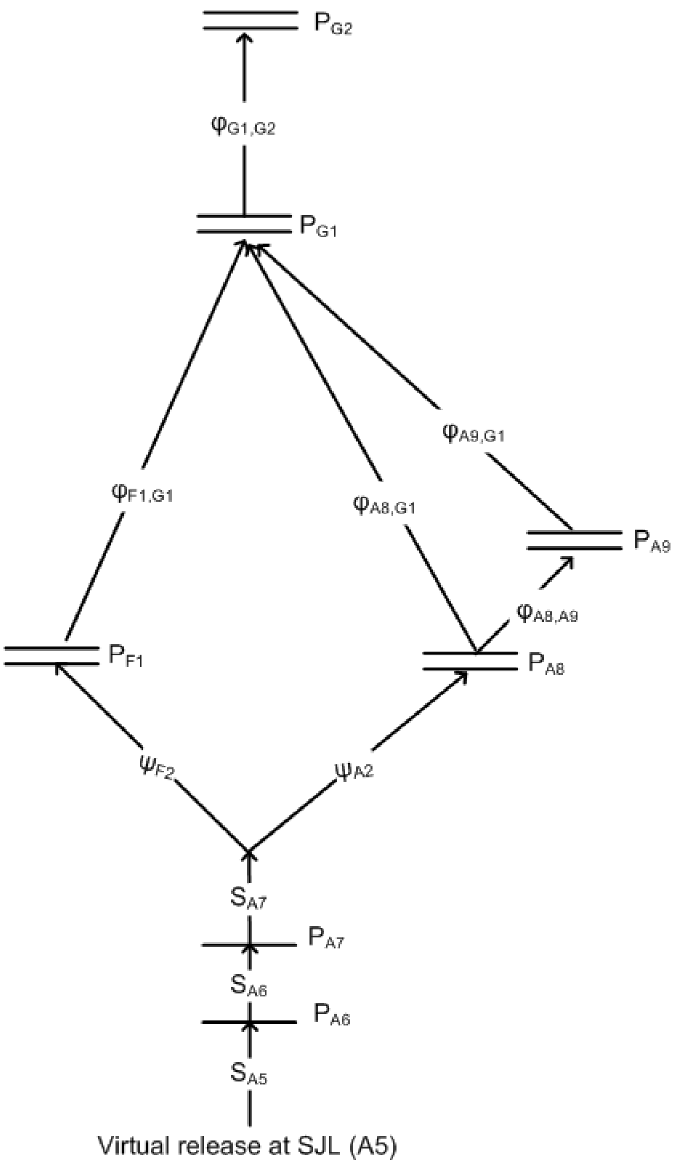


Figure 6. Schematic of reduced 2012 mark-recapture Submodel II with estimable parameters. Single lines denote single-array or redundant double-line telemetry stations, and double lines denote dual-array telemetry stations. Names of telemetry stations correspond to site labels in Figure 2.

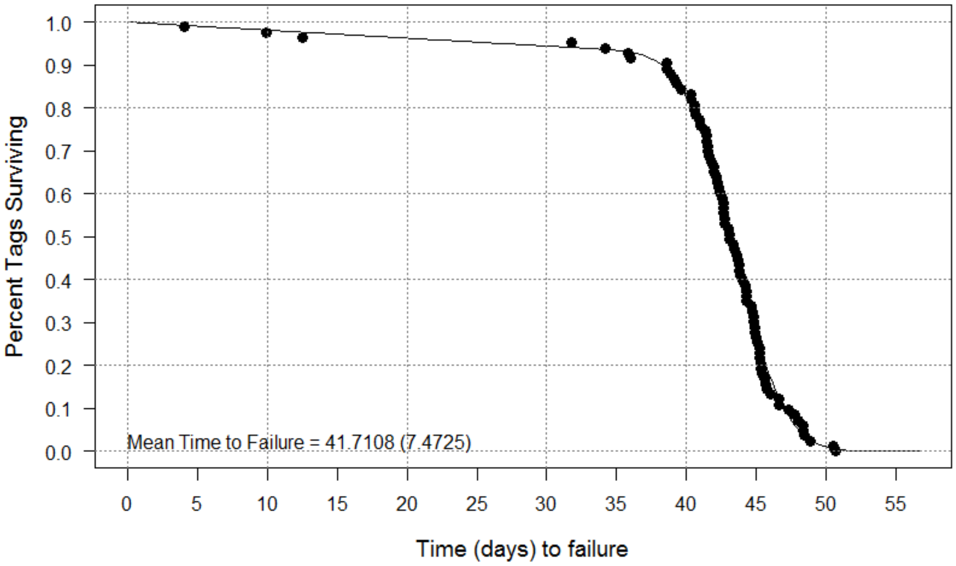


Figure 7. Observed tag failure times from the 2012 tag-life studies, pooled over the two studies, and fitted four-parameter vitality curve.

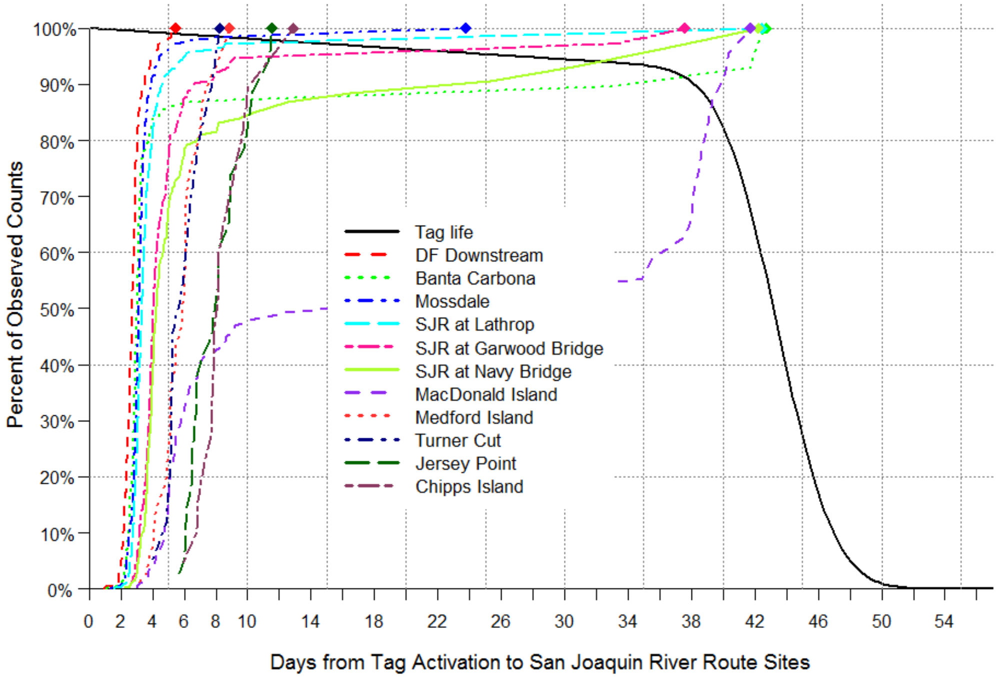


Figure 8. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the San Joaquin River route to Chipps Island in 2012, including detections that may have come from predators.

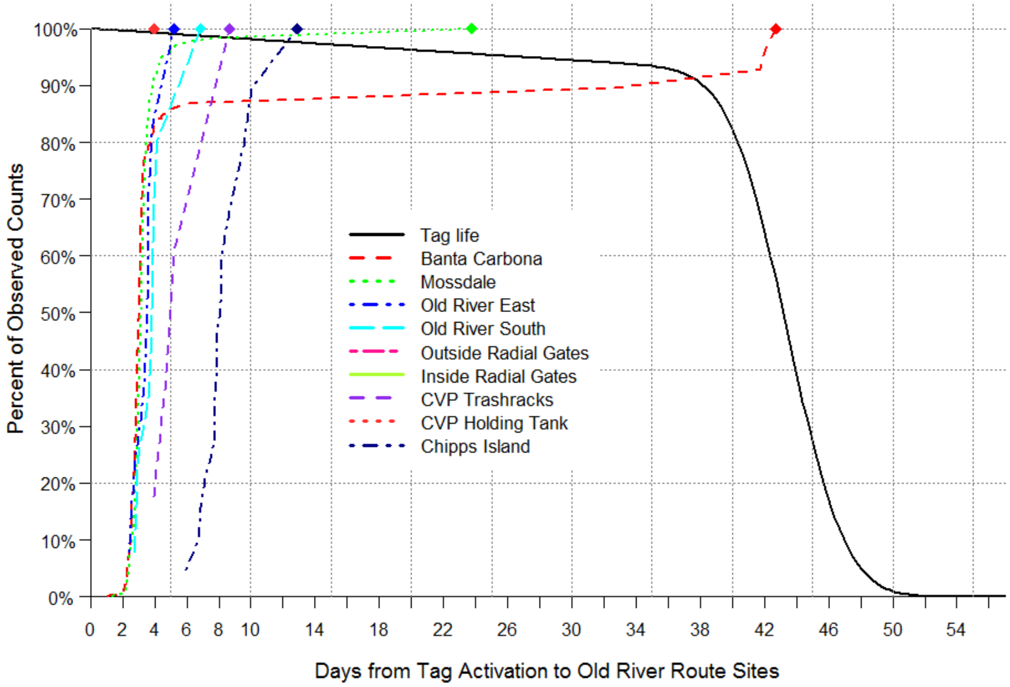


Figure 9. Four-parameter vitality survival curve for tag life, and the cumulative arrival timing of acoustic-tagged juvenile Chinook Salmon at receivers in the Old River route to Chipps Island in 2012, including detections that may have come from predators.

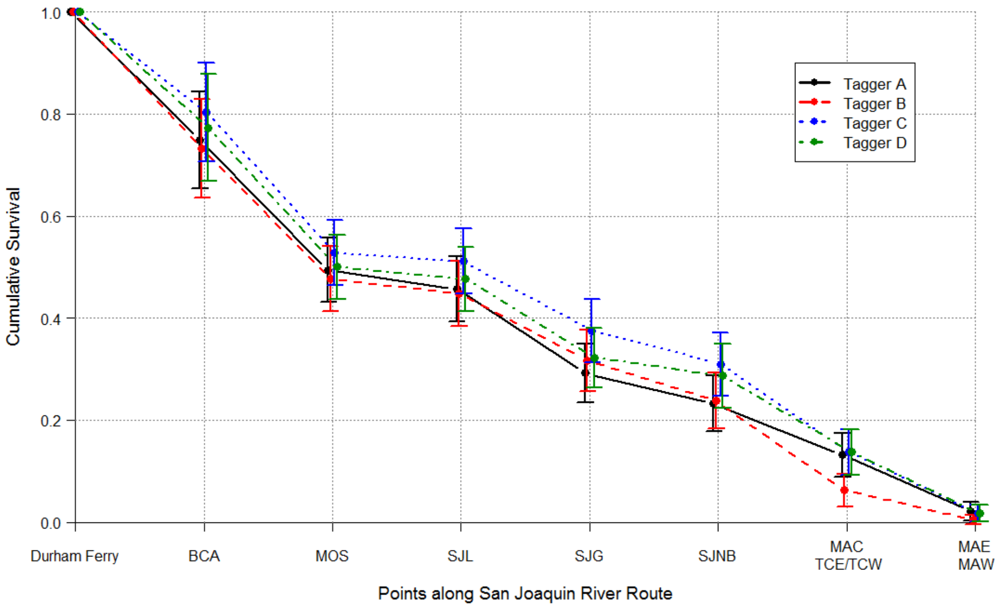


Figure 10. Cumulative survival from release at Durham Ferry to various points along the San Joaquin River route to Chipps Island, by tagger. Error bars are 95% confidence intervals.

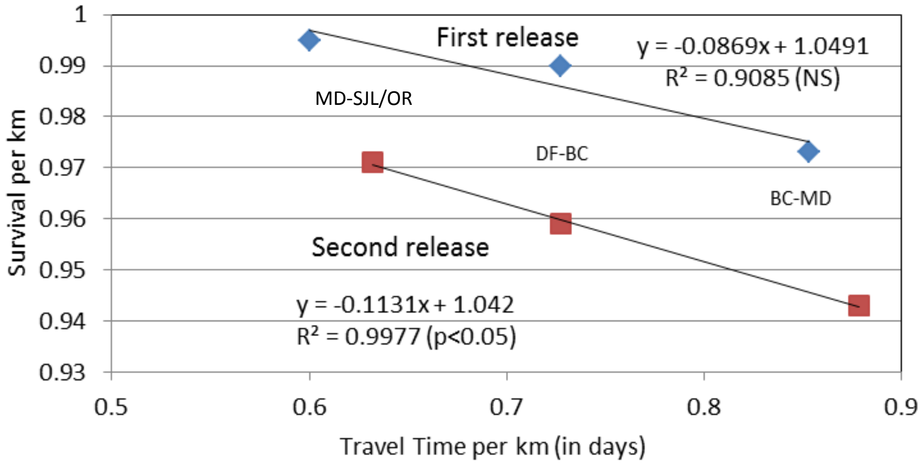


Figure 11: Travel time per km (in days) versus survival per km for river reaches, upstream of Mossdale in release group 1 and release group 2. Survival and travel time were without predator-type detections. Refer to Table 22 for data used.

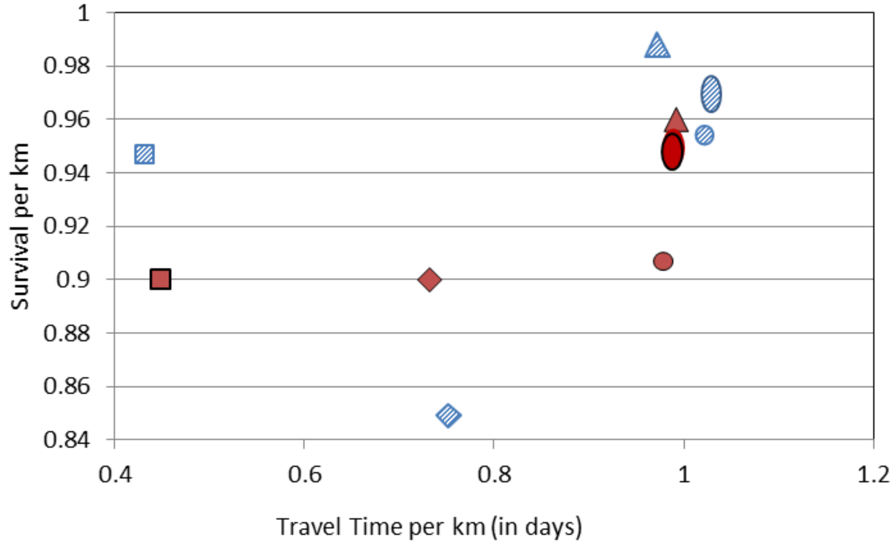


Figure 12: Travel time per km (in days) versus survival per km for reaches in the San Joaquin Delta for release group 1 (blue diagonal) and release group 2 (red solid). From Upstream to Downstream, reaches in order are: Lathrop to Garwood Bridge (triangles), Garwood Bridge to Navy Bridge Drive (squares), Navy Bridge to Turner Cut Junction (circles), MacDonald Island to Medford Island (diamonds) and Medford Island to Jersey Point (ovals). No recoveries were made at Chipps Island for the second release group to estimate travel time from Jersey Point to Chipps Island.

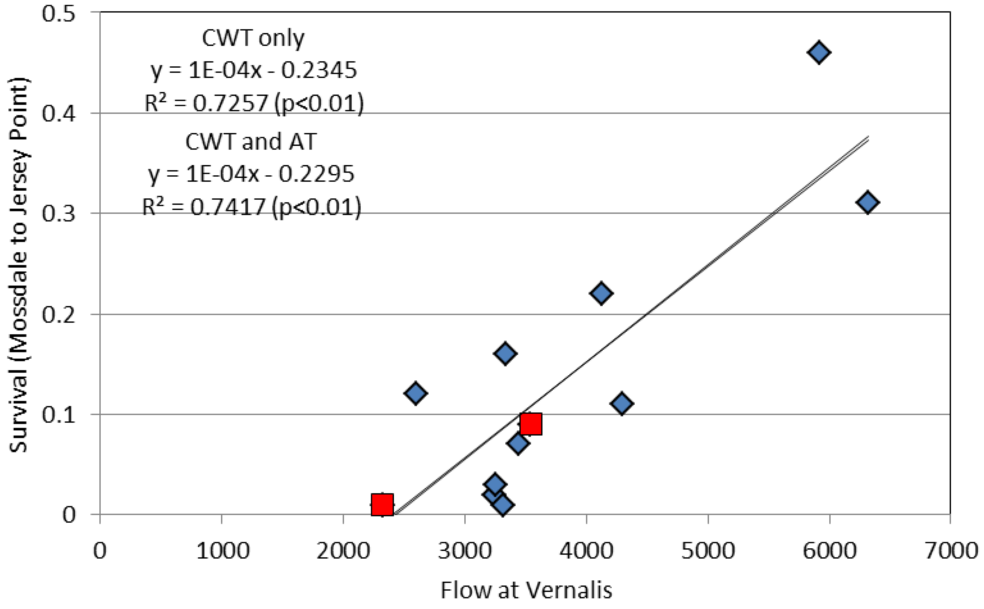


Figure 13: Estimates of survival between Mossdale and Jersey Point for CWT salmon (blue diamonds) and acoustic tag fish in 2012 (red squares) with the physical head of Old River barrier installed. Linear regression lines are plotted for both sets of data but overlap.

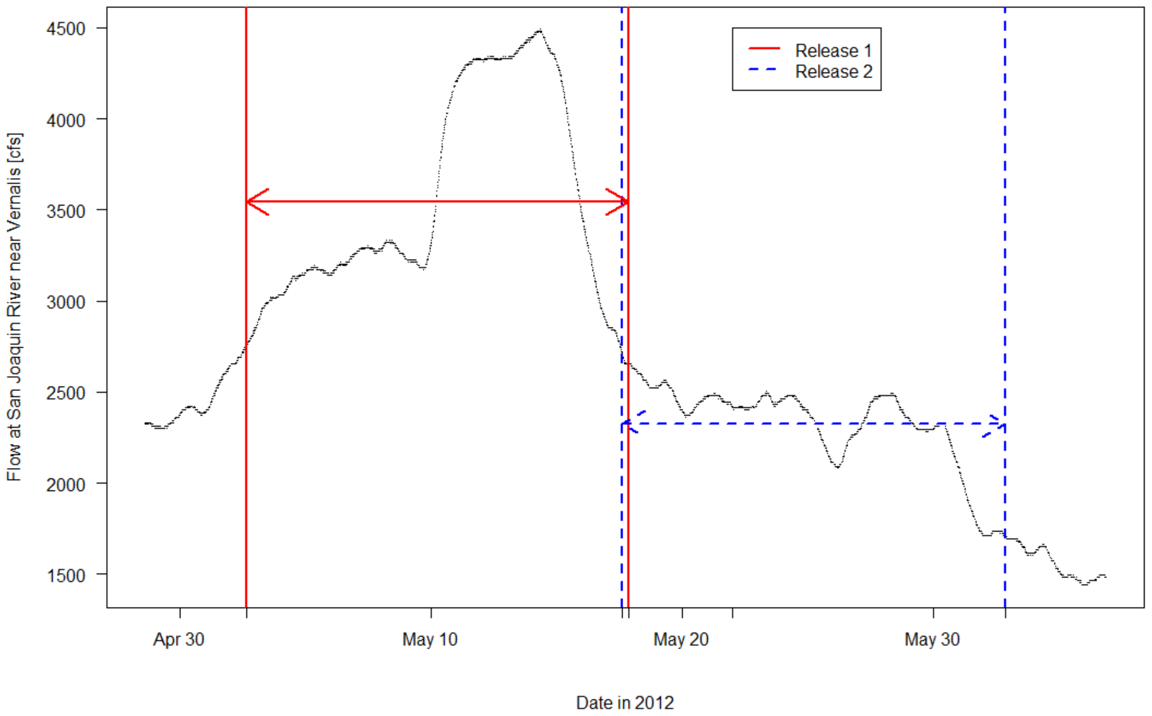


Figure 14. River discharge (flow) at Vernalis during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow heights indicates mean flow during travel period.

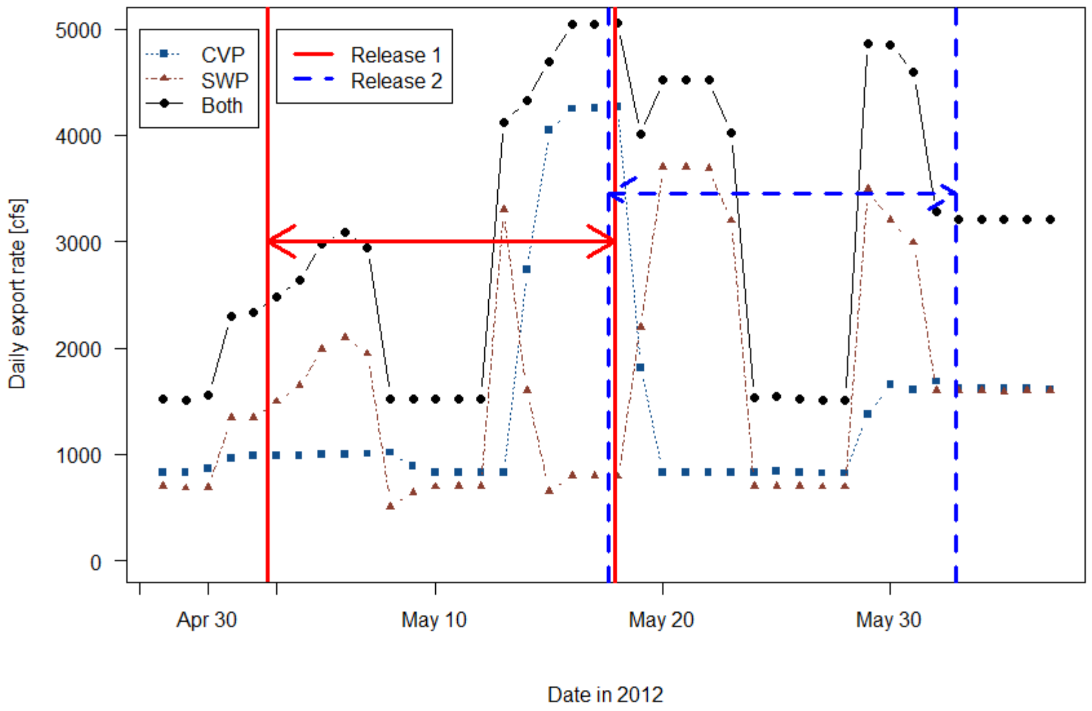


Figure 15. Daily export rate (cfs) at CVP and SWP during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates mean combined export rate during travel period.

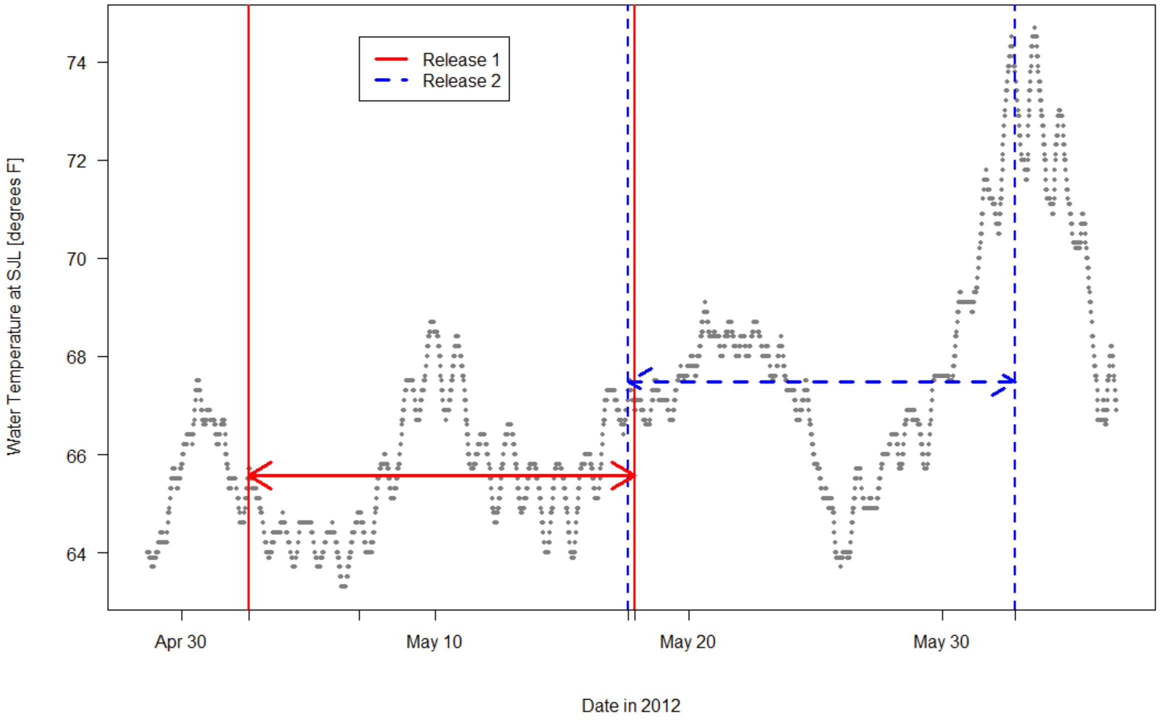


Figure 16. Temperature (°F) at the San Joaquin River gaging station near Lathrop during 2012 study. Vertical lines represent expected period of travel from initial release at Durham Ferry to Chipps Island, based on release dates and maximum observed travel time over both releases. Arrow height indicates mean temperature during travel period.

Tables

Table 1. Tagging, transport and holding date and times, and the number released (N) for Chinook Salmon as part of 2012 Chinook Salmon Study. Numbers of tagged fish use the format: [Number of Vemco-tagged fish]: [Number of HTI-tagged fish].

				Release A		Release B		Release C		Release D		Release E		Release F				
Tagging Date	Transport Date/ Time	Number trans-ported	Trans-port Tank #	Date; Time	N	Date; Time	N	Date; Time	N	Date; Time	N	Date; time	N	Date; Time	N	Dummy tagged	Start Holding Date; Time	Total released (A – F)
5/1/12	5/1/12; 1352-1435	60: 15	1	5/2; 1505, 1506	24: 6	5/2; 1900, 1901	24: 6	5/2; 2256	12: 3							6	5/1; 1538	160: 42
		20: 6	2					5/2; 2257, 2306	20: 6							1		
	5/1/12; 1850-1930	60:15	1							5/3; 0300, 0301	24: 6	5/3; 0703, 0704	36: 9			0	5/1; 2020	
		20: 6	2											5/3; 1100,	20: 6	8		
5/3/12	5/3/12; 1237-1322	60: 15	1	5/4; 1500, 1503	24: 6	5/4; 1855, 1856	24: 6	5/4; 2256	12: 3							3	5/3; 1415	160: 42
		20: 6	2					5/4; 2256, 2304	20: 6							5		
	5/3/12; 1640-1725	60: 15	1							5/5; 0300	24: 6	5/5; 0702, 0703	24: 6	5/5; 1102	12: 3	3	5/3; 1808	
		20: 6	2											5/5; 1101, 1103	20: 6	4		
5/5/12	5/5/12; 1235 - 1320	60: 15	1	5/6; 1502, 1503	24: 6	5/6; 1856; 1857	24: 6	5/6; 2255	12: 3							9	5/5; 1356	160: 42
		20: 6	2					5/6; 2254, 2255	20: 6							6		
	5/5/12; 1717 - 1756	60: 15	1							5/7; 0300,	24: 6	5/7; 0700, 0701, 0702	36: 9			5	5/5; 1839	
		20: 6	2											5/7; 1100,	20: 6	9		

Table 1: (Continued)

				Release A		Release B		Release C		Release D		Release E		Release F				
Tagging Date	Transport Date/ Time	Number trans-ported	Trans-port Tank #	Date; Time	N	Date; Time	N	Date; Time	N	Date; Time	N	Date; time	N	Date; Time	N	Dummy tagged	Start Holding Date; Time	Total released (A – F)
5/16/12	5/16; 1238 - 1323	60: 15	1	5/17; 1455, 1500	24[1]: 6	5/17; 1858, 1859[2]	24: 6	5/17; 2302	12: 3							1	5/16; 1449	160[1]: 45
		20: 8	2					5/17; 2301	20: 8							6		
	5/16; 1640 - 1731	60: 16	1							5/18; 0300	24: 6	5/18; 0700, 0701	36: 10			2	5/16; 1810	
		20: 6	2											5/18; 1100	20: 6	6		
5/18/12	5/18; 1246 - 1330	60: 16	1	5/19; 1458, 1459	24: 6	5/19; 1904, 1906	24: 6	5/19; 2259	12: 4							2	5/18; 1400	160: 46
		20: 8	2					5/19; 2258, 2259	20: 8							6		
	5/18; 1619 - 1709	60:16	1							5/19; 0303, 0305[2]	24: 6	5/19; 0700[2]	36: 10			1	5/18; 1736	
		20: 6	2											5/19; 1100[2]	20: 6	6		
5/20/12	5/20; 1206 - 1249	59: 15	1	5/21; 1505, 1506	23: 6	5/21; 1902, 1903	24: 6	5/21; 2259	12: 3							6	5/20; 1324	160: 44
		21: 8	2	5/21; 1506	1: 0			5/21; 2258, 2259	20: 8							9		
	5/20; 1557 - 1638	60: 15	1							5/22; 0300	24: 6	5/22; 0701, 0702	24: 6	5/22; 1100	12: 3	6	5/20; 1712	
		20: 6	2												20: 6	9		

[1] one tag not used in analyses; tag looked odd, [2] released from shore due to high winds or dead battery in boat.

Table 2. Characteristics assessed for Chinook Salmon smolt condition and short-term survival

Characteristic	Normal	Abnormal
Percent Scale Loss	Lower relative numbers based on 0-100%	Higher relative numbers based on 0-100%
Body Color	High contrast dark dorsal surfaces and light sides	Low contrast dorsal surfaces and coppery colored sides
Fin Hemorrhaging	No bleeding at base of fins	Blood present at base of fins
Eyes	Normally shaped	Bulging or with hemorrhaging
Gill Color	Dark beet red to cherry red colored gill filaments	Grey to light red colored gill filaments
Vigor	Active swimming (prior to anesthesia)	Lethargic or motionless (prior to anesthesia)

Table 3. Names and descriptions of receivers and hydrophones used in the 2012 Chinook Salmon tagging study, with receiver codes used in Figure 2, the survival model (Figures 2 – 5), and in data processing by the United States Geological Survey (USGS). The release site was located at Durham Ferry.

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
San Joaquin River near Durham Ferry upstream of the release site, upstream node	37.685806	121.256500	DFU1	A0a	300856
San Joaquin River near Durham Ferry upstream of the release site, downstream node	37.686444	121.256806	DFU2	A0b	300857
San Joaquin River near Durham Ferry; release site (no acoustic hydrophone located here)	37.687011	121.263448	DF	A1	
San Joaquin River near Durham Ferry downstream of the release site, upstream node	37.688222	121.276139	DFD1	A2a	300858
San Joaquin River near Durham Ferry downstream of the release site, downstream node	37.688333	121.276139	DFD2	A2b	300859
San Joaquin River near Banta Carbona	37.727722	121.298917	BCA	A3	300860
San Joaquin River near Mossdale Bridge, upstream node	37.792194	121.307278	MOSU	A4a	300861
San Joaquin River near Mossdale Bridge, downstream node	37.792356	121.307369	MOSD	A4b	300862
San Joaquin River upstream of Head of Old River, upstream node (not used in survival model)	37.805528	121.320000	HORU	B0a	300863
San Joaquin River upstream of Head of Old River, downstream node (not used in survival model)	37.805000	121.321306	HORD	B0b	300864
San Joaquin River near Lathrop, upstream	37.810875[a]	121.322500[a]	SJLU	A5a	300869/300870
San Joaquin River near Lathrop, downstream	37.810807[a]	121.321269[a]	SJLD	A5b	300871/300872
San Joaquin River near Garwood Bridge, upstream	37.934972	121.329333	SJGU	A6a	300877
San Joaquin River near Garwood Bridge, downstream	37.935194	121.329833	SJGD	A6b	300878
San Joaquin River at Stockton Navy Drive Bridge	37.946806	121.339583	SJNB	A7	300879
San Joaquin River at MacDonald Island, upstream	38.018022[a]	121.462758[a]	MACU	A8a	300899/300901
San Joaquin River at MacDonald Island, downstream	38.023877[a]	121.465916[a]	MACD	A8b	300900/300902
San Joaquin River near Medford Island, east	38.053134[a]	121.510815[a]	MFE	A9a	300903/300904
San Joaquin River near Medford Island, west	38.053773[a]	121.513315[a]	MFW	A9b	300905/300906
Old River East, near junction with San Joaquin, upstream	37.811653[a]	121.335486[a]	OREU	B1a	300865/300866

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

Table 3. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
Old River East, near junction with San Joaquin, downstream	37.812284[a]	121.335558[a]	ORED	B1b	300867/300868
Old River South, upstream	37.819583	121.378111	ORSU	B2a	300873
Old River South, downstream	37.820028	121.378889	ORSD	B2b	300874
Old River at Highway 4, upstream	37.893864[a]	121.567083[a]	OR4U	B3a	300882/300883
Old River at Highway 4, downstream	37.895125[a]	121.566403[a]	OR4D	B3b	300884/300885
Old River North of Empire Cut, upstream receiver (not used in survival model)	37.967125[a]	121.574514[a]	OLDU	B4a	450022
Old River North of Empire Cut, downstream receiver (not used in survival model)	37.967375[a]	121.574389[a]	OLDD	B4b	450023
Middle River Head, upstream	37.824744	121.380056	MRHU	C1a	300875
Middle River Head, downstream	37.824889	121.380417	MRHD	C1b	300876
Middle River at Highway 4, upstream	37.895750	121.493861	MR4U	C2a	300881
Middle River at Highway 4, downstream	37.896222	121.492417	MR4D	C2b	300880
Middle River at Empire Cut, upstream receiver (not used in survival model)	37.941685[a]	121.533250[a]	MREU	C3a	300898/450021
Middle River at Empire Cut, downstream receiver (not used in survival model)	37.942861[a]	121.532370[a]	MRED	C3b	300897/450030
Radial Gate at Clifton Court Forebay, upstream (in entrance channel to forebay), array 1	37.830086	121.556594	RGU1	D1a	300888
Radial Gate at Clifton Court Forebay, upstream, array 2	37.829606	121.556989	RGU2	D1b	300889
Radial Gate at Clifton Court Forebay, downstream (inside forebay), array 1 in dual array	37.830147[a]	121.557528[a]	RGD1	D2a	300890/300892/ 460009/460011
Radial Gate at Clifton Court Forebay, downstream, array 2 in dual array	37.829822[a]	121.557900[a]	RGD2	D2b	300891/460010
Central Valley Project trashracks, upstream	37.816900[a]	121.558459[a]	CVPU	E1a	300894/460012
Central Valley Project trashracks, downstream	37.816647	121.558981	CVPD	E1b	300895
Central Valley Project holding tank (all holding tanks pooled)	37.815844	121.559128	CVPtank	E2	300896
Turner Cut, east (closer to San Joaquin)	37.991694	121.455389	TCE	F1a	300887
Turner Cut, west (farther from San Joaquin)	37.990472	121.456278	TCW	F1b	300886
San Joaquin River at Jersey Point, east (upstream)	38.056351[a]	121.686535[a]	JPE	G1a	300915 - 300922
San Joaquin River at Jersey Point, west (downstream)	38.055167[a]	121.688070[a]	JPW	G1b	300923 - 300930

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

Table 3. (Continued)

Individual Receiver Name and Description	Hydrophone Location		Receiver Code	Survival Model Code	Data Processing Code
	Latitude (°N)	Longitude (°W)			
False River, west (closer to San Joaquin)	38.056834[a]	121.671403[a]	FRW	H1a	300913/300914
False River, east (farther from San Joaquin)	38.057118[a]	121.669673[a]	FRE	H1b	300911/300912
Chipps Island (aka Mallard Island), east (upstream)	38.048772[a]	121.931198[a]	MAE	G2a	300931 - 300942
Chipps Island (aka Mallard Island), west (downstream)	38.049275[a]	121.933839[a]	MAW	G2b	300943, 300979 - 300983, 300985 - 300990
Threemile Slough, south (not used in survival model)	38.107771[a]	121.684042[a]	TMS	T1a	300909/300910
Threemile Slough, north (not used in survival model)	38.111556[a]	121.682826[a]	TMN	T1b	300907/300908

a = Average latitude and longitude given for sites with multiple hydrophones or for sites with multiple locations throughout the study

Table 4. Environmental monitoring sites used in predator decision rule and route entrainment analysis. Database = CDEC (http://cdec.water.ca.gov/) or Water Library (http://www.water.ca.gov/waterdatalibrary/).

Environmental Monitoring Site			Detection Site	Data Available					Database
Site Name	Latitude (°N)	Longitude (°W)		River Flow	Water Velocity	River Stage	Pumping	Reservoir Inflow	
CLC	37.8298	121.5574	RGU, RGD	No	No	No	No	Yes	CDEC
FAL	38.0555	121.6672	FRE/FRW	Yes	Yes	Yes	No	No	CDEC
GLC	37.8201	121.4497	ORS	Yes	Yes	Yes	No	No	CDEC
MAL	38.0428	121.9201	MAE/MAW	No	No	Yes	No	No	CDEC
MDM	37.9425	121.534	MR4, MRE	Yes	Yes	Yes	No	No	CDEC[a]
MSD	37.7860	121.3060	HOR, MOS	Yes	Yes	Yes	No	No	Water Library
ODM	37.8101	121.5419	CVP	Yes	Yes	Yes	No	No	CDEC
OH1	37.8080	121.3290	ORE	Yes	Yes	Yes	No	No	CDEC
OH4	37.8900	121.5697	OR4	Yes	Yes	Yes	No	No	CDEC
ORI	37.8280	121.5526	RGU, RGD	Yes	Yes	No	No	No	Water Library
PRI	38.0593	121.5575	MAC, MFE/MFW	Yes	Yes	Yes	No	No	CDEC
RMID040	37.8350	121.3838	MRH	No	No	Yes	No	No	Water Library
ROLD040	37.8286	121.5531	RGU, RGD	No	No	Yes	No	No	Water Library
SJG	37.9351	121.3295	SJG, SJNB	Yes	Yes	Yes	No	No	CDEC
SJJ	38.0520	121.6891	JPE/JPW	Yes	Yes	Yes	No	No	CDEC
SJL	37.8100	121.3230	SJL	Yes	Yes	Yes	No	No	Water Library
TRN	37.9927	121.4541	TCE/TCW	Yes	Yes	Yes	No	No	CDEC
TRP	37.8165	121.5596	CVP	No	No	No	Yes	No	CDEC
TSL	38.1004	121.6866	TMS/TMN	Yes	Yes	Yes	No	No	CDEC
VNS	37.6670	121.2670	DFU, DFD, BCA	Yes	No	Yes	No	No	CDEC
WCI	37.8316	121.5541	RGU, RGD	Yes	Yes	No	No	No	Water Library

a = California Water Library was used for river stage

Table 5a. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Only transitions observed in 2012 are represented here. No detections were observed at MRH, RGU, or RGD in 2012. See Table 5b for Flow, Water Velocity, Extra Conditions, and Comment. Footnotes refer to both this table and Table 5b.

Detection Site	Previous Site	Residence Time[a] (hr)		Migration Rate[b, c] (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
DFU	DF, DFD	0.5	1	0.2 (0.6[f])	4		1	1
	DFU	0.5	1				2	0
DFD	DF, DFU	4	8	0.05	4		1	0
	DFD	2	49				2	0
	BCA	2	4	0.1	4		0	0
BCA	DF, DFU	5	10	0.1	4		1	0
	BCA	0.1	168				2	0
	MOS	0.1	0.2	0.1	4		0	0
MOS	DF, DFD, BCA	10	20	0.2	5.5	8	1	0
	MOS	2	261				2	1
	HOR	1	2	0.2	5.5	8	2	1
SJL	MOS, HOR	5	15	0.2	5.5	8	2	0
	SJL	1	293				3	1
SJG	HOR, SJL	12	24	0.2	5.5	8	1	0
	SJG	6	360				1	1
	SJNB	3	6	0.2	4	8	2	2
SJNB	SJG	15 (6[f])	30 (12[f])	0.2	5.5	8	2	0
	SJNB	4	360				2	3
MAC	SJG, SJNB	30	60	0.2	5.5	8	1	0
	MAC	30	360				2	3
	MFE/MFW	15	30	0.2	4	8	2	3

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Approximate migration rate calculated on most direct pathway

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

f = See comments for alternate criteria

Table 5a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)		Migration Rate[b, c] (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
MFE/MFW	MAC	30	60	0.2	5.5	8	2	0
	MFE/MFW	15	360				3	3
HOR	DF, MOS	10	20	0.2	5.5	8	1 (2[f])	0
	HOR	3	288				2	1
	SJL	3 (4[f])	6 (8[f])	0.2 (0.1[f])	5.5 (6[f])	8	2	1
ORE	HOR	5	15	0.2	5.5	8	1	0
	ORE	1	287				1	0
ORS	ORE	12	24	0.2	5.5	8	1	0
	ORS	4	360				2	1
OR4	ORS	40	80	0.2	5.5	8	1	0
	MR4	40	80	0.1	5.5		2	3
	OR4	25	129				2	2
OLD	OR4	40	80	0.2	5.5	8	2	0
	MRE	40	80	0.1	5.5		1	0
MR4	MRE	10	20	0.2	5.5	8	1	2
MRE	SJNB, MAC	20	40	0.1	5.5		1	0
	TCE/TCW	20	40	0.1	5.5		1	0
CVP	DF, ORS	10	20	0.2	5.5	8	1	1
	CVP	10	390				3	3
	OR4	10	20	0.5	5.5	8	2	3
CVPtank	CVP	20	360				2	3

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Approximate migration rate calculated on most direct pathway

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

f = See comments for alternate criteria

Table 5a. (Continued)

Detection Site	Previous Site	Residence Time[a] (hr)		Migration Rate[b, c] (km/hr)		BLPS (Absolute value)	No. of Visits	No. of Cumulative Upstream Forays
		Near Field	Mid-field					
		Maximum	Maximum	Minimum	Maximum	Maximum	Maximum	Maximum
TCE/TCW	SJG, SJNB	12	24	0.2	5.5	8	1	0
	MAC	12	24	0.2	5.5	8	2	3
	TCE/TCW	3	360				1	3
JPE/JPW	MAC, MFE/MFW, TMN/TMS	40	80	0.1	5.5	8	1	0
	FRE/FRW	30	360	0.1	5.5		3	3
	JPE/JPW	30	360				3	0
MAE/MAW	MFE/MFW, CVPtank	40	80	0.1	5.5	8	1	0
	TMN/TMS, JPE/JPW, FRE/FRW	40	80	0.1	5.5	8	2	0
FRE/FRW	MAC, MFE/MFW, OLD	40	80	0.1	5.5	8	1	0
	JPE/JPW	30	360	0.1			3	3
TMN/TMS	MAC, MFE/MFW	10	20	0.2	3	8	1	0
	JPE/JPW	10	20	0.5	3	8	1	3

a = Near-field residence time includes up to 12 hours missing between detections, while mid-field residence time includes entire time lag between first and last detections without intervening detections elsewhere

b = Approximate migration rate calculated on most direct pathway

c = Missing values for transitions to and from same site: travel times must be 12 to 24 hours, unless otherwise specified under "Extra conditions"

Table 5b. Cutoff values used in predator filter in 2012. Observed values past cutoff or unmet conditions indicate a predator. Only transitions observed in 2012 are represented here. No detections were observed at MRH, RGU, or RGD in 2012. Footnotes, Extra Conditions and Comment refer to both this table and Table 5a.

		Flow[d] (cfs)		Water Velocity[d] (ft/sec)				
Detection Site	Previous Site	At arrival	At departure[e]	At arrival	At departure[e]	Average during transition	Extra Conditions	Comment
DFU	DF, DFD							Alternate value if coming from DFD
	DFU						Not allowed	
DFD	DF, DFU							
	DFD						Not allowed	
	BCA						Not allowed	
BCA	DF, DFU							
	BCA						Travel time < 25	
	MOS						Not allowed	
MOS	DF, DFD, BCA							
	MOS						Travel time < 20	
	HOR					< 0.1		
SJL	MOS, HOR							
	SJL						Travel time < 20	
SJG	HOR, SJL							
	SJG							
	SJNB	< 1700	< 4000	< 0.5	< 1	< 0.5	Change in river stage at arrival: -0.1 to 0.1	
SJNB	SJG			< 2 (> 2[f])				Alternate values for change in river stage at arrival: < -0.1 or > 0.1
	SJNB	< 600 (> -250)[g]	> -250 (< 600)[g]	< 0.2 (> -0.1)[g]	> -0.1 (< 0.2)[g]	< 1.5		
MAC	SJG, SJNB							
	MAC			< 0.2 (> -0.1)[g]	> -0.1 (< 0.2)[g]			

d = Classified as predator if flow or velocity condition, if any, is violated
e = Condition at departure from previous site
f = See comments for alternate criteria
g = High flow/velocity on departure requires low values on arrival (and vice versa)

Table 5b. (Continued)

		Flow[d] (cfs)		Water Velocity[d] (ft/sec)				
Detection Site	Previous Site	At arrival	At departure[e]	At arrival	At departure[e]	Average during transition	Extra Conditions	Comment
MAC	MFE/MFW			< -0.4	< 0.2	< 0.2		
MFE/MFW	MAC							
	MFE/MFW			< 0.2 (> -0.1)[g]	> -0.1 (< 0.2)[g]			
	SJG	<100 (>-300)[g]	>-300 (<100)[g]	<0.1 (>-0.5)[g]	>-0.5 (<0.1)[g]	<0.5		
HOR	DF, MOS							Alternate value if coming from MOS
	HOR						Travel time < 20	
	SJL			< 1.5	< 0.15 (0.25[f])	< 1 (1.1[f])		Alternate value if next transition is downstream
ORE	HOR							
	ORE						Not allowed	
ORS	ORE	> -2500		> -0.5				
	ORS	< 2500 (> -2500)[g]	> -2500 (< 2500)[g]	< 0.5 (> -0.5)[g]	> -0.5 (< 0.5)[g]			
OR4	ORS	> -700		> -0.3				
	MR4							
	OR4	< 700 (> -700)[g]	> -700 (< 700)[g]	< 0.3 (> -0.3)[g]	> -0.3 (< 0.3)[g]			
OLD	OR4	> -2000	> -1000	> -0.1	> -0.05			
	MRE							
MR4	MRE	< 2500	< 1000	< 0.25	< 0.1	< 0.1		
MRE	SJNB, MAC	< 1000		< 0.1				
	TCE/TCW	< 1000	< 200	< 0.1	< 0.05			

d = Classified as predator if flow or velocity condition, if any, is violated

e = Condition at departure from previous site

f = See comments for alternate criteria

g = High flow/velocity on departure requires low values on arrival (and vice versa)

Table 5b. (Continued)

Detection Site	Previous Site	Flow[d] (cfs)		Water Velocity[d] (ft/sec)			Extra Conditions	Comment
		At arrival	At departure[e]	At arrival	At departure[e]	Average during transition		
CVP	DF, ORS							
	CVP						CVP pumping > 1500 cfs on arrival, < 1500 cfs on departure	
	OR4	< 3000	< 2000	< 1.5	< 0.8	< 0.1	CVP pumping > 1500 cfs on arrival	
CVPtank	CVP						Travel time < 100	
TCE/TCW	SJG, SJNB	< 1200		< 0.2				
	MAC	< 1200		< 0.2	< 0.2	< 0.2		
	TCE/TCW	< 500 (> 500)[g]	> 500 (< 500)[g]	< 0.1 (> 0.1)[g]	> 0.1 (< 0.1)[g]	-0.2 to 0.2	Travel time < 13	
JPE/JPW	MAC, MFE/MFW, TMN/TMS FRE/FRW							
	JPE/JPW						Travel time < 50	
MAE/MAW	MFE/MFW, CVPtank			> -2.5				
	TMN/TMS, JPE/JPW, FRE/FRW			> -2.5				
FRE/FRW	MAC, MFE/MFW, OLD							
FRE/FRW	MAC, MFE/MFW, OLD JPE/JPW							
TMN/TMS	MAC, MFE/MFW JPE/JPW				> -0.4			

d = Classified as predator if flow or velocity condition, if any, is violated

e = Condition at departure from previous site

g = High flow/velocity on departure requires low values on arrival (and vice versa)

Table 6: Water temperature and dissolved oxygen in the transport tank after loading prior to transport, after transport, and in the river at Durham Ferry release site, just prior to placing fish in holding containers; the number of mortalities after transport and prior to release.

		Tank #1						Tank #2								
Transport			After loading		After transport				After loading		After transport			River		
Date	Loading time	Ice Added	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	# morts after transport	Ice Added	Temp (˚C)	DO (mg/L)	Temp (˚C)	DO (mg/L)	# morts after transport	Temp (˚C)	DO (mg/L)	Mortalities just prior to release
5/1/2012	1331	Yes	18.4	8.73	18.5	11.7	0	Yes	18.6	8.22	18.5	9.94	0	19.3	10.54	0
5/1/2012	1810	No	16.8	9.68	16.5	9.83	0	No	17.1	8.57	16.7	9.12	0	18.8	10.91	0
5/3/2012	1219	No	18.8	9.64	19.1	9.76	0	No	18.5	9.07	18.7	9.41	0	18.0	9.22	0
5/3/2012	1616	Yes	18.2	10.04	18.1	10.67	0	Yes	18.1	10.01	17.8	10.22	0	18.4	9.55	0
5/5/2012	1208	Yes	18.9	10.44	19.1	11.76	0	Yes	18.9	10.23	18.8	10.57	0	17.5	9.66	0
5/5/2012	1652	Yes	18.4	10.36	18.5	11.89	0	Yes	18.3	10.47	18.1	10.63	0	18.0	10.14	0
													Average	18.3		
5/16/2012	1222	Yes	19.3	9.37	19.7	9.38	0	Yes	19.4	9.46	19.7	9.42	0	19.1	11.45	0
5/16/2012	1617	Yes	19.4	9.35	19.7	10.25	0	Yes	19.5	9.38	19.5	9.51	0	19.9	9.59	0
5/18/2012	1228	Yes	19.0	9.71	19.8	10.86	0	Yes	18.9	9.64	19.3	9.74	0	19.0	8.4	0
5/18/2012	1556	Yes	19.5	9.66	19.6	10.74	0	Yes	19.6	9.67	19.8	9.73	0	19.8	8.56	0
5/20/2012	1143	Yes	19.4	10.05	19.6	10.97	0	Yes	19.0	9.67	19.3	9.81	0	19.6	9.40	0
5/20/2012	1537	Yes	20.0	10.16	20.3	11.38	0	Yes	20.3	9.61	20.5	9.84	0	20.7	10.38	0
													Average	19.7		

Table 7. Results of dummy tagged Chinook Salmon evaluated after being held for 48 hours at the release sites as part of the 2012 Chinook Salmon Study.

Holding Site	Examination Date, Time	Mean (sd) Fork Length (mm)	Mortality	Mean (sd) Scale Loss %	Normal Body Color	No Fin Hemorrhaging	Normal Eye Quality	Normal Gill Color
Durham Ferry	5/3/12, 1100	108.2 (5.6)	0/15	5.5 (2.9)	15/15	15/15	15/15	15/15
Durham Ferry	5/5/12, 1100	108.3 (3.7)	0/15	3.3 (1.0)	15/15	15/15	15/15	15/15
Durham Ferry	5/18/12, 1100	111.3 (5.4)	0/15	2.3 (1.0)	15/15	15/15	15/15	15/15
Durham Ferry	5/20/12, 1100	112.0 (4.8)	0/15	2.7 (1.5)	15/15	15/15	15/15	12/15

Table 8. Number of tags from each release group that were detected after release in 2012, including predator-type detections and detections omitted from the survival analysis.

Release Group	1	2	Total
Number Released	480	479	959
Number Detected	355	358	713
Number Detected Downstream	354	353	707
Number Detected Upstream of Study Area	196	339	535
Number Detected in Study Area	301	181	482
Number Detected in San Joaquin River Route	288	161	449
Number Detected in Old River Route	8	3	11
Number Assigned to San Joaquin River Route	286	160	446
Number Assigned to Old River Route	7	3	10

Table 9. Number of tags observed from each release group at each detection site in 2012, including predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream	DFU	A0	1	10	11
Durham Ferry Downstream	DFD	A2	101	168	269
Banta Carbona	BCA	A3	120	244	364
Mossdale	MOS	A4	299	181	480
Head of Old River	HOR	B0	297	172	469
Lathrop	SJL	A5	288	161	449
Garwood Bridge	SJG	A6	232	78	310
Navy Drive Bridge	SJNB	A7	187	54	241
MacDonald Island Upstream	MACU	A8a	88	12	100
MacDonald Island Downstream	MACD	A8b	84	9	93
MacDonald Island (Pooled)	MAC	A8	88	12	100
Medford Island East	MFE	A9a	41	6	47
Medford Island West	MFW	A9b	41	6	47
Medford Island (Pooled)	MFE/MFW	A9	41	6	47
Turner Cut East	TCE	F1a	10	2	12
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	11	2	13
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	3	9
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	3	9
Old River at Highway 4, Upstream	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route	OR4	B3	1	0	1
Old River at Highway 4, OR Route	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)	OR4	B3	2	0	2
Old River near Empire Cut, Upstream	OLDU	B4a	2	0	2
Old River near Empire Cut, Downstream	OLDD	B4b	0	0	0
Old River near Empire Cut, SJR Route	OLD	B4	1	0	1
Old River near Empire Cut, OR Route	OLD	B4	1	0	1
Old River near Empire Cut (Pooled)	OLD	B4	2	0	2
Middle River Head	MRH	C1	0	0	0
Middle River at Highway 4, Upstream	MR4U	C2a	1	0	1
Middle River at Highway 4, Downstream	MR4D	C2b	1	0	1
Middle River at Highway 4, SJR Route	MR4	C2	1	0	1
Middle River at Highway 4, OR Route	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)	MR4	C2	1	0	1

Table 9. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Middle River near Empire Cut, Upstream	MREU	C3a	3	0	3
Middle River near Empire Cut, Downstream	MRED	C3b	3	0	3
Middle River near Empire Cut, SJR Route	MRE	C3	3	0	3
Middle River near Empire Cut, OR Route	MRE	C3	0	0	0
Middle River near Empire Cut (Pooled)	MRE	C3	3	0	3
Radial Gates Upstream (Pooled)	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)	RGD	D2	0	0	0
Central Valley Project Trashrack	CVP	E1	4	1	5
CVP Trashrack: SJR Route	CVP	E1	1	0	1
CVP Trashrack: OR Route	CVP	E1	3	1	4
Central Valley Project Holding Tank	CVPtank	E2	1	0	1
CVP tank: SJR Route	CVPtank	E2	0	0	0
CVP tank: OR Route	CVPtank	E2	1	0	1
Threemile Slough South	TMS	T1a	6	0	6
Threemile Slough North	TMN	T1b	4	0	4
Threemile Slough (Pooled)	TMS/TMN	T1	6	0	6
Jersey Point East	JPE	G1a	26	2	28
Jersey Point West	JPW	G1b	25	2	27
Jersey Point: SJR Route	JPE/JPW	G1	26	2	28
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	26	2	28
False River West	FRW	H1a	7	0	7
False River East	FRE	H1b	6	0	6
False River: SJR Route	FRE/FRW	H1	7	0	7
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	7	0	7
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

Table 10. Number of tags observed from each release group at each detection site in 2012 and used in the survival analysis, including predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags. * = site was included in full survival model but omitted from reduced model used for analysis.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream*	DFU	A0	1	7	8
Durham Ferry Downstream	DFD	A2	101	166	267
Banta Carbona	BCA	A3	120	243	363
Mossdale	MOS	A4	297	181	478
Lathrop	SJL	A5	286	160	446
Garwood Bridge	SJG	A6	232	78	310
Navy Drive Bridge	SJNB	A7	186	53	239
MacDonald Island Upstream	MACU	A8a	80	11	91
MacDonald Island Downstream	MACD	A8b	74	8	82
MacDonald Island (Pooled)	MAC	A8	86	12	98
Medford Island East	MFE	A9a	38	6	44
Medford Island West	MFW	A9b	38	6	44
Medford Island (Pooled)	MFE/MFW	A9	38	6	44
Turner Cut East	TCE	F1a	10	2	12
Turner Cut West	TCW	F1b	7	2	9
Turner Cut (Pooled)	TCE/TCW	F1	11	2	13
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	3	9
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	3	9
Old River at Highway 4, Upstream*	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream*	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route*	OR4	B3	1	0	1
Old River at Highway 4, OR Route*	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)*	OR4	B3	2	0	2
Middle River Head*	MRH	C1	0	0	0
Middle River at Highway 4, Upstream*	MR4U	C2a	0	0	0
Middle River at Highway 4, Downstream*	MR4D	C2b	0	0	0
Middle River at Highway 4, SJR Route*	MR4	C2	0	0	0
Middle River at Highway 4, OR Route*	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)*	MR4	C2	0	0	0
Radial Gates Upstream (Pooled)*	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)*	RGD	D2	0	0	0
Central Valley Project Trashrack*	CVP	E1	4	1	5
CVP Trashrack: SJR Route*	CVP	E1	1	0	1
CVP Trashrack: OR Route*	CVP	E1	3	1	4

Table 10. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank*	CVPtank	E2	1	0	1
CVP tank: SJR Route*	CVPtank	E2	0	0	0
CVP tank: OR Route*	CVPtank	E2	1	0	1
Jersey Point East	JPE	G1a	24	2	26
Jersey Point West	JPW	G1b	23	2	25
Jersey Point: SJR Route	JPE/JPW	G1	24	2	26
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	24	2	26
False River West	FRW	H1a	0	0	0
False River East	FRE	H1b	0	0	0
False River: SJR Route	FRE/FRW	H1	0	0	0
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	0	0	0
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

Table 11. Number of tags from each release group in 2012 first classified as in a predator at each detection site, based on the predator filter.

Detection Site and Code			Durham Ferry Release Groups					
			Classified as Predator on Arrival at Site			Classified as Predator on Departure from Site		
Detection Site	Site Code	Survival Model Code	1	2	Total	1	2	Total
Durham Ferry Upstream	DFU	A0	0	8	8	0	0	0
Durham Ferry Downstream	DFD	A2	4	7	11	0	10	10
Banta Carbona	BCA	A3	0	2	2	1	4	5
Mossdale	MOS	A4	1	2	3	0	3	3
Head of Old River	HOR	B0	1	4	5	0	1	1
Lathrop	SJL	A5	1	1	2	6	6	12
Garwood Bridge	SJG	A6	3	1	4	9	5	14
Navy Drive Bridge	SJNB	A7	1	2	3	11	9	20
MacDonald Island	MAC	A8	2	1	3	15	0	15
Medford Island	MFE/MFW	A9	0	0	0	0	0	0
Old River East	ORE	B1	0	1	1	0	0	0
Old River South	ORS	B2	0	0	0	0	1	1
Old River at Highway 4	OR4	B3	0	0	0	0	0	0
Old River near Empire Cut	OLD	B4	1	0	1	0	0	0
Middle River Head	MRH	C1	0	0	0	0	0	0
Middle River at Highway 4	MR4	C2	0	0	0	0	0	0
Middle River near Empire Cut	MRE	C3	0	0	0	0	0	0
Radial Gates Upstream	RGU	D1	0	0	0	0	0	0
Radial Gates Downstream	RGD	D2	0	0	0	0	0	0
Central Valley Project Trashrack	CVP	E1	0	0	0	0	1	1
Central Valley Project Holding Tank	CVPtank	E2	0	0	0	0	0	0
Turner Cut	TCE/TCW	F1	3	0	3	2	0	2
Jersey Point	JPE/JPW	G1	0	0	0	0	0	0
Chipps Island	MAE/MAW	G2	0	0	0	0	0	0
False River	FRE/FRW	H1	0	0	0	0	0	0
Threemile Slough	TMS/TMN	T1	0	0	0	0	0	0
Total Tags			17	29	46	44	40	84

Table 12. Number of tags from each release group that were detected after release in 2012, excluding predator-type detections, and including detections omitted from the survival analysis.

Release Group	1	2	Total
Number Released	480	479	959
Total Number Detected	351	346	697
Total Number Detected Downstream	350	345	695
Total Number Detected Upstream of Study Area	191	327	518
Total Number Detected in Study Area	301	179	480
Number Detected in San Joaquin River Route	287	157	444
Number Detected in Old River Route	8	3	11
Number Assigned to San Joaquin River Route	287	157	444
Number Assigned to Old River Route	7	3	10

Table 13. Number of tags observed from each release group at each detection site in 2012, excluding predator-type detections. Routes (SJR = San Joaquin River, OR = Old River) represent route assignment at the head of Old River. Pooled counts are summed over all receivers in array and all routes. Route could not be identified for some tags.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream	DFU	A0	1	1	2
Durham Ferry Downstream	DFD	A2	97	159	256
Banta Carbona	BCA	A3	119	242	361
Mossdale	MOS	A4	299	179	478
Head of Old River	HOR	B0	297	169	466
Lathrop	SJL	A5	287	157	444
Garwood Bridge	SJG	A6	231	75	306
Navy Drive Bridge	SJNB	A7	186	51	237
MacDonald Island Upstream	MACU	A8a	88	10	98
MacDonald Island Downstream	MACD	A8b	84	8	92
MacDonald Island (Pooled)	MAC	A8	88	10	98
Medford Island East	MFE	A9a	41	6	47
Medford Island West	MFW	A9b	41	6	47
Medford Island (Pooled)	MFE/MFW	A9	41	6	47
Turner Cut East	TCE	F1a	9	2	11
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	10	2	12
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	2	8
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	2	8
Old River at Highway 4, Upstream	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route	OR4	B3	1	0	1
Old River at Highway 4, OR Route	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)	OR4	B3	2	0	2
Old River near Empire Cut, Upstream	OLDU	B4a	1	0	1
Old River near Empire Cut, Downstream	OLDD	B4b	0	0	0
Old River near Empire Cut, SJR Route	OLD	B4	1	0	1
Old River near Empire Cut, OR Route	OLD	B4	0	0	0
Old River near Empire Cut (Pooled)	OLD	B4	1	0	1
Middle River Head	MRH	C1	0	0	0
Middle River at Highway 4, Upstream	MR4U	C2a	1	0	1
Middle River at Highway 4, Downstream	MR4D	C2b	1	0	1
Middle River at Highway 4, SJR Route	MR4	C2	1	0	1
Middle River at Highway 4, OR Route	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)	MR4	C2	1	0	1

Table 13. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Middle River near Empire Cut, Upstream	MREU	C3a	3	0	3
Middle River near Empire Cut, Downstream	MRED	C3b	3	0	3
Middle River near Empire Cut, SJR Route	MRE	C3	3	0	3
Middle River near Empire Cut, OR Route	MRE	C3	0	0	0
Middle River near Empire Cut (Pooled)	MRE	C3	3	0	3
Radial Gates Upstream (Pooled)	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)	RGD	D2	0	0	0
Central Valley Project Trashrack	CVP	E1	4	1	5
CVP Trashrack: SJR Route	CVP	E1	1	0	1
CVP Trashrack: OR Route	CVP	E1	3	1	4
Central Valley Project Holding Tank	CVPtank	E2	1	0	1
CVP tank: SJR Route	CVPtank	E2	0	0	0
CVP tank: OR Route	CVPtank	E2	1	0	1
Threemile Slough South	TMS	T1a	6	0	6
Threemile Slough North	TMN	T1b	4	0	4
Threemile Slough (Pooled)	TMS/TMN	T1	6	0	6
Jersey Point East	JPE	G1a	26	2	28
Jersey Point West	JPW	G1b	25	2	27
Jersey Point: SJR Route	JPE/JPW	G1	26	2	28
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	26	2	28
False River West	FRW	H1a	7	0	7
False River East	FRE	H1b	6	0	6
False River: SJR Route	FRE/FRW	H1	7	0	7
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	7	0	7
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

Table 14. Number of tags observed from each release group at each detection site in 2012 and used in the survival analysis, excluding predator-type detections. Pooled counts are summed over all receivers in array. Route could not be identified for some tags. * = site was included in full survival model but omitted from reduced model used for analysis.

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Release site at Durham Ferry			480	479	959
Durham Ferry Upstream*	DFU	A0	1	1	2
Durham Ferry Downstream	DFD	A2	97	159	256
Banta Carbona	BCA	A3	119	242	361
Mossdale	MOS	A4	299	179	478
Lathrop	SJL	A5	287	157	444
Garwood Bridge	SJG	A6	231	75	306
Navy Drive Bridge	SJNB	A7	185	50	235
MacDonald Island Upstream	MACU	A8a	83	9	92
MacDonald Island Downstream	MACD	A8b	80	8	88
MacDonald Island (Pooled)	MAC	A8	87	10	97
Medford Island East	MFE	A9a	38	6	44
Medford Island West	MFW	A9b	38	6	44
Medford Island (Pooled)	MFE/MFW	A9	38	6	44
Turner Cut East	TCE	F1a	9	2	11
Turner Cut West	TCW	F1b	8	2	10
Turner Cut (Pooled)	TCE/TCW	F1	10	2	12
Old River East	ORE	B1	6	3	9
Old River South Upstream	ORSU	B2a	6	2	8
Old River South Downstream	ORSD	B2b	5	0	5
Old River South (Pooled)	ORS	B2	6	2	8
Old River at Highway 4, Upstream*	OR4U	B3a	2	0	2
Old River at Highway 4, Downstream*	OR4D	B3b	2	0	2
Old River at Highway 4, SJR Route*	OR4	B3	1	0	1
Old River at Highway 4, OR Route*	OR4	B3	1	0	1
Old River at Highway 4 (Pooled)*	OR4	B3	2	0	2
Middle River Head*	MRH	C1	0	0	0
Middle River at Highway 4, Upstream*	MR4U	C2a	0	0	0
Middle River at Highway 4, Downstream*	MR4D	C2b	0	0	0
Middle River at Highway 4, SJR Route*	MR4	C2	0	0	0
Middle River at Highway 4, OR Route*	MR4	C2	0	0	0
Middle River at Highway 4 (Pooled)*	MR4	C2	0	0	0
Radial Gates Upstream (Pooled)*	RGU	D1	0	0	0
Radial Gates Downstream (Pooled)*	RGD	D2	0	0	0
Central Valley Project Trashrack*	CVP	E1	4	1	5
CVP Trashrack: SJR Route*	CVP	E1	1	0	1
CVP Trashrack: OR Route*	CVP	E1	3	1	4

Table 14. (Continued)

Detection Site	Site Code	Survival Model Code	Release Group 1	Release Group 2	Total
Central Valley Project Holding Tank*	CVPtank	E2	1	0	1
CVP tank: SJR Route*	CVPtank	E2	0	0	0
CVP tank: OR Route*	CVPtank	E2	1	0	1
Jersey Point East	JPE	G1a	24	2	26
Jersey Point West	JPW	G1b	23	2	25
Jersey Point: SJR Route	JPE/JPW	G1	24	2	26
Jersey Point: OR Route	JPE/JPW	G1	0	0	0
Jersey Point (Pooled)	JPE/JPW	G1	24	2	26
False River West	FRW	H1a	0	0	0
False River East	FRE	H1b	0	0	0
False River: SJR Route	FRE/FRW	H1	0	0	0
False River: OR Route	FRE/FRW	H1	0	0	0
False River (Pooled)	FRE/FRW	H1	0	0	0
Chipps Island East	MAE	G2a	15	0	15
Chipps Island West	MAW	G2b	15	0	15
Chipps Island: SJR Route	MAE/MAW	G2	14	0	14
Chipps Island: OR Route	MAE/MAW	G2	1	0	1
Chipps Island (Pooled)	MAE/MAW	G2	15	0	15

Table 15. Number of juvenile Chinook Salmon tagged by each tagger in each release group during the 2012 tagging study. OK with updated numbers

	Release Group		
Tagger	1	2	Total Tags
A	119	120	239
B	118	119	237
C	120	119	239
D	123	121	244
Total Tags	480	479	959

Table 16. Release size and counts of tag detections at key detection sites by tagger in 2012, excluding predator-type detections. * = used in chi-square test of independence.

	Tagger			
Detection Site	A	B	C	D
Release at Durham Ferry*	239	237	239	244
Mossdale (MOS)*	118	112	126	122
Lathrop (SJL)*	108	102	120	114
MacDonald Island (MAC)	27	13	29	28
Turner Cut (TCE/TCW)	4	1	3	4
Medford Island (MFE/MFW)	13	8	9	14
MacDonald Island, Medford Island, or Turner Cut (pooled)*	31	14	32	32
Old River East (ORE)*	1	4	2	2
Old River South (ORS)	1	3	2	2
Old River at Highway 4 (OR4)	1	0	0	1
Middle River at Highway 4 (MR4)	0	0	0	0
Clifton Court Forebay Interior (RGD)	0	0	0	0
Central Valley Project Holding Tank (CVPtank)	0	0	0	1
Jersey Point (JPE/JPW)*	10	3	6	7
Chipps Island (MAE/MAW)*	5	1	4	5

Table 17. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2012 tagging study, excluding predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups.

	Release Occasion		
Parameter	1	2	Population Estimate
ψ_{AA}	0.88 (0.03)	0.82 (0.10)	0.87 (0.03)
ψ_{AF}	0.10 (0.03)	0.16 (0.10)	0.11 (0.03)
S_{AA}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
S_{AF}	0 (0)	0 (0)	0 (0)
ψ_{A}^{a}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{B}^{a}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.11 (0.03)	0.16 (0.11)	0.11 (0.03)
S_{A}	0.05^{cd} (0.01)	0^{d} (0)	0.03^{c} (0.01)
S_{B}^{b}	0.16^{c} (0.15)	0 (0)	0.11^{c} (0.10)
S_{Total}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
$S_{A(MD)}$	0.09^{d} (0.02)	0.01^{d} (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.33^{d} (0.03)	0.07^{d} (0.02)	0.23 (0.02)
ϕ_{A1A4}	0.63^{d} (0.02)	0.37^{d} (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) (α = 0.05) for all release occasions and for population estimate.

b = No tags were detected in subroute C; survival estimate used $\phi_{B1,B2} = S_{B1} * \psi_{B2}$ under assumption $\psi_{B2} = 1$.

c = No significant difference between route A and route B estimate ($P \geq 0.19$).

d = Release group 1 had significantly higher survival than release group 2 ($P < 0.0001$).

Table 18. Performance metric estimates (standard error in parentheses) for tagged juvenile Chinook Salmon released in the 2012 tagging study, including predator-type detections. South Delta ("SD") survival extended to MacDonald Island and Turner Cut in Route A. Population-level estimates were from pooled release groups.

	Release Occasion		
Parameter	1	2	Population Estimate
ψ_{AA}	0.86 (0.03)	0.85 (0.09)	0.86 (0.03)
ψ_{AF}	0.12 (0.03)	0.13 (0.09)	0.12 (0.03)
S_{AA}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
S_{AF}	0 (0)	0 (0)	0 (0)
ψ_{A}^{a}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{B}^{a}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.12 (0.03)	0.14 (0.09)	0.12 (0.03)
S_{A}	0.05^{cd} (0.01)	0^{d} (0)	0.03^{c} (0.01)
S_{B}^{b}	0.16^{c} (0.15)	0 (0)	0.11^{c} (0.10)
S_{Total}	0.05^{d} (0.01)	0^{d} (0)	0.03 (0.01)
$S_{A(MD)}$	0.09^{d} (0.02)	0.01^{d} (0.01)	0.06 (0.01)
$S_{A(SD)}$	0.34^{d} (0.03)	0.08^{d} (0.02)	0.24 (0.02)
ϕ_{A1A4}	0.62^{d} (0.02)	0.38^{d} (0.02)	0.50 (0.02)

a = Significant preference for route A (San Joaquin Route) (α = 0.05) for all release occasions and for population estimate.

b = No tags were detected in subroute C; survival estimate used $\phi_{B1,B2} = S_{B1} * \psi_{B2}$ under assumption $\psi_{B2} = 1$.

c = No significant difference between route A and route B estimate ($P \geq 0.19$).

d = Release group 1 had significantly higher survival than release group 2 ($P < 0.0001$).

Table 19. Estimates (standard errors in parentheses) of model survival and transition parameters by release group, and of the difference (Δ) between release group estimates: Δ = Release group 1 - Release group 2. P = P-value from one-sized z-test of Δ>1. Estimates were based on data that excluded predator-type detections. * = significant (positive) difference between release groups for family-wise α=0.10.

Parameter	Release 1	Release 2	Δ	P
S_{A2}	0.90 (0.06)	0.63 (0.04)	0.27 (0.07)	0.0001*
S_{A3}	0.78 (0.04)	0.59 (0.03)	0.19 (0.05)	0.0001*
S_{A4}	0.98 (0.01)	0.89 (0.02)	0.08 (0.02)	0.0004*
S_{A5}	0.81 (0.02)	0.48 (0.04)	0.33 (0.05)	<0.0001*
S_{A6}	0.85 (0.03)	0.73 (0.08)	0.13 (0.08)	0.0594
S_{A7}	0.49 (0.04)	0.23 (0.06)	0.27 (0.07)	0.0001*
$S_{B2,G2}$[a]	0.17 (0.15)	0	0.17 (0.15)	0.1367
$\phi_{A1,A2}$	0.89 (0.05)	1.00 (0.06)	-0.11 (0.07)	0.9407
$\phi_{A8,A9}$	0.44 (0.05)	0.59 (0.16)	-0.16 (0.16)	0.8309
$\phi_{A8,G1}$	0.08 (0.03)	0	0.08 (0.03)	0.0030*
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.16 (0.21)	0.2265
$\phi_{B1,B2}$[a]	1	0.67 (0.27)	0.33 (0.27)	0.1106
$\phi_{F1,G1}$	0	0	0	NA
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.54 (0.10)	<0.0001*

[a] These reaches are in the Old River route

Table 20a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2012 tagging study, without predator-type detections (see Table 20b for travel time from release with predator-type detections). Standard errors are in parentheses. There were no detections at the MRH, RGU, or RGD sites; all tags detected at FRE/FRW or MR4 were later detected at competing receivers, so those sites are omitted here.

	Without Predator-Type Detections					
	All Releases		Release 1		Release 2	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Upstream (DFU)	2	0.06 (0.02)	1	0.10 (NA)	1	0.04 (NA)
Durham Ferry Downstream (DFD)	251	0.03 (<0.01)	92	0.03 (<0.01)	159	0.03 (<0.01)
Banta Carbona (BCA)	353	0.27 (0.01)	111	0.25 (0.01)	242	0.29 (0.01)
Mossdale (MOS)	464	0.53 (0.01)	285	0.48 (0.01)	179	0.61 (0.02)
Lathrop (SJL)	430	0.71 (0.01)	273	0.65 (0.01)	157	0.85 (0.03)
Garwood Bridge (SJG)	293	1.41 (0.03)	218	1.31 (0.02)	75	1.85 (0.08)
Navy Drive Bridge (SJNB)	226	1.48 (0.03)	176	1.39 (0.02)	50	1.96 (0.10)
MacDonald Island (MAC)	89	2.83 (0.10)	79	2.74 (0.10)	10	3.88 (0.44)
Turner Cut (TCE/TCW)	12	2.84 (0.16)	10	2.91 (0.19)	2	2.57 (0.19)
Medford Island (MFE/MFW)	44	3.39 (0.25)	38	3.32 (0.27)	6	3.88 (0.55)
Old River East (ORE)	9	0.70 (0.06)	6	0.66 (0.04)	3	0.80 (0.19)
Old River South (ORS)	8	1.01 (0.07)	6	0.97 (0.04)	2	1.16 (0.43)
Old River at Highway 4 (OR4), SJR Route	1	5.08 (NA)	1	5.08 (NA)	0	NA
Old River at Highway 4 (OR4), OR Route	1	4.29 (NA)	1	4.29 (NA)	0	NA
Central Valley Project Trashrack (CVP), SJR Route	1	5.62 (NA)	1	5.62 (NA)	0	NA
Central Valley Project Trashrack (CVP), OR Route	4	2.52 (0.57)	3	2.41 (0.72)	1	2.92 (NA)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	0	NA	0	NA
Central Valley Project Holding Tank (CVPtank), OR Route	1	2.15 (NA)	1	2.15 (NA)	0	NA
Jersey Point (JPE/JPW), SJR Route	26	5.98 (0.63)	24	6.91 (0.69)	2	4.26 (1.26)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chipps Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chipps Island (MAE/MAW)	11	5.75 (0.41)	11	5.75 (0.41)	0	NA

Table 20b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon from release at Durham Ferry during the 2012 tagging study, with predator-type detections (see Table 20a for travel time from release without predator-type detections). Standard errors are in parentheses. There were no detections at the MRH, RGU, or RGD sites; all tags detected at FRE/FRW or MR4 were later detected at competing receivers, so those sites are omitted here.

	With Predator-Type Detections					
	All Releases		Release 1		Release 2	
Detection Site and Route	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry Upstream (DFU)	8	0.20 (0.11)	1	0.10 (NA)	7	0.23 (0.16)
Durham Ferry Downstream (DFD)	262	0.03 (<0.01)	96	0.03 (<0.01)	166	0.04 (<0.01)
Banta Carbona (BCA)	355	0.28 (0.01)	112	0.25 (0.01)	243	0.29 (0.01)
Mossdale (MOS)	464	0.53 (0.01)	283	0.48 (0.01)	181	0.63 (0.02)
Lathrop (SJL)	432	0.72 (0.01)	272	0.65 (0.01)	160	0.89 (0.03)
Garwood Bridge (SJG)	297	1.44 (0.03)	219	1.33 (0.02)	78	1.93 (0.09)
Navy Drive Bridge (SJNB)	230	1.56 (0.04)	177	1.44 (0.03)	53	2.19 (0.13)
MacDonald Island (MAC)	90	3.21 (0.17)	78	3.07 (0.17)	12	4.55 (0.72)
Turner Cut (TCE/TCW)	13	3.11 (0.26)	11	3.23 (0.31)	2	2.57 (0.19)
Medford Island (MFE/MFW)	44	3.39 (0.25)	38	3.32 (0.27)	6	3.88 (0.55)
Old River East (ORE)	9	0.77 (0.09)	6	0.66 (0.04)	3	1.18 (0.46)
Old River South (ORS)	9	1.11 (0.13)	6	0.97 (0.04)	3	1.52 (0.64)
Old River at Highway 4 (OR4), SJR Route	1	5.08 (NA)	1	5.08 (NA)	0	NA
Old River at Highway 4 (OR4), OR Route	1	4.29 (NA)	1	4.29 (NA)	0	NA
Central Valley Project Trashrack (CVP), SJR Route	1	5.62 (NA)	1	5.62 (NA)	0	NA
Central Valley Project Trashrack (CVP), OR Route	4	2.52 (0.57)	3	2.41 (0.72)	1	2.92 (NA)
Central Valley Project Holding Tank (CVPtank), SJR Route	0	NA	0	NA	0	NA
Central Valley Project Holding Tank (CVPtank), OR Route	1	2.15 (NA)	1	2.15 (NA)	0	NA
Jersey Point (JPE/JPW), SJR Route	26	5.98 (0.63)	24	6.19 (0.69)	2	4.26 (1.26)
Jersey Point (JPE/JPW), OR Route	0	NA	0	NA	0	NA
Chipps Island (MAE/MAW), SJR Route	10	5.99 (0.41)	10	5.99 (0.41)	0	NA
Chipps Island (MAE/MAW), OR Route	1	4.12 (NA)	1	4.12 (NA)	0	NA
Chipps Island (MAE/MAW)	11	5.75 (0.41)	11	5.75 (0.41)	0	NA

Table 21a. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2012 tagging study, without predator-type detections (see Table 21b for travel time through reaches with predator-type detections). Standard errors are in parentheses. Reaches beginning at sites with no detections are not shown (i.e., reaches that start at MRH, MR4, RGU, RGD, and FRE/FRW).

		Without Predator-Type Detections					
Reach		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	BCA	251	0.03 (<0.01)	92	0.03 (<0.01)	159	0.03 (<0.01)
BCA	MOS	230	0.28 (0.01)	87	0.24 (0.01)	143	0.31 (0.01)
MOS	SJL	429	0.14 (<0.01)	272	0.13 (<0.01)	157	0.16 (0.01)
	ORE	9	0.25 (0.04)	6	0.23 (0.04)	3	0.32 (0.09)
SJL	SJG	293	0.65 (0.02)	218	0.60 (0.02)	75	0.86 (0.05)
SJG	SJNB	226	0.08 (<0.01)	176	0.08 (<0.01)	50	0.09 (0.01)
SJNB	MAC	84	1.25 (0.07)	75	1.21 (0.07)	9	1.72 (0.37)
	TCE/TCW	12	1.19 (0.18)	10	1.37 (0.15)	2	0.72 (0.31)
MAC	MFE/MFW	39	0.23 (0.03)	33	0.24 (0.03)	6	0.21 (0.07)
	JPE/JPW/FRE/FRW	22	2.20 (0.26)	20	2.47 (0.27)	2	1.05 (0.13)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
MFE/MFW	JPE/JPW/FRE/FRW	17	1.54 (0.21)	15	1.80 (0.19)	2	0.74 (0.20)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
TCE/TCW	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	OR4	1	2.25 (NA)	1	2.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
ORE	ORS	8	0.27 (0.03)	6	0.29 (0.03)	2	0.22 (0.05)
	MRH	0	NA	0	NA	0	NA
ORS	OR4	1	3.25 (NA)	1	3.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	3	0.95 (0.12)	2	0.90 (0.16)	1	1.09 (NA)

Table 21a. (Continued)

Reach		Without Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
OR4 via OR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	1	0.55 (NA)	1	0.55 (NA)	0	NA
CVP via OR	CVPtank	1	0.01 (NA)	1	0.01 (NA)	0	NA
CVP via SJR	CVPtank	0	NA	0	NA	0	NA
JPE/JPW	MAE/MAW (Chipps Island)	9	1.21 (0.14)	9	1.21 (0.14)	0	NA
MAC		10	3.54 (0.34)	10	3.54 (0.34)	0	NA
MFE/MFW		8	3.04 (0.25)	8	3.04 (0.259)	0	NA
TCE/TCW		0	NA	0	NA	0	NA
OR4		0	NA	0	NA	0	NA
CVPtank		1	1.97 (NA)	1	1.97 (NA)	0	NA

Table 21b. Average travel time in days (harmonic mean) of acoustic-tagged juvenile Chinook Salmon through the San Joaquin River Delta river reaches during the 2012 tagging study, with predator-type detections (see Table 21a for travel time through reaches without predator-type detections). Standard errors are in parentheses. Reaches beginning at sites with no detections are not shown (i.e., reaches that start at MRH, MR4, RGU, RGD, and FRE/FRW).

Reach		With Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
Durham Ferry (Release)	BCA	262	0.03 (<0.01)	96	0.03 (<0.01)	166	0.04 (<0.01)
BCA	MOS	231	0.28 (0.01)	86	0.24 (0.01)	145	0.31 (0.01)
MOS	SJL	431	0.14 (<0.01)	271	0.13 (<0.01)	160	0.17 (0.01)
	ORE	9	0.28 (0.06)	6	0.23 (0.04)	3	0.52 (0.27)
SJL	SJG	297	0.67 (0.02)	219	0.62 (0.02)	78	0.90 (0.05)
SJG	SJNB	230	0.08 (<0.01)	177	0.08 (<0.01)	53	0.09 (0.01)
SJNB	MAC	85	1.38 (0.10)	74	1.32 (0.10)	11	2.04 (0.49)
	TCE/TCW	13	1.33 (0.23)	11	1.57 (0.24)	2	0.72 (0.31)
MAC	MFE/MFW	39	0.23 (0.03)	33	0.24 (0.03)	6	0.21 (0.07)
	JPE/JPW/FRE/FRW	22	2.20 (0.26)	20	2.47 (0.27)	2	1.05 (0.13)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
MFE/MFW	JPE/JPW/FRE/FRW	17	1.54 (0.21)	15	1.80 (0.19)	2	0.74 (0.20)
	OR4	0	NA	0	NA	0	NA
	MR4	0	NA	0	NA	0	NA
TCE/TCW	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	OR4	1	2.25 (NA)	1	2.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
ORE	ORS	9	0.29 (0.04)	6	0.29 (0.03)	3	0.31 (0.14)
	MRH	0	NA	0	NA	0	NA
ORS	OR4	1	3.25 (NA)	1	3.25 (NA)	0	NA
	MR4	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	3	0.95 (0.12)	2	0.90 (0.16)	1	1.09 (NA)

Table 21b. (Continued)

Reach		With Predator-Type Detections					
		All Releases		Release 1		Release 2	
Upstream Boundary	Downstream Boundary	N	Travel Time	N	Travel Time	N	Travel Time
OR4 via OR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
OR4 via SJR	JPE/JPW/FRE/FRW	0	NA	0	NA	0	NA
	RGU	0	NA	0	NA	0	NA
	CVP	1	0.55 (NA)	1	0.55 (NA)	0	NA
CVP via OR	CVPtank	1	0.01 (NA)	1	0.01 (NA)	0	NA
CVP via SJR	CVPtank	0	NA	0	NA	0	NA
JPE/JPW	MAE/MAW (Chipps Island)	9	1.21 (0.14)	9	1.21 (0.14)	0	NA
MAC		10	3.54 (0.34)	10	3.54 (0.34)	0	NA
MFE/MFW		8	3.04 (0.225)	8	3.04 (0.25)	0	NA
TCE/TCW		0	NA	0	NA	0	NA
OR4		0	NA	0	NA	0	NA
CVPtank		1	1.97 (NA)	1	1.97 (NA)	0	NA

Table 22: Distance in km, estimated survival and survival rate per km (S^(1/km)), travel time in days, and travel time in days per km (TT^(1/km)), for the first (1st) and second (2nd) release groups of Chinook Salmon in 2012. Survival and travel time data were obtained from tables Table A5-2, and Table 21a. Distance was estimated using the shortest distance between the two points calculated from Google Earth. Data were used to generate Figure 12.

Reach	Distance in km	Survival		Survival per km		Travel time		Travel time per km	
		1st	**2nd**	**1st**	**2nd**	**1st**	**2nd**	**1st**	**2nd**
Durham Ferry (Release) to Banta Carbona	11	0.90	0.63	0.990	0.959	0.03	0.03	0.727	0.727
Banta Carbona to Mossdale	9	0.78	0.59	0.973	0.943	0.24	0.31	0.853	0.878
Mossdale to Lathrop/Old River	4	0.98	0.89	0.995	0.971	0.13	0.16	0.600	0.632
Lathrop to Stockton South (Garwood Bridge)	18	0.81	0.48	0.988	0.960	0.60	0.86	0.972	0.992
Stockton South to Stockton Navy Bridge	3	0.85	0.73	0.947	0.900	0.08	0.09	0.431	0.448
Navy Bridge to Turner Cut Junction	15	0.49	0.23	0.954	0.907	1.37	0.72	1.021	0.978
MacDonald Island to Medford Island	5	0.44	0.59	0.849	0.900	0.24	0.21	0.752	0.732
Medford Island to Jersey Point	21	0.49	0.33	0.967	0.949	1.80	0.74	1.028	0.986
Jersey Point to Chipps Island	22	0.54	0.00	0.972	0.000	1.21		1.009	

Table 23. Results of single-variate analyses of route entrainment at the Turner Cut Junction (all release groups). The values df1, df2 are degrees of freedom for the F-test.

	F-test			
Covariate[a]	*F*	df1	df2	*P*
Change in flow at TRN	0.6896	1	8	0.4304
Change in velocity at TRN	0.6470	1	8	0.4444
Exports at CVP	0.3355	1	9	0.5766
Change in stage at TRN	0.2824	1	8	0.6095
Flow during transition from SJG	0.1864	1	9	0.6761
Stage at TRN	0.1696	1	9	0.6901
Velocity during transition from SJG	0.1311	1	9	0.7256
Release Group	0.0730	1	9	0.7931
Arrive during day at junction	0.0558	1	9	0.8185
Fork Length	0.0331	1	9	0.8597
Exports at SWP	0.0286	1	9	0.8694
Negative flow at TRN	0.0063	1	9	0.9385
Flow at TRN	0.0031	1	9	0.9568
Velocity at TRN	0.0024	1	9	0.9623

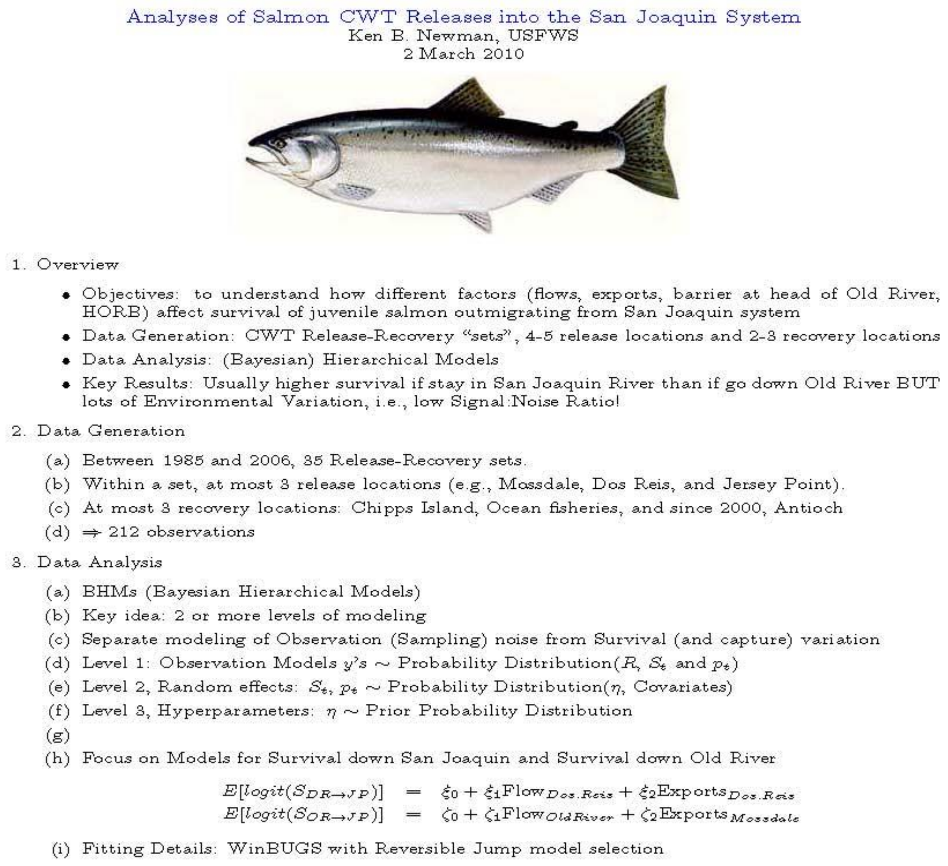
a = No covariate was significant at 5% level

Table 24. Summary statistics from multiple regression of flow at Vernalis and tag type to explain survival from Mossdale to Jersey Point with the physical head of Old River barrier. Tag type (CWT or Acoustic) was not significant (p value = 0.992775).

SUMMARY OUTPUT			Mossdale data only					
Regression Statistics								
Multiple R	0.86119676							
R Square	0.74165986							
Adjusted R Square	0.69468892							
Standard Error	0.07221227							
Observations	14							
ANOVA								
	df	*SS*	*MS*	*F*	*Significance F*			
Regression	2	0.164674977	0.082337	15.78976	0.000584865			
Residual	11	0.057360738	0.005215					
Total	13	0.222035714						
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-0.2287319	0.10572806	-2.1634	0.053388	-0.461437753	0.00397403	-0.46143775	0.003974031
X Variable 1 (tag)	-0.0005306	0.057279985	-0.00926	0.992775	-0.126603014	0.12554178	-0.12660301	0.125541781
X Variable 2 (flow)	9.533E-05	1.76263E-05	5.408389	0.000214	5.65346E-05	0.00013413	5.6535E-05	0.000134125

Appendices 1-5:

Appendix 1. Analyses of CWT salmon released in the south Delta by Ken Newman as part of the VAMP peer review in 2010.



Analyses of Salmon CWT Releases into the San Joaquin System

Ken B. Newman, USFWS
2 March 2010

1. Overview
    - Objectives: to understand how different factors (flows, exports, barrier at head of Old River, HORB) affect survival of juvenile salmon outmigrating from San Joaquin system
    - Data Generation: CWT Release-Recovery "sets", 4-5 release locations and 2-3 recovery locations
    - Data Analysis: (Bayesian) Hierarchical Models
    - Key Results: Usually higher survival if stay in San Joaquin River than if go down Old River BUT lots of Environmental Variation, i.e., low Signal:Noise Ratio!
2. Data Generation
    (a) Between 1985 and 2006, 35 Release-Recovery sets.
    (b) Within a set, at most 3 release locations (e.g., Mossdale, Dos Reis, and Jersey Point).
    (c) At most 3 recovery locations: Chipps Island, Ocean fisheries, and since 2000, Antioch
    (d) ⇒ 212 observations
3. Data Analysis
    (a) BHMs (Bayesian Hierarchical Models)
    (b) Key idea: 2 or more levels of modeling
    (c) Separate modeling of Observation (Sampling) noise from Survival (and capture) variation
    (d) Level 1: Observation Models y's $\sim$ Probability Distribution(R, S_t and p_t)
    (e) Level 2, Random effects: S_t, p_t $\sim$ Probability Distribution(η, Covariates)
    (f) Level 3, Hyperparameters: $\eta \sim$ Prior Probability Distribution
    (g)
    (h) Focus on Models for Survival down San Joaquin and Survival down Old River

$$\begin{aligned} E[logit(S_{DR\rightarrow JP})] &= \xi_0 + \xi_1 \text{Flow}_{Dos.Reis} + \xi_2 \text{Exports}_{Dos.Reis} \\ E[logit(S_{OR\rightarrow JP})] &= \zeta_0 + \zeta_1 \text{Flow}_{OldRiver} + \zeta_2 \text{Exports}_{Mossdale} \end{aligned}$$

    (i) Fitting Details: WinBUGS with Reversible Jump model selection

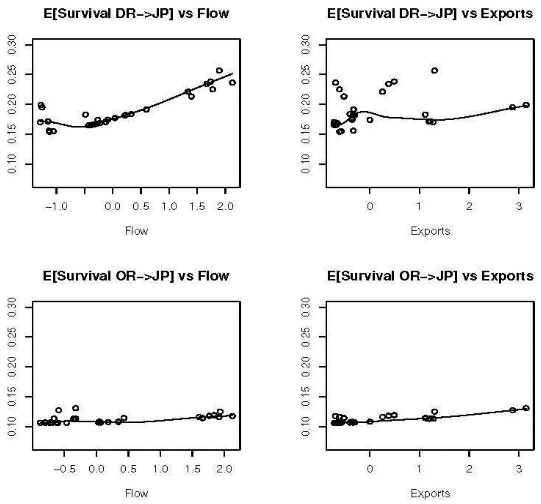
4. Results

   (a) Posterior Probabilities

Models	$S_{MD\rightarrow JP}$	$S_{OR\rightarrow JP}$
Constant	0.38	0.45
Flow	0.29	0.23
Exports	0.17	0.21
Both	0.16	0.11

   (b) Coefficients

Covariate	Average	SD	2.5%	median	97.5%
SJ-flow	0.16	0.25	-0.09	0.0	0.77
SJ-exports	0.07	0.19	-0.17	0.0	0.61
OR-flow	0.04	0.22	-0.42	0.0	0.62
OR-exports	0.04	0.20	-0.32	0.0	0.60



5. Caveats and Comments

   (a) Priors *do* matter, especially with Hierarchical Models
   (b) More to wring out of CWTs? Using time of capture? Add arrival time/travel time model?
   (c) Acoustic tags far preferable?
   (d) Value in probing extreme values for flows and exports

Some references:

- Clark, J.S. 2005. "Why environmental scientists are becoming Bayesians." *Ecology Letters*, **8**: 2–14.
- Clark, J.S., and Gelfand, A.E. 2006. "A future for models and data in environmental science." *Trends in Ecology and Evolution*, **21**: 375–380.
- Newman, K.B., and Brandes, P.L. 2010. Hierarchical modeling of juvenile Chinook salmon survival as a function of Sacramento-San Joaquin Delta water exports. *North American Journal of Fisheries Management*, **30**: 157–169.

Appendix 2: Standard Operating Procedure

Acoustic Tagging for Salmon 2012 South Delta Studies 4/10/12 (file dated 4/23/12)

Equipment Set Up:

- Fill surgical instrument disinfection trays with chlorhexidine (brand name Nolvasan)
    - Autoclave instruments such that each tagging event begins with sterile instruments
- Activate transmitters and confirm operational status
    - Position the transmitter in an isolated compartment to enable tracking of the transmitter ID through the implantation process
- Disinfect transmitters in chlorhexidine
    - Ensure at least 20 minutes of contact time with chlorhexidine
    - Following disinfection, thoroughly rinse transmitters in distilled or de-ionized water prior to implantation
    - Following disinfection, transmitters should only be handled by gloved hands or clean surgical instruments such as forceps
- Fill rinse tray with de-ionized or distilled water
- Set up scale, measuring board, and surgical platform or foam
    - Apply stress coat to weigh boat, measuring board, and platform to reduce damage to fish skin or mucus layer
- Fill gravity feed carboys. Add 2 ml of the MS-222 stock solution and 2 ml of the sodium bicarbonate stock solution to the 10 L of water in the MS-222 carboy. Concentration may be increased upon group consensus and in consultation with coordinator.
- Fill anesthesia container to indicated volume line. Set the initial concentration in collaboration with the tagging coordinator. Suggested starting concentration is 70 mg/ L. Concentration may be adjusted upon group consensus and in consultation with coordinator. Concentration changes should be executed for all taggers simultaneously and recorded on the tagging datasheet.
- Prepare recovery containers by filling with water, adding stress coat, and supersaturating with oxygen
    - Immediately following surgery fish will be held in recovery containers that provide 130% to 150% DO for a minimum of 10 minutes
    - Holding time in recovery containers begins when the last fish is added to the container and will be monitored using a timer
- Prepare a reject container for fish that cannot be tagged by filling with water and equipping with a bubbler . These fish will be returned to a separate holding tank.
- Start tagging data sheets. Note the time the tagging session was started and complete all appropriate data fields. Start a Daily Fish Reject Tally datasheet to account for fish that are handled but not tagged.
- The tagger should wear medical-grade exam gloves during all fish handling and tagging procedures
- Prepare the transport truck to accept containers of tagged fish.
- Prepare transport containers and lids to receive tagged fish

Surgery

- Food should be withheld from fish for ~24 h prior to surgical implantation of the transmitter.
- Anesthetize fish
    - Net one fish from source tank/raceway and place directly into an anesthesia container. Immediately start a timer to monitor anesthesia exposure time and place a lid on the container.
    - Remove the lid after about 1 minute to observe the fish for loss of equilibrium. Keep the fish in the water for an additional 30-60 seconds after it has lost equilibrium. Time to sedation should normally be 2-4 minutes, with an average of about 3 minutes. If loss of equilibrium takes less than 1 minute or if a fish is exposed to anesthesia for more than 5 minutes, reject that fish. If after anesthetizing a few fish they are consistently losing equilibrium in more or less time than typical, the anesthesia concentration may need to

be adjusted. Anesthesia concentration should only be adjusted in coordination with all study taggers and the tagging coordinator.

        - Changes to anesthesia concentration should be done at 5 mg/L increments. For example, if the initial dosage was 70 mg/L, an adjusted dose should be 65 mg/L or 75 mg/L.
        - When an anesthesia change is agreed upon, all taggers should drain their anesthesia containers, refill with 10 L of water, and re-mix to the new anesthesia concentration
    - If a fish is unacceptable for tagging due to issues with anesthesia, place the fish in the “Reject” container and log it on the reject tally datasheet.
    - The anesthesia container should be emptied and remixed at regular intervals throughout the tagging operation to ensure the appropriate concentration and to avoid warming
    - The gravity feed containers should be monitored for volume and temperature and changed as needed to avoid inadequate volume to complete a surgery and significant warming

- Recording fish length, weight, and condition
    - Start a timer when a fish is removed from the anesthesia container to record the time the fish is out of water (recorded as “air time”).
    - Transfer the fish to the scale and record the weigh to the nearest 0.1g
        - Scales should be calibrated regularly to ensure accuracy
        - Fish must weigh at least 13 g to be selected for tagging so that tag burden does not exceed 5% of the weight of the fish. Transmitters used for this study are Vemco brand V5 models, weighing 0.65 g in air.
    - Transfer the fish to the measuring board and determine forklength to the nearest mm.
    - Check for any abnormalities and descaling. If the fish is abnormal or grossly descaled, note this on the datasheet and place the fish in the reject container.
        - Scale condition is noted as Normal (N), Partial (P), or Descaled (D) and is assessed on the most compromised side of each fish. The normal scale condition is defined as loss of less than 5% of scales on one side of the fish. Partial descaling is defined as loss of 6-19% of scales on one side of the fish. Fish are classified as descaled if they have lost 20% or more of the scales on one side of the fish, and should not be tagged due to compromised osmoregulatory ability.
    - Data must be vocally relayed to the recorder, and the recorder should repeat the information back to the tagger to avoid miscommunication.
    - Any fish dropped on the floor should be rejected.

- Transmitter Implantation
    - Anesthesia should be administered through the gravity feed irrigation system as soon as the fish is on the surgical platform. Use the flow control valves to adjust the flow rate as needed so that the opercular rate of the fish is steady.
        - Note that low-flow or inconsistent irrigation can mimic shallow anesthesia
    - Using a scalpel, make an incision approximately 3-5 mm in length beginning a few mm in front of the pelvic girdle. The incision should be about 3 mm away from and parallel to the mid-ventral line, and just deep enough to penetrate the peritoneum, avoiding the internal organs. The spleen is generally near the incision point so the depth and placement of the incision are critical.
        - There is no exact specification for the selection of a micro scalpel for steelhead. A general recommendation is to use a 5 mm blade for fish larger than about 50 g.
        - The incision should only be long enough to allow entry of the tag.
    - Forceps may be used to open the incision to check for potential organ damage. If you observe damage or note excessive bleeding, reject the fish.
    - Scalpel blades can be used on several fish, but if the scalpel is pulling roughly or making jagged incisions, it should be changed prior to tagging the next fish.

  - Gently insert the tag into the body cavity and position it so that it lies directly beneath the incision and the ceramic head is facing forward. This positioning will provide a barrier between the suture needle and internal organs.
  - Close the incision with two simple interrupted stitches.
    - Vicryl Plus sutures are recommended
    - 5-0 suture size is appropriate for juvenile Chinook Salmon or similar fish with weights less than~ 50 g
    - If the incision cannot effectively be closed with two stitches, a third stitch may be added. The presence of a third suture should be noted on the datasheet.
  - Ideally the gravity feed irrigation system should be switched to fresh water or a combination of sedation and freshwater during the final stages of surgery to begin recovery from anesthesia. Typically a good time to switch to freshwater is when the second suture is initiated.
  - Transfer the fish from the surgical platform to a recovery container and stop the timer recording air time
    - Avoid excessive handling of fish during transfer. Ideally the fish will be moved to the recovery container on the surgical platform to reduce handling.
  - Once a recovery container has been fully stocked, start a timer to monitor the 10 min of exposure to high DO concentrations for recovery.
  - Between surgeries the tagger should place surgical instruments and any partially consumed suture material into the chlorhexidine bath. Multiple sets of surgical instruments should be rotated to ensure 10 min of contact time with chlorhexidine. Once disinfected, instruments should be rinsed in distilled or de-ionized water. Organic debris in the disinfectant bath reduces effectiveness, so be sure to change the bath regularly.

Tag Validation

- Filled recovery containers will be moved to the tag validation station.
  - Recovery containers may be moved from the tagging location to the tag validation station during the 10 min recovery time, but they must not be established on flow-through water exchange. The flow-through exchange will immediately reduce the DO saturation.
- Use the appropriate receiving system to confirm the identity and function of the transmitters in the recovery container. Record validation on the datasheet.
- Following tag validation, recovery containers are held in a flow-through tank until the tagging session is complete, at which time they are loaded onto a truck for transport to the holding and release location.

Cleanup

- Both the tagger and assistant must review the full complement of tagging datasheets and initial each sheet to confirm that the set of transmitters they were assigned to implant have been implanted. Use the list of transmitters provided by the tag coordinator to ensure that all transmitters supplied to you were implanted and recorded. Both the tagger and the assistant must initial the header of each of the datasheets. This review step is completed for each tagging session (that is, for each transport truck that is loaded).
- Return tag tray and datasheets to coordinator at end of each tagging session.
- Complete the reject fish tally datasheet and return to the tag coordinator.
- Use a spray disinfectant to disinfect tagging surfaces and supplies, and position them to dry.
- Return any rejected fish to the appropriate raceway where they cannot be selected for future tagging efforts.
- At the completion of the tagging effort each day, package surgical instruments for the autoclave so they can be sterilized prior to the next tagging session.

Important things to remember:

- Water containers used for tagging should be filled just prior to tagging to avoid temperature changes and should be changed frequently.
- Fish cannot be transferred between water sources until the difference between the water temperatures of the two sources is less than two degrees Celsius.
- No water sources used in the tagging operation should be more than two degrees different in water temperature from the source water temperature.
- All containers holding fish should have lids in place.
- If a tag is dropped bring it to the tagging coordinator to confirm that it is still functioning before it is implanted. The transmitter may also require disinfection if it fell onto a dirty surface.
- Carefully handle all fish containers to minimize disturbances to fish.
- Containers used to transport fish to the release site cannot be used for tagging operations until they have been held in the freezer for 24 h.

Appendix 3: Water temperature (every 15 minutes) in transport tanks during transport of tagged fish from the Tracy Fish Collection Facility to the release site (Durham Ferry)

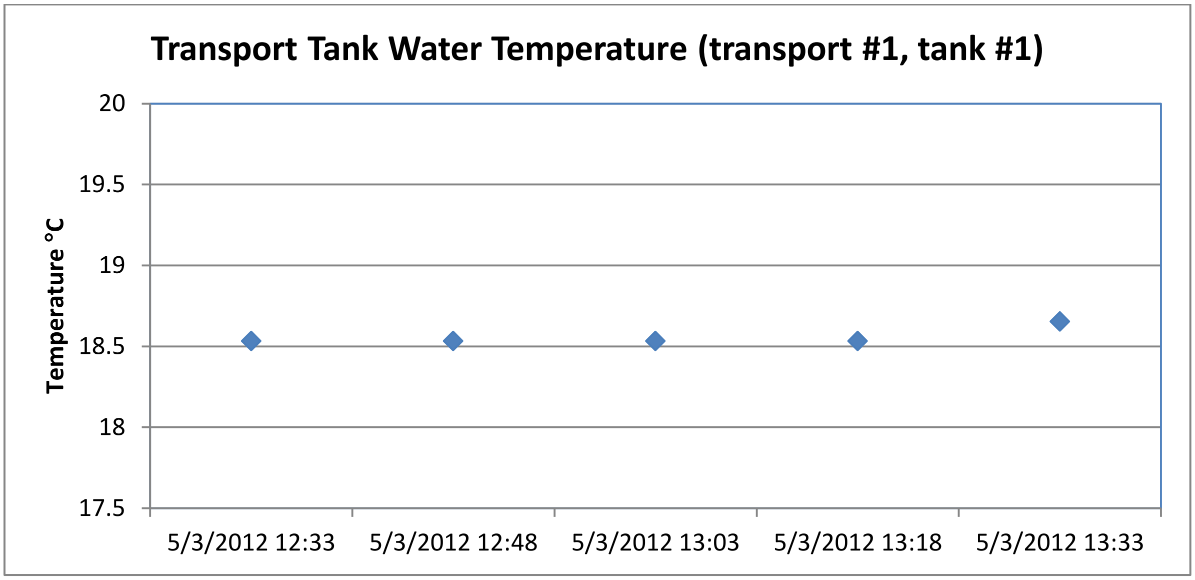


Figure A3-1. Transport tank water temperature during transport #1, tank #1 on May 3, 2012.

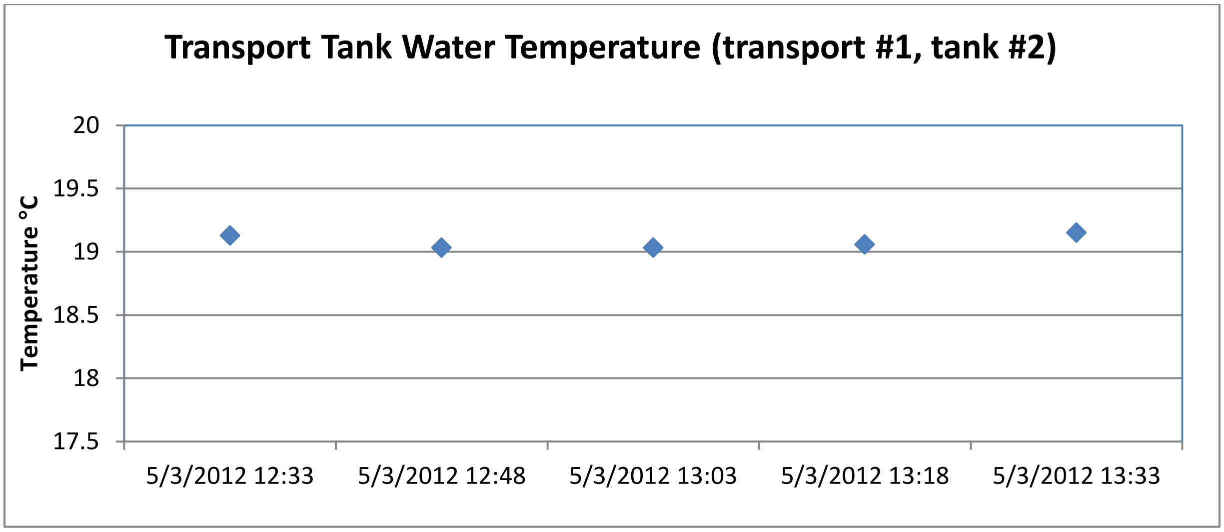


Figure A3-2. Transport tank water temperature during transport #1, tank #2 on May 3, 2012.

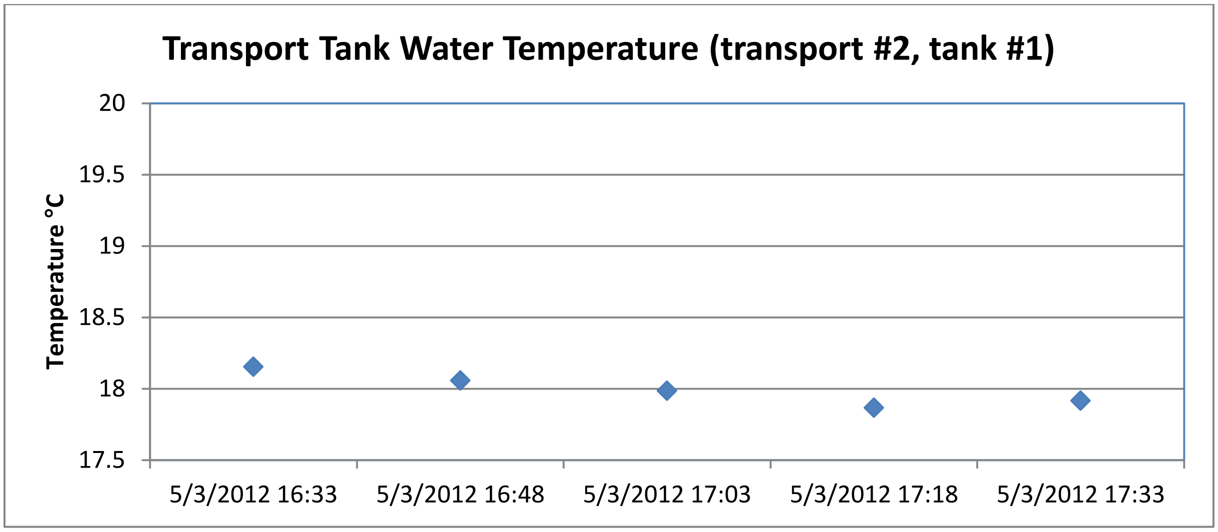


Figure A3-3. Transport tank water temperature during transport #2, tank #1 on May 3, 2012.

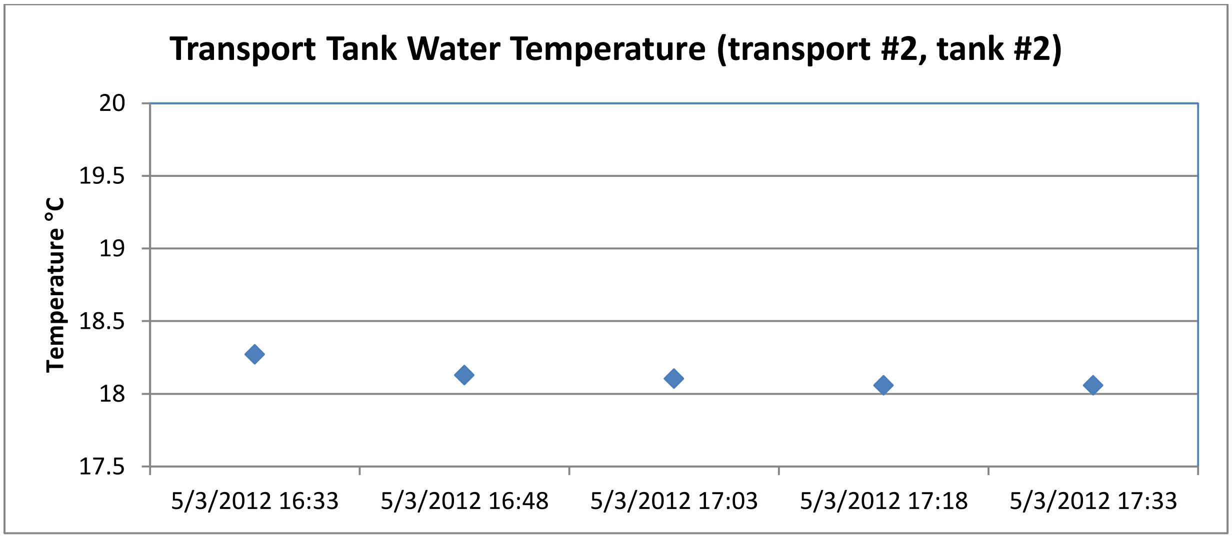


Figure A3-4. Transport tank water temperature during transport #2, tank #2 on May 3, 2012.

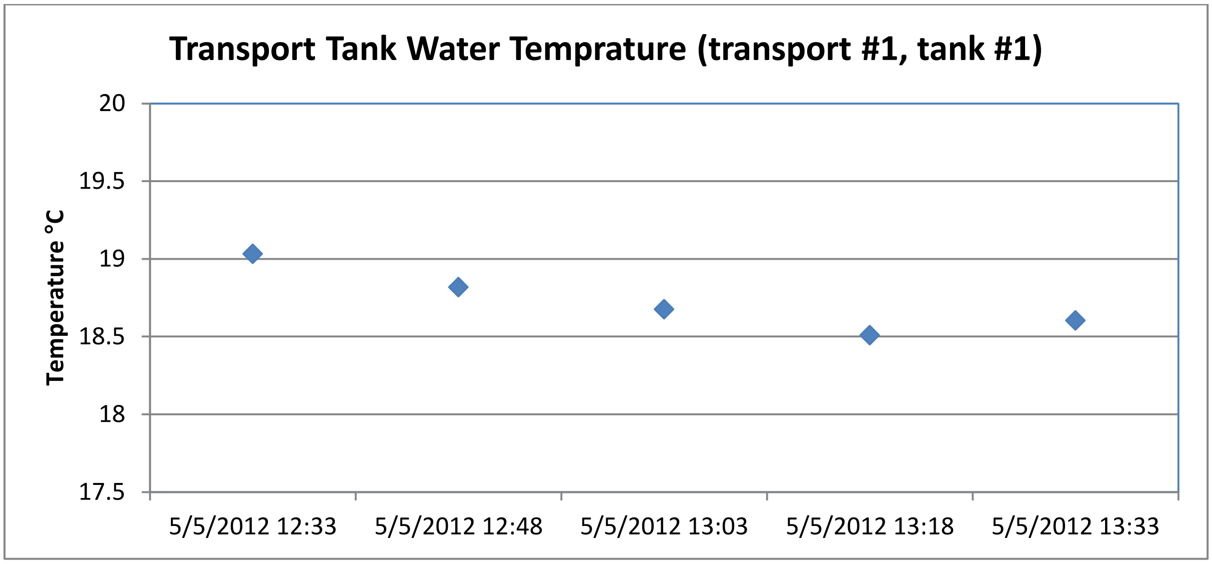


Figure A3-5. Transport tank water temperature during transport #1, tank #1 on May 5, 2012.

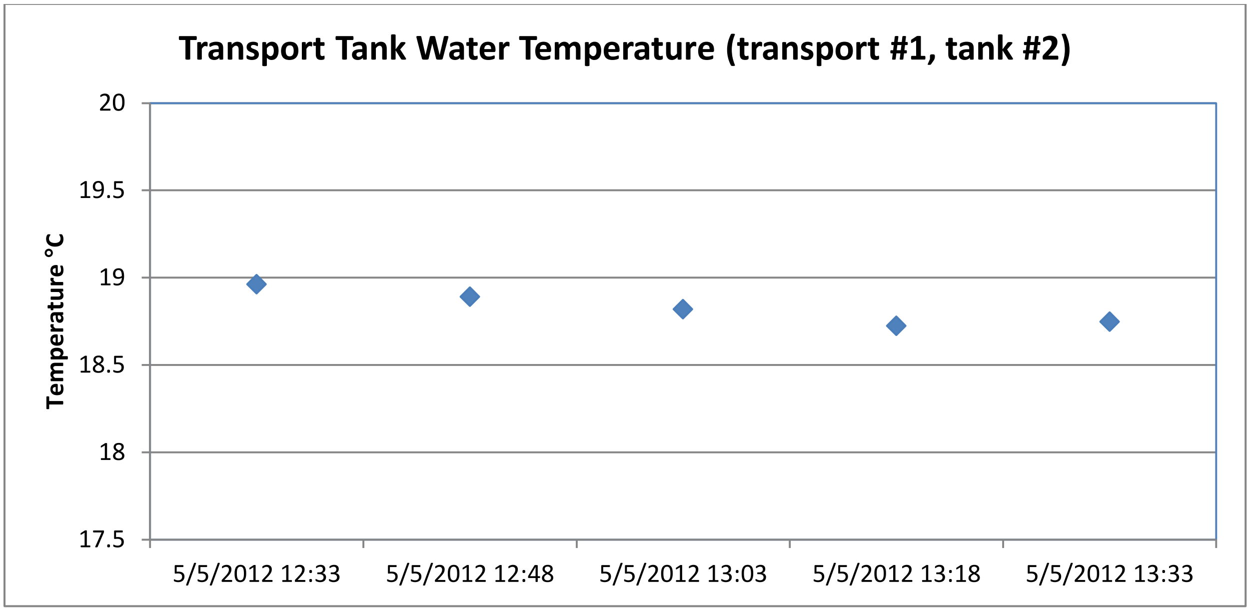


Figure A3-6. Transport tank water temperature during transport #1, tank #2 on May 5, 2012.

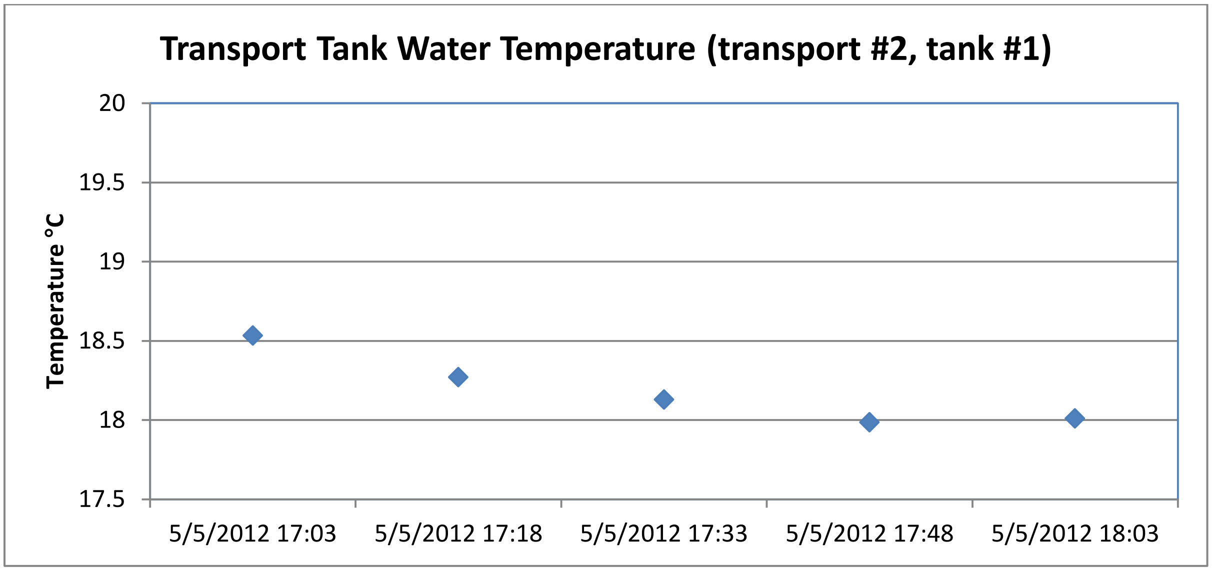


Figure A3-7. Transport tank water temperature during transport #2, tank #1 on May 5, 2012.

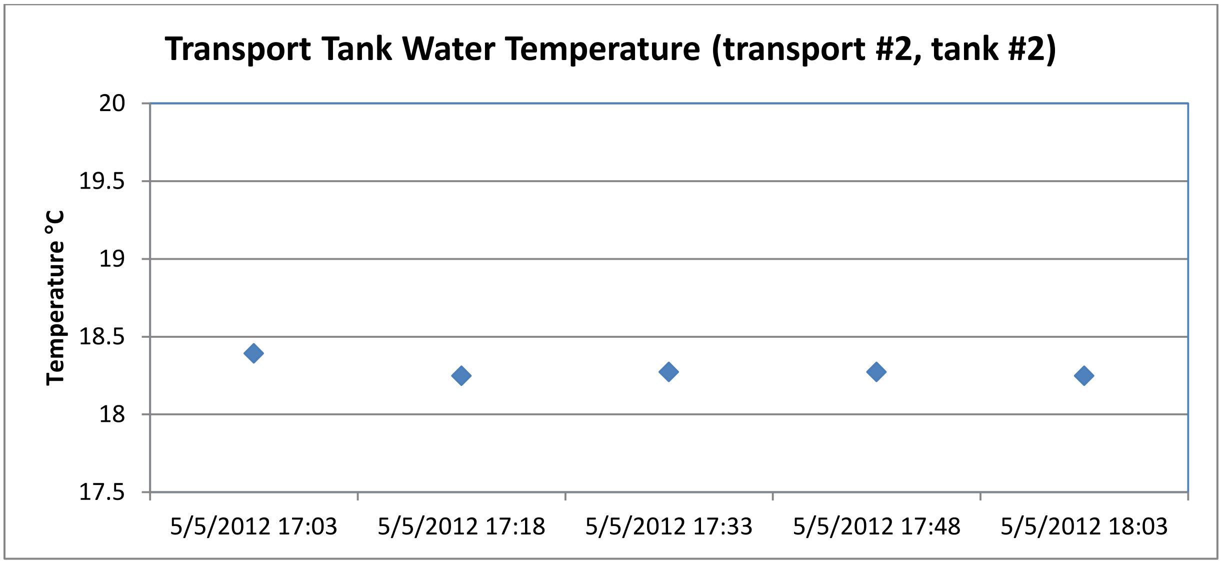


Figure A3-8. Transport tank water temperature during transport #2, tank #2 on May 5, 2012.

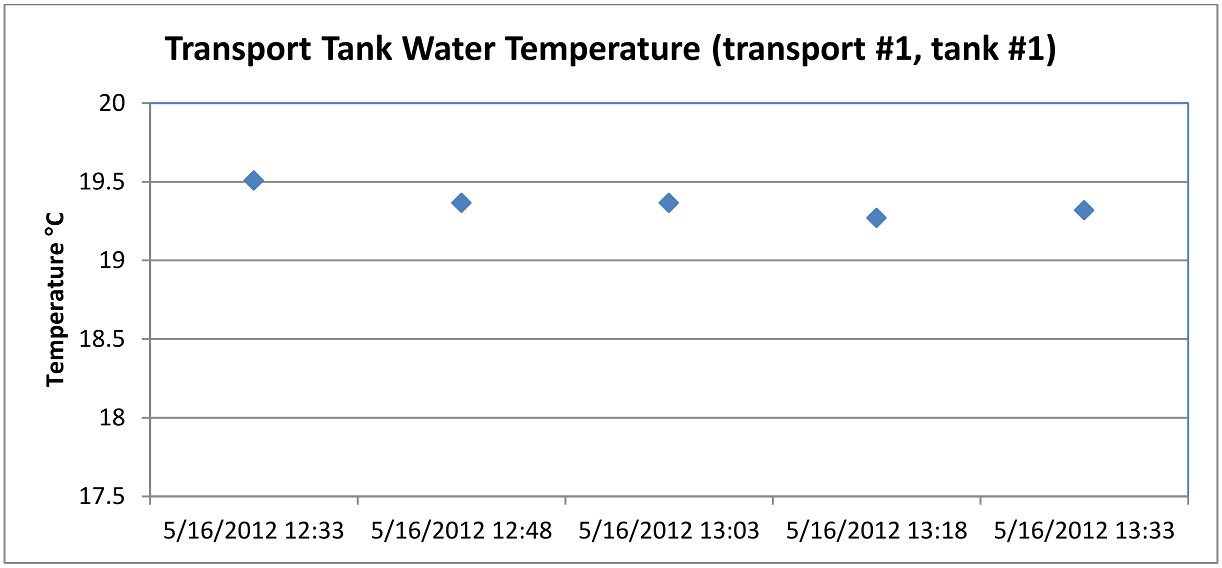


Figure A3-9. Transport tank water temperature during transport #1, tank #1 on May 16, 2012.

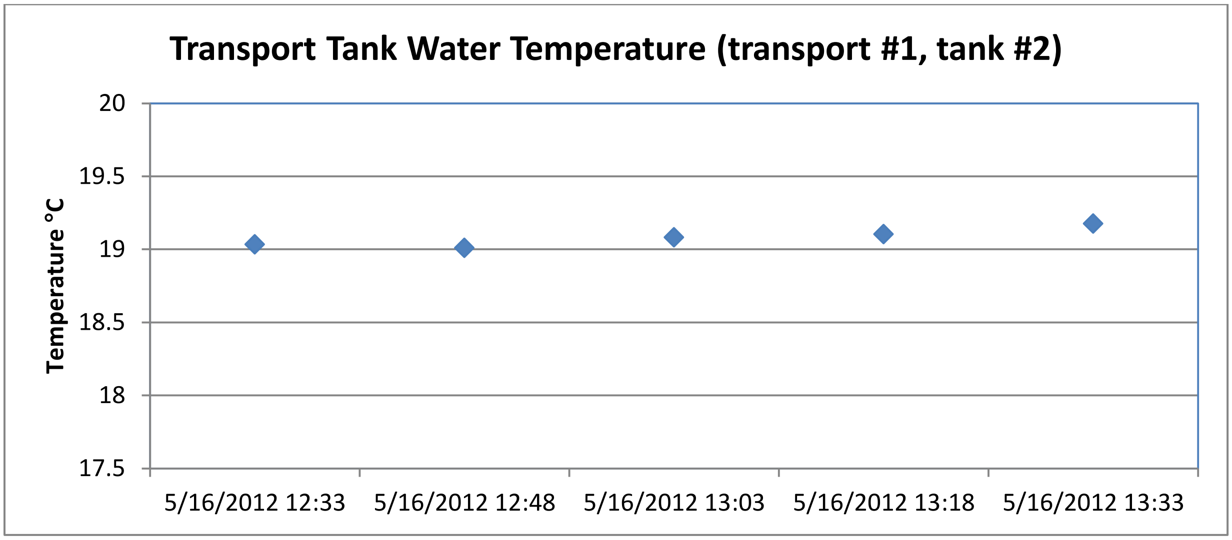


Figure A3-10. Transport tank water temperature during transport #1, tank #2 on May 16, 2012.

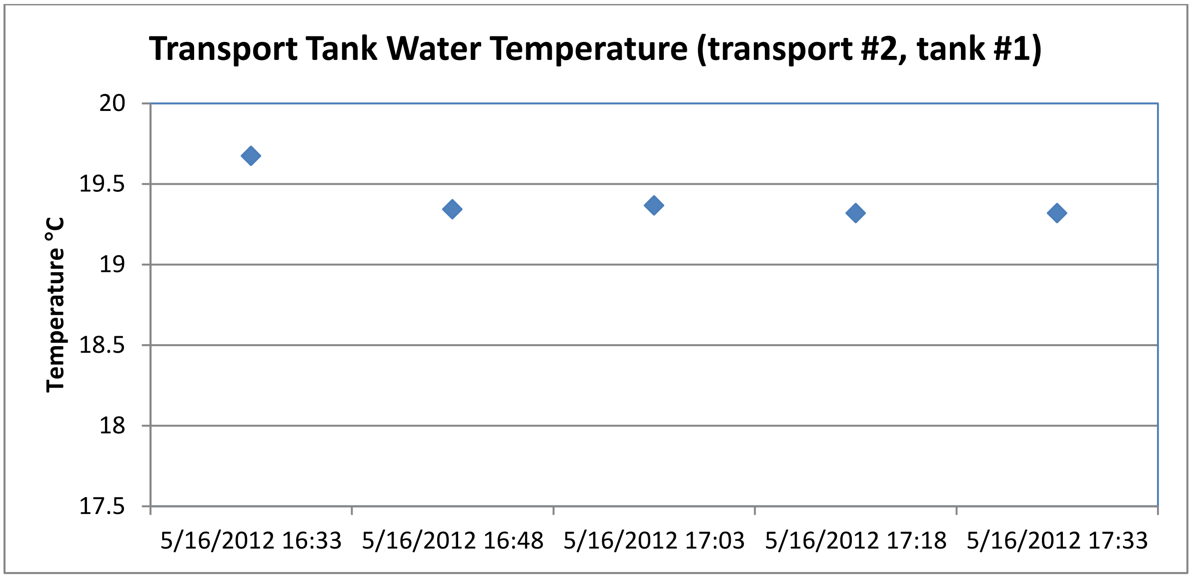


Figure A3-11. Transport tank water temperature during transport #2, tank #1 on May 16, 2012.

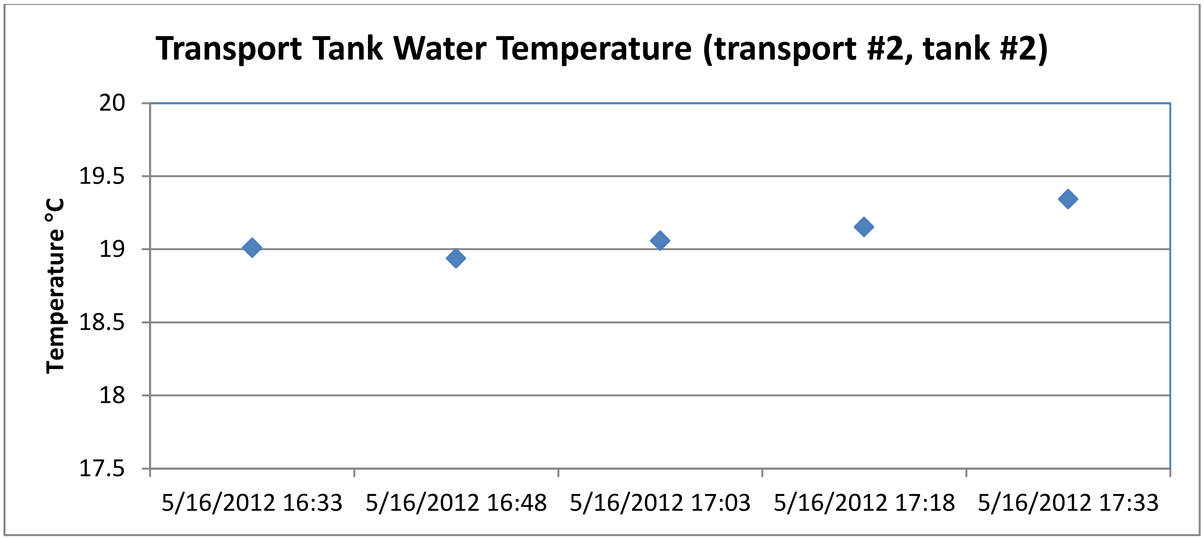


Figure A3-12. Transport tank water temperature during transport #2, tank#2 on May 16, 2012.

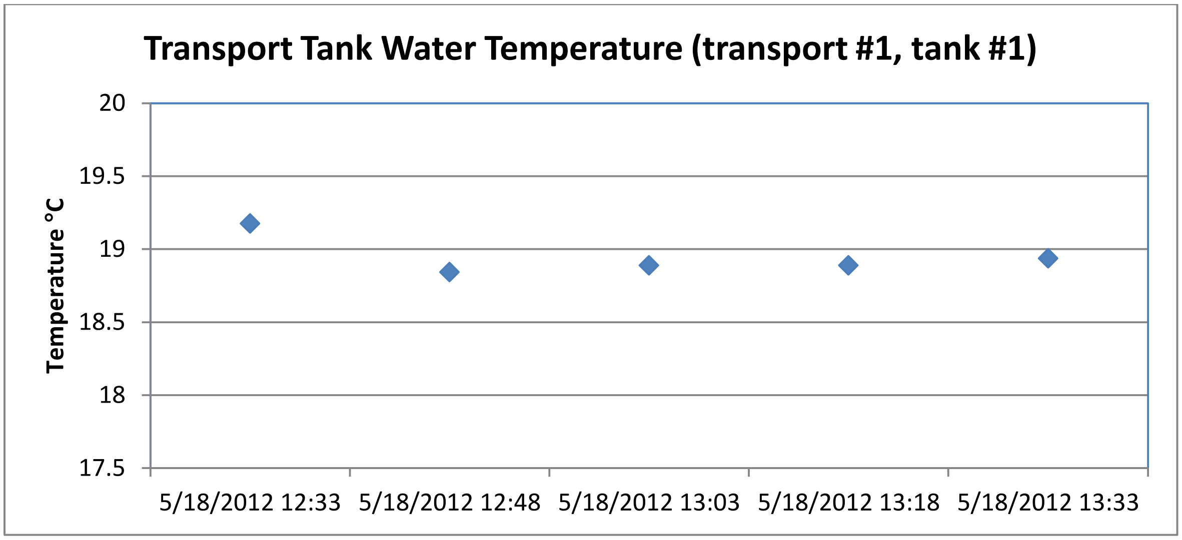


Figure A3-13. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

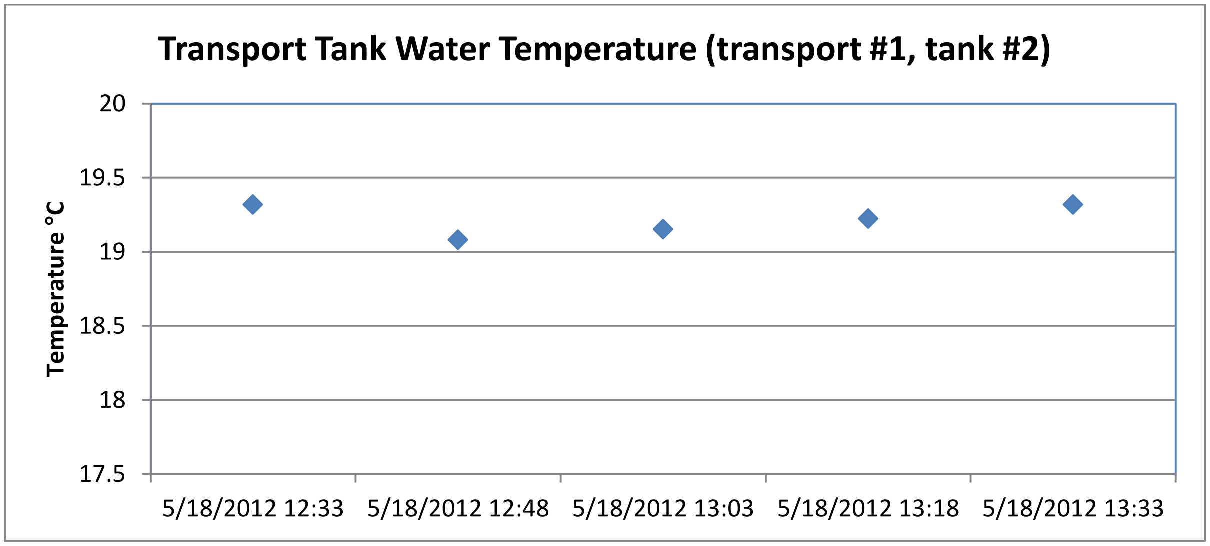


Figure A3-14. Transport tank water temperature during transport #1, tank #2 on May 18, 2012.

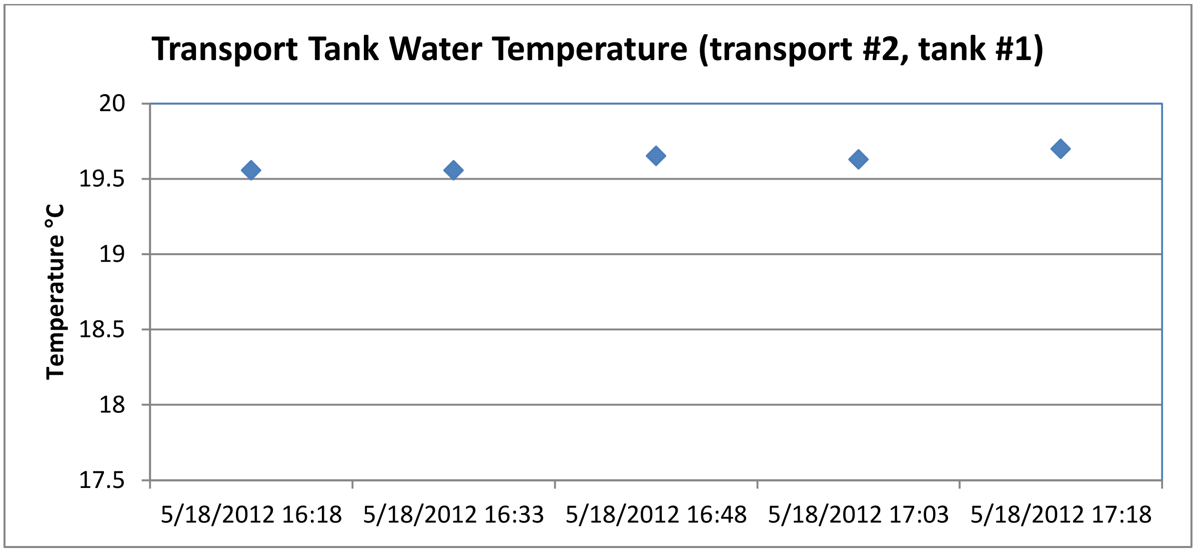


Figure A3-15. Transport tank water temperature during transport #1, tank #1 on May 18, 2012.

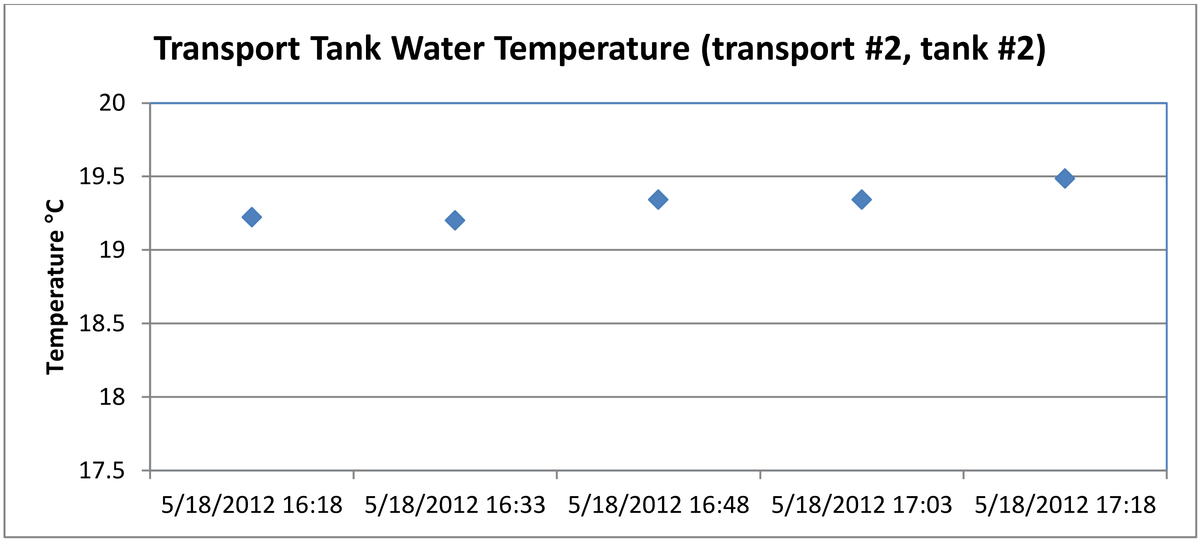


Figure A3-16. Transport tank water temperature during transport #2, tank #2 on May 18, 2012.

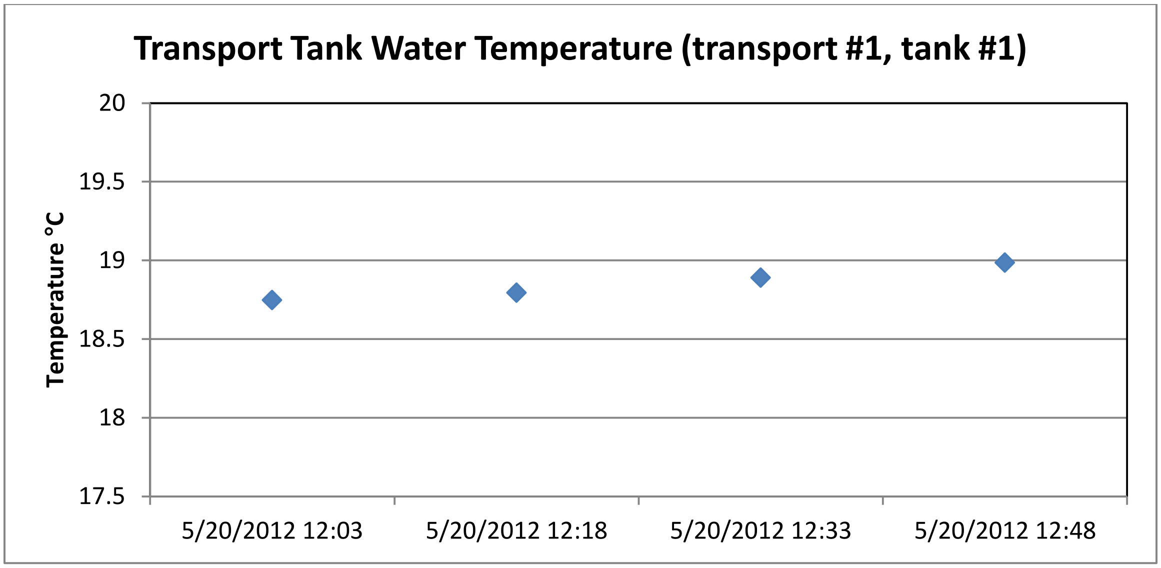


Figure A3-17. Transport tank water temperature during transport #1, tank #1 on May 20, 2012.

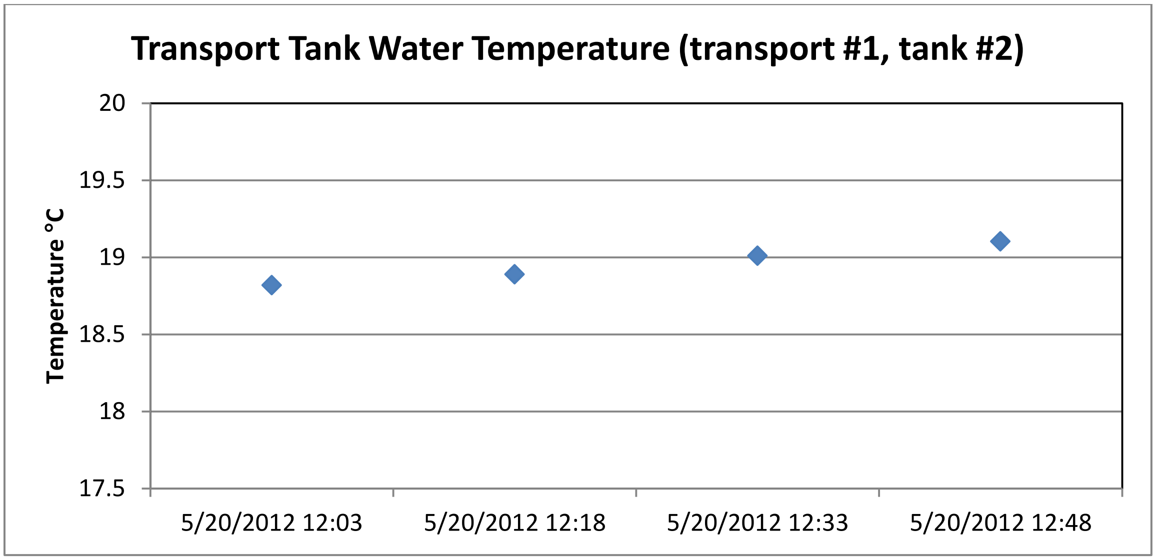


Figure A3-18. Transport tank water temperature during transport #1, tank #2 on May 20, 2012.

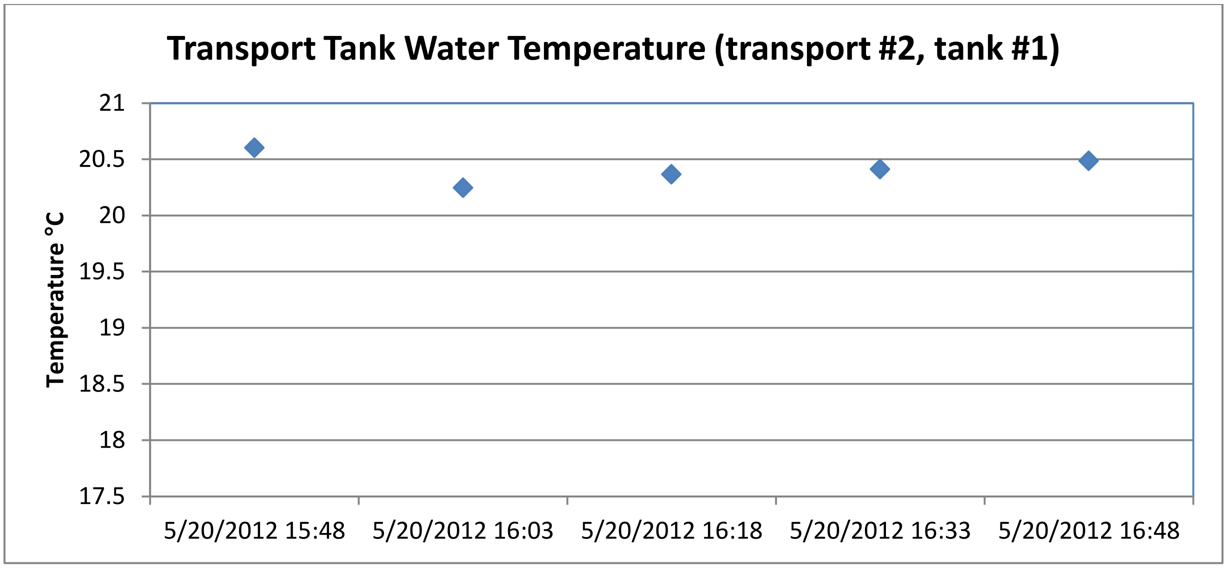


Figure A3-19. Transport tank water temperature during transport #2, tank #1 on May 20, 2012.

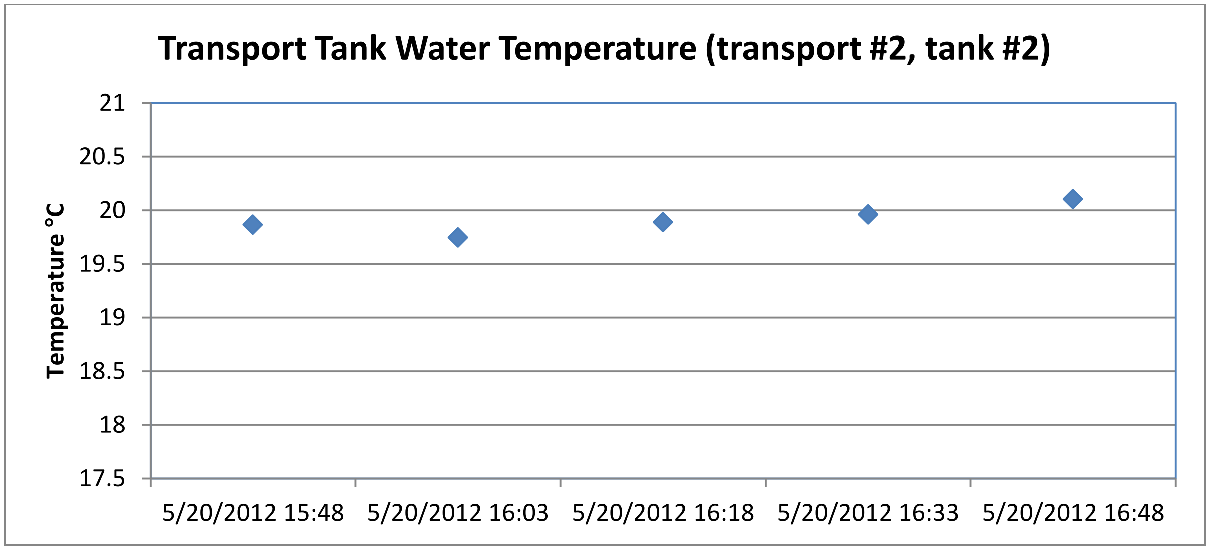


Figure A3-20. Transport tank water temperature during transport #2, tank #2 on May 20, 2012.

Appendix 4:

U.S. Fish & Wildlife Service

FY2012 Technical Report:
Pathogen screening and gill Na-K-ATPase assessment of juvenile Chinook salmon used in south delta acoustic tag studies.

J. Scott Foott

September 2012

U.S. DEPARTMENT OF THE INTERIOR
MARCH 3, 1849

US Fish and Wildlife Service

California-Nevada Fish Health Center

24411 Coleman Fish Hatchery Rd

Anderson, CA 96007

SUMMARY:
Pathogen testing was conducted on dummy-tag cohorts of acoustic tagged Merced River Hatchery juvenile Chinook salmon used in studies corresponding to 7 May and 23 May releases. No virus or *Renibacterium salmoninarum* infection was detected in the fish. The 23 May group had 37% prevalence of both suture abnormalities and A*eromonas – Pseudomonas* sp. infection however there was little correlation between the 2 findings. As in the past, *Tetracapsuloides bryosalmonae* infection was highly prevalent (≥ 97%) and the associated Proliferative Kidney Disease became more pronounced in the 23 May sample. No mortality occurred in the live cage populations at either sample date. Gill Na-K-ATPase data is not reported due to a problem with a key assay reagent. The combination of kidney impairment and poor suture condition of the 23 May salmon indicates that health of the two release groups was not equivalent.

Recommended citation for this report is:
Foott JS. 2012. FY2012 Technical Report: Pathogen screening and gill Na-K-ATPase assessment of juvenile Chinook salmon used in south delta acoustic tag studies. U.S. Fish & Wildlife Service California-Nevada Fish Health Center, Anderson, CA. Available: http://www.fws.gov/canvfhc/reports.asp.

INTRODUCTION

As a component of the 2012 Chinook salmon survival studies on reach-specific survival and distribution of migrating Chinook salmon in the San Joaquin River and delta, the CA-NV Fish Health Center conducted a general pathogen screening and smolt physiological assessment. The health and physiological condition of the study fish can help explain their performance and survival during the studies. Pathogen screenings during past VAMP studies using Merced River Hatchery (MRH) Chinook have regularly found infection with the myxozoan parasite *Tetracapsuloides bryosalmonae*, the causative agent of Proliferative Kidney Disease (PKD). This parasite has been shown to cause mortality in Chinook salmon with increased mortality and faster disease progression in fish at higher water temperatures (Ferguson 1981; Foott et al. 2007). The objectives of this project were to survey the juvenile Chinook salmon used for the studies for specific fish pathogens including *Tetracapsuloides bryosalmonae* and assess smolt development from gill Na^+ - K^+- ATPase activity.

METHODS

Prior to the 7 May and 23 May sample, 30 juvenile salmon were held within live cages for approximately 48h in the San Joaquin River at Durham Ferry. These fish were surgically-implanted with a dummy tag similar in size to the acoustic tag of release cohorts. Fish were evaluated for gill and skin condition (including suture) and tissues collected for assays. A grading scale ranging 0-3 was used to score inflammation or ulceration of tissue at the suture location and openness of the surgical incision (based on training session by Cramer Fish Sciences attended by J. Day).

> 0: Clean, completely closed and healed incision with taut suture. No external indication of pulling of tissue or inflammation.
>
> 1: Mostly closed, but not healed incision. Minor petechial hemorrhage.
>
> 2: Incision more than half open, and not healed. Inflammation present over more than half the suture area.
>
> 3: Incision completely open. Severely inflamed tissue surrounding and/or pushing out from incision site. Severe hemorrhaging extending equal to or greater than the length of the incision site. Suture may be lost entirely or embedded within inflamed tissue. Necrotic tissue visible.

Gill lamellae were collected first into SEI buffer and frozen on dry ice. Gill Na^+/K^+-Adenosine Triphosphatase (ATPase) activity was assayed by the method of McCormick (1993). Kidney was collected aseptically and inoculated onto brain-heart infusion agar. Bacterial isolates were screened by standard microscopic and biochemical tests (USFWS and AFS-FHS 2010). *Renibacterium salmoninarum* (bacteria that causes bacterial kidney disease) was screened by fluorescent antibody test (FAT) of kidney imprints. Three fish pooled samples of kidney and spleen were inoculated onto EPC and CHSE-214 cell lines held at 15°C for 21 d (USFWS and AFS-FHS 2010). The gill, liver, intestine and posterior kidney were rapidly removed from the fish and immediately fixed in Davidson's fixative, processed for 5 µm paraffin sections and stained with hematoxylin and eosin (Humason 1979). Infections of the myxozoan parasite, *T. bryosalmonae,* were rated for intensity of parasite infection and associated tissue inflammation (Proliferative Kidney Disease). Intensity of infection was rated as none (zero), low (<10), moderate (11-30) or high (>30) based on number of *T. bryosalmonae* trophozoites observed in the kidney section. Severity of kidney inflammation (PKD) was rated as normal, focal, multifocal or diffuse.

RESULTS AND DISCUSSION

All salmon were alive at the time of sample collection for both dates. Suture condition of 23 May fish was judged to be poor (11 of 30 fish with #2 or 3 ratings). Several sutures were observed on the pelvic girdle. All sutures in the 7 May group were intact and showed no hemorrhage.

The prevalence of systemic bacterial infection (A*eromonas – Pseudomonas* sp. (aquatic bacteria clade) was also 37% in the 23 May group however there was little association with suture hemorrhage (only 4 of 11 fish with hemorrhaged sutures had bacterial infections). No virus or *Renibacterium salmoninarum* infection was detected in the fish (Table 1). *Tetracapsuloides bryosalmonae* was seen in $\geq$ 97% of the kidney sections from both sample groups (Table 1).

Table A4-1. Prevalence of infection (number positive / total sample) for systemic bacteria (AP= *Aeromonas* or *Pseudomonas sp.)*, *R. salmoninarum* by direct fluorescent antibody test (Rsal-DFAT), virus, and *T. bryosalmonae* observed in kidney sections.

Sample date	Bacteria	Rsal - DFAT	Virus	*T.byrosalmonae*
7 May	1 / 30 (3) AP	0 / 29	0 / 10 (3p)	29 / 30 (97)
23 May	11 / 30 (37) AP	0 / 30	0 / 10 (3p)	30 / 30 (100)

The *T. bryosalmonae* infection was judged to be at an early state in the 7 May sample fish. High numbers of the parasites were seen in both groups however kidney inflammation was markedly worse in the 23 May fish (Fig. 1 and 2). Swollen kidneys and spleens were also observed in the 23 May group. Overt anemia (pale gills) was not seen in any salmon on either collection date. The systemic nature of the infection was reflected in the occurrence of the parasite in multiple tissues (spleen, visceral adipose capillaries, liver sinuses, and kidney) including blood vessels within the gill (Fig. 3). One 7 May gill section contained two *Ichthyophthirius multifilii* trophozoites however there was little tissue response. Liver hepatocytes showed little glycogen or fat content in both sample groups possibly reflective of low feed rate. No gill Na-K-ATPase data is reported due to abnormal kinetic profiles. The ADP standard curve was normal which indicates that the majority of enzymes and co-factors were functional. The pH and magnesium conditions were also normal for the assay. We suspect that the recently purchased Sigma Chemical Adenosine TriPhosphate was faulty as this nucleotide is the substrate for the ouabain-sensitive gill Na-K-ATPase enzyme.

The advanced proliferative kidney disease, increased prevalence of systemic bacteria, and hemorrhaged sutures observed in the 23 May salmon suggests that the two release groups were not equivalent in health condition. The impact on immediate (1-3 days) post-release survival of these impairments on 23 May salmon is likely to be limited however longer term survival and swimming performance could be reduced. Past work on PKD effects on smolt performance have shown that severe kidney inflammation and anemia are associated with impaired swimming and saltwater adaptation (Foott et al. 2007 and 2008).

Figure A4-1. Prevalence of *T. byrosalmonae* intensity ratings for Chinook salmon sampled on 7 and 23 May. Intensity of *T. byrosalmonae* infection observed in kidney section rated as none (0), low (<10), moderate (11-30), and high (>30). Numbers over ratings are prevalence data. Majority of parasites observed in the 7 May kidneys were found in the sinuses indicating an early stage of infection.

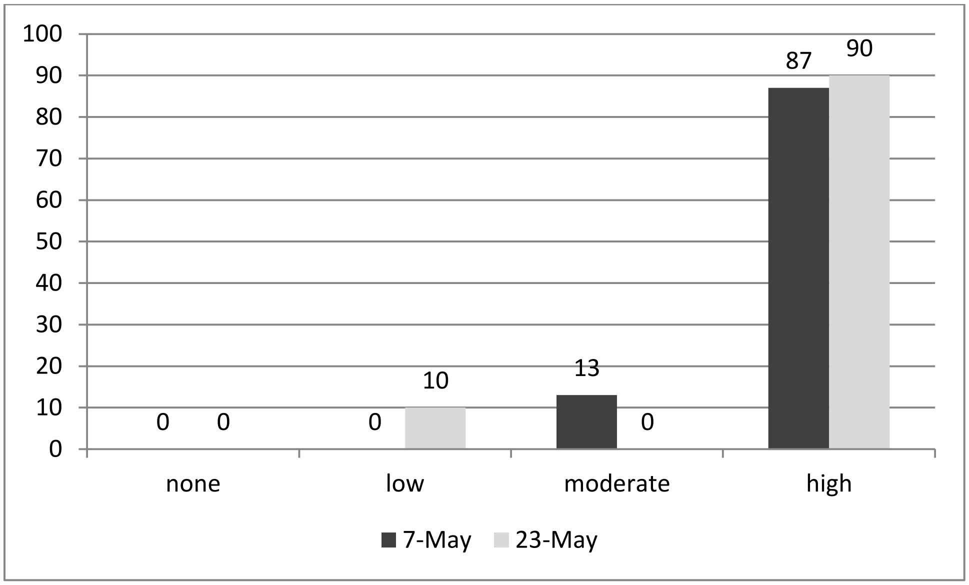


Figure A4-2. Prevalence of proliferative kidney disease ratings for Chinook salmon sampled on 7 and 23 May. Severity of kidney inflammation rated as normal, focal, multifocal, or diffuse. Numbers over ratings are prevalence data.

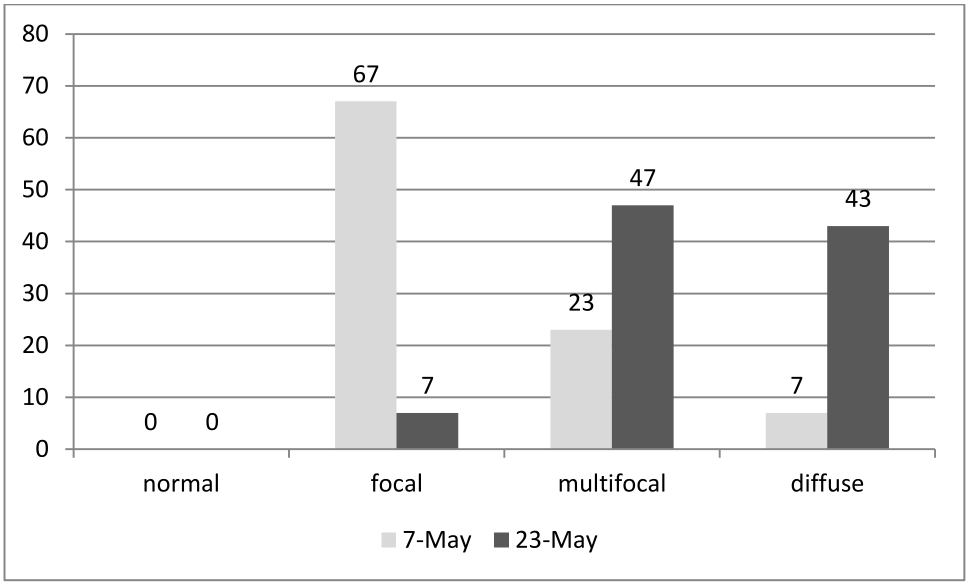


Figure A4-3. Micrograph of *T. byrosalmonae* (arrow) within gill blood vessel.

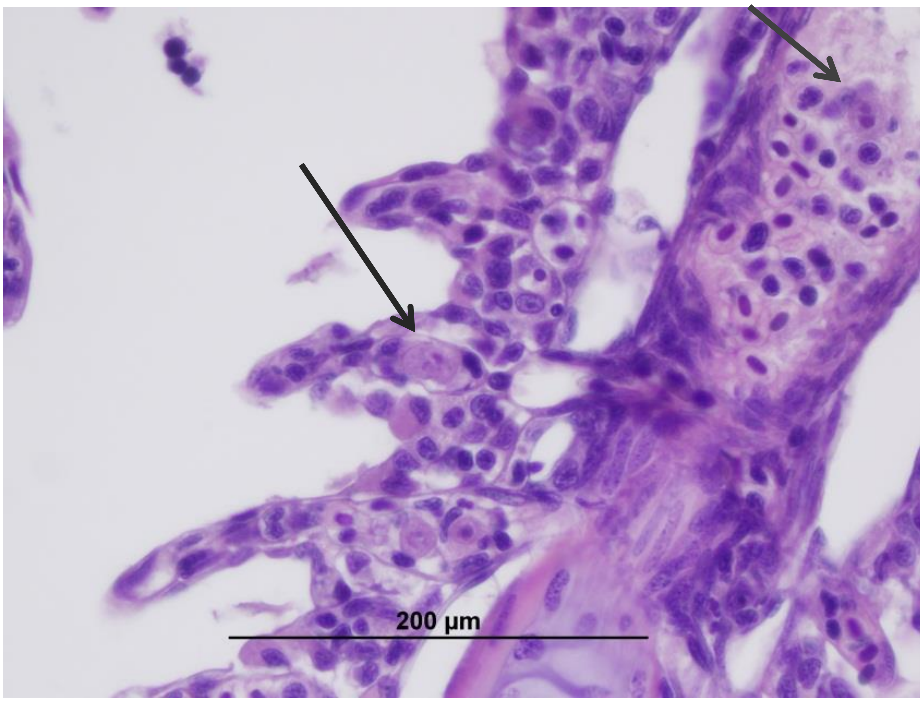
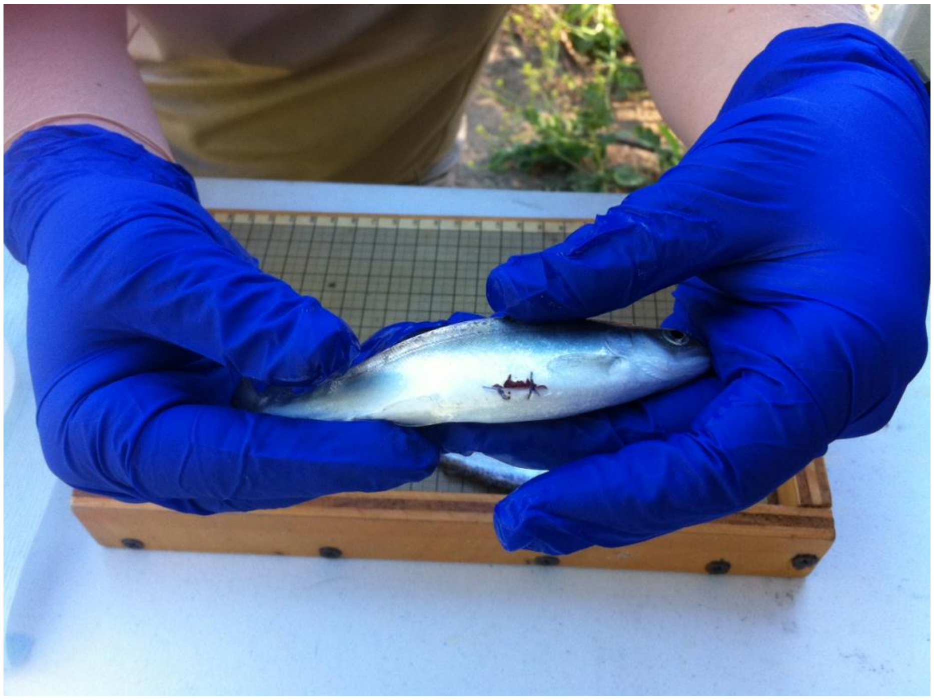


Figure A4-4. Suture condition rating 2 (exposed edge with hemorrhage) in 23 May salmon.



ACKNOWLEDGEMENTS
Ken Nichols, Anne Bolick, Kim True, and Julie Day with the FHC performed both field and laboratory work on this project and biologists with the USFWS Stockton FWO provided access to the live cages at Durham Ferry.

REFERENCES

Foott JS and R Stone. 2008. FY 2008 Investigational report: Evaluation of sonic tagged Chinook juveniles used in the 2008 VAMP study for delayed mortality and saltwater survival – effects of Proliferative Kidney Disease. US Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. Available: http://www.fws.gov/canvfhc/reports.asp (September 2010).

Foott JS, R Stone and K Nichols. 2007. Proliferative Kidney Disease (*Tetracapsuloides bryosalmonae*) in Merced River Hatchery juvenile Chinook salmon: mortality and performance impairment in 2005 smolts. California Fish and Game 93: 57-76.

Ferguson, HW. 1981. The effects of water temperature on the development of Proliferative Kidney Disease in rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Disease 4: 175-177.

Humason GL. 1979. Animal Tissue Techniques, 4th edition. W H Freeman and Co., San Francisco.

McCormick SD. 1993. Methods for Nonlethal Gill Biopsy and Measurement of Na^+, K^+-ATPase Activity. Canadian Journal of Fisheries and Aquatic Sciences. 50: 656-658.

USFWS and AFS-FHS (U.S. Fish and Wildlife Service and American Fisheries Society-Fish Health Section). 2010. Standard procedures for aquatic animal health inspections. *In* AFS-FHS. FHS blue book: suggested procedures for the detection and identification of certain finfish and shellfish pathogens, 2010 edition. AFS-FHS, Bethesda, Maryland.

Appendix 5. Survival Model Parameters

Table A5-1. Definitions of parameters used in the release-recapture survival model; full or reduced model, or both, is specified. Parameters used only in particular submodels are noted.

Parameter	Model	Definition
S_{A2}	Both	Probability of survival from Durham Ferry Downstream (DFD) to Banta Carbona (BCA)
S_{A3}	Both	Probability of survival from Banta Carbona (BCA) to Mossdale (MOS)
S_{A4}	Both	Probability of survival from Mossdale (MOS) to Lathrop (SJL) or Old River East (ORE)
S_{A5}	Both	Probability of survival from Lathrop (SJL) to Garwood Bridge (SJG)
S_{A6}	Both	Probability of survival from Garwood Bridge (SJG) to Navy Drive Bridge (SJNB)
S_{A7}	Both	Probability of survival from Navy Drive Bridge (SJNB) to MacDonald Island (MAC) or Turner Cut (TCE/TCW)
$S_{A7,G2}$	Both	Overall survival from Navy Drive Bridge (SJNB) to Chipps Island (MAE/MAW) (derived from Submodel I)
$S_{A8,G2}$	Both	Overall survival from MacDonald Island (MAC) to Chipps Island (MAE/MAW) (Submodel I)
S_{B1}	Full	Probability of survival from Old River East (ORE) to Old River South (ORS)
$S_{B2,G2}$	Reduced	Overall survival from Old River South (ORS) to Chipps Island (MAE/MAW) (derived from Submodel I)
$S_{F1,G2}$	Both	Overall survival from Turner Cut (TCE/TCW) to Chipps Island (MAE/MAW) (Submodel I)
$\phi_{A1,A0}$	Full	Joint probability of moving from Durham Ferry release site upstream toward DFU, and surviving to DFU
$\phi_{A1,A2}$	Both	Joint probability of moving from Durham Ferry release site downstream toward DFD, and surviving to DFD
$\phi_{A1,A3}$	Both	Joint probability of moving from Durham Ferry release site downstream toward BCA, and surviving to BCA; = $\phi_{A1,A2}\ S_{A2}$
$\phi_{A8,A9}$	Both	Joint probability of moving from MAC toward MFE/MFW, and surviving from MAC to MFE/MFW (Submodel II)
$\phi_{A8,B3}$	Full	Joint probability of moving from MAC toward OR4, and surviving from MAC to OR4 (Submodel II)
$\phi_{A8,C2}$	Full	Joint probability of moving from MAC toward MR4, and surviving from MAC to MR4 (Submodel II)
$\phi_{A8,GH}$	Full	Joint probability of moving from MAC directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving JPE/JPW or FRE/FRW (Submodel II)
$\phi_{A8,G1}$	Reduced	Joint probability of moving from MAC toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A8,GH}\psi_{G1(A)}$
$\phi_{A9,B3}$	Full	Joint probability of moving from MFE/MFW toward OR4, and surviving from MFE/MFW to OR4 (Submodel II)
$\phi_{A9,C2}$	Full	Joint probability of moving from MFE/MFW toward MR4, and surviving from MFE/MFW to MR4 (Submodel II)
$\phi_{A9,GH}$	Full	Joint probability of moving from MFE/MFW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving to JPE/JPW or FRE/FRW (Submodel II)
$\phi_{A9,G1}$	Reduced	Joint probability of moving from MFE/MFW toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{A9,GH}\psi_{G1(A)}$
$\phi_{B1,B2}$	Reduced	Joint probability of moving from ORE toward ORS, and surviving from ORE to ORS; = $S_{B1}\psi_{B2}$
$\phi_{B2,B3}$	Full	Joint probability of moving from ORS toward OR4, and surviving from ORS to OR4
$\phi_{B2,C2}$	Full	Joint probability of moving from ORS toward MR4, and surviving from ORS to MR4
$\phi_{B2,D1}$	Full	Joint probability of moving from ORS toward RGU, and surviving from ORS to RGU
$\phi_{B2,E1}$	Full	Joint probability of moving from ORS toward CVP, and surviving from ORS to CVP
$\phi_{B3,D1}$	Full	Joint probability of moving from OR4 toward RGU and surviving from OR4 to RGU conditional on coming from lower San Joaquin River (Submodel II)

Table A5-1. (Continued)

Parameter	Model	Definition
$\phi_{B3,E1}$	Full	Joint probability of moving from OR4 toward CVP, and surviving from OR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{B3,GH(A)}$	Full	Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel II [route A])
$\phi_{B3,GH(B)}$	Full	Joint probability of moving from OR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from OR4 to JPE/JPW or FRE/FRW (Submodel I [route B])
$\phi_{C1,B3}$	Full	Joint probability of moving from MRH toward OR4, and surviving from MRH to OR4
$\phi_{C1,C2}$	Full	Joint probability of moving from MRH toward MR4, and surviving from MRH to MR4
$\phi_{C1,D1}$	Full	Joint probability of moving from MRH toward RGU, and surviving from MRH to RGU
$\phi_{C1,E1}$	Full	Joint probability of moving from MRH toward CVP, and surviving from MRH to CVP
$\phi_{C2,D1}$	Full	Joint probability of moving from MR4 toward RGU and surviving from MR4 to RGU conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{C2,E1}$	Full	Joint probability of moving from MR4 toward CVP, and surviving from MR4 to CVP, conditional on coming from lower San Joaquin River (Submodel II)
$\phi_{C2,GH(A)}$	Full	Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel II [route A])
$\phi_{C2,GH(B)}$	Full	Joint probability of moving from MR4 toward Jersey Point (JPE/JPW) or False River (FRE/FRW), and surviving from MR4 to JPE/JPW or FRE/FRW (Submodel I [route B])
$\phi_{D1,D2}$	Full	Joint probability of moving from RGU toward RGD, and surviving from RGU to RGD (equated between submodels I and II)
$\phi_{D2,G2}$	Full	Joint probability of moving from RGD toward Chipps Island (MAE/MAW) and surviving from RGU to MAE/MAW (equated between submodels I and II)
$\phi_{E1,E2}$	Full	Joint probability of moving from CVP toward CVPtank, and surviving from CVP to CVPtank (equated between submodels I and II)
$\phi_{E2,G2}$	Full	Joint probability of moving from CVPtank toward Chipps Island (MAE/MAW) and surviving from CVPtank to MAE/MAW (equated between submodels I and II)
$\phi_{F1,B3}$	Full	Joint probability of moving from TCE/TCW toward OR4, and surviving from TCE/TCW to OR4 (Submodel II)
$\phi_{F1,C2}$	Full	Joint probability of moving from TCE/TCW toward MR4, and surviving from TCE/TCW to MR4 (Submodel II)
$\phi_{F1,GH}$	Full	Joint probability of moving from TCE/TCW directly toward Jersey Point (JPE/JPW) or False River (FRE/FRW) without passing Highway 4 sites, and surviving to JPE/JPW or FRE/FRW (Submodel II)
$\phi_{F1,G1}$	Reduced	Joint probability of moving from TCE/TCW toward Jersey Point (JPE/JPW) and surviving to JPE/JPW (Submodel II); = $\phi_{F1,GH}\psi_{G1(A)}$
$\phi_{G1,G2(A)}$	Both	Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel II [route A])
$\phi_{G1,G2(B)}$	Full	Joint probability of moving from JPE/JPW toward Chipps Island (MAE/MAW), and surviving to MAE/MAW (Submodel I [route B])
ψ_{A1}	Both	Probability of remaining in the San Joaquin River at the head of Old River; = 1 - ψ_{B1}
ψ_{A2}	Both	Probability of remaining in the San Joaquin River at the junction with Turner Cut; = 1 - ψ_{F2}
ψ_{B1}	Both	Probability of entering Old River at the head of Old River; = 1 - ψ_{A1}
ψ_{B2}	Full	Probability of remaining in Old River at the head of Middle River; = 1 - ψ_{C2}
ψ_{C2}	Full	Probability of entering Middle River at the head of Middle River; = 1 - ψ_{B2}
ψ_{F2}	Both	Probability of entering Turner Cut at the junction with the San Joaquin River; = 1 - ψ_{A2}
$\psi_{G1(A)}$	Full	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{H1(A)}$
$\psi_{G1(B)}$	Full	Probability of moving downriver in the San Joaquin River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{H1(B)}$

Table A5-1. (Continued)

Parameter	Model	Definition
$\psi_{H1(A)}$	Full	Probability of entering False River at the Jersey Point/False River junction (Submodel II [route A]); = 1 - $\psi_{G1(A)}$
$\psi_{H1(B)}$	Full	Probability of entering False River at the Jersey Point/False River junction (Submodel I [route B]); = 1 - $\psi_{G1(B)}$
P_{A0a}	Full	Conditional probability of detection at DFU1
P_{A0b}	Full	Conditional probability of detection at DFU2
P_{A2a}	Both	Conditional probability of detection at DFD1
P_{A2b}	Both	Conditional probability of detection at DFD2
P_{A2}	Both	Conditional probability of detection at DFD (either DFD1 or DFD2)
P_{A3}	Both	Conditional probability of detection at BCA
P_{A4}	Both	Conditional probability of detection at MOS
P_{A5}	Both	Conditional probability of detection at SJL
P_{A6}	Both	Conditional probability of detection at SJG
P_{A7}	Both	Conditional probability of detection at SJNB
P_{A8a}	Both	Conditional probability of detection at MACU
P_{A8b}	Both	Conditional probability of detection at MACD
P_{A8}	Both	Conditional probability of detection at MAC (either MACU or MACD)
P_{A9a}	Both	Conditional probability of detection at MFE
P_{A9b}	Both	Conditional probability of detection at MFW
P_{A9}	Both	Conditional probability of detection at MFE or MFW
P_{B1}	Both	Conditional probability of detection at ORE
P_{B2a}	Both	Conditional probability of detection at ORSU
P_{B2b}	Both	Conditional probability of detection at ORSD
P_{B2}	Both	Conditional probability of detection at ORS (either ORSU or ORSD)
P_{B3a}	Full	Conditional probability of detection at OR4U
P_{B3b}	Full	Conditional probability of detection at OR4D
P_{C1}	Full	Conditional probability of detection at MRH
P_{C2a}	Full	Conditional probability of detection at MR4U
P_{C2b}	Full	Conditional probability of detection at MR4D
P_{D1}	Full	Conditional probability of detection at RGU (either RGU1 or RGU2)
P_{D2a}	Full	Conditional probability of detection at RGD1
P_{D2b}	Full	Conditional probability of detection at RGD2
P_{E1}	Full	Conditional probability of detection at CVP
P_{E2}	Full	Conditional probability of detection at CVPtank
P_{F1a}	Both	Conditional probability of detection at TCE
P_{F1b}	Both	Conditional probability of detection at TCW
P_{F1}	Both	Conditional probability of detection at TCE/TCW
P_{G1a}	Both	Conditional probability of detection at JPE
P_{G1b}	Both	Conditional probability of detection at JPW

Table A5-1. (Continued)

Parameter	Model	Definition
P_{G1}	Both	Conditional probability of detection at JPE/JPW
P_{G2a}	Both	Conditional probability of detection at MAE
P_{G2b}	Both	Conditional probability of detection at MAW
P_{G2}	Both	Conditional probability of detection at MAE/MAW
P_{H1a}	Full	Conditional probability of detection at FRW
P_{H1b}	Full	Conditional probability of detection at FRE

Table A5-2. Parameter estimates (standard errors in parentheses) from reduced survival model for tagged juvenile Chinook Salmon released in 2012, excluding predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled release groups. Some parameters were not estimable because of sparse data.

	Release Occasion		
Parameter	1	2	Population Estimate
S_{A2}	0.90 (0.06)	0.63 (0.04)	0.79 (0.04)
S_{A3}	0.78 (0.04)	0.59 (0.03)	0.65 (0.03)
S_{A4}	0.98 (0.01)	0.89 (0.02)	0.95 (0.01)
S_{A5}	0.81 (0.02)	0.48 (0.04)	0.69 (0.02)
S_{A6}	0.85 (0.03)	0.73 (0.08)	0.82 (0.03)
S_{A7}	0.49 (0.04)	0.23 (0.06)	0.44 (0.03)
$S_{A7,G2}$	0.07 (0.02)	0	0.06 (0.01)
$S_{A8,G2}$	0.16 (0.04)	0	0.14 (0.04)
$S_{B2,G2}$	0.17 (0.15)	0	0.13 (0.12)
$S_{F1,G2}$	0	0	0
$\phi_{A1,A2}$	0.89 (0.05)	1.00 (0.06)	0.97 (0.04)
$\phi_{A1,A3}$	0.80 (0.04)	0.63 (0.03)	0.76 (0.02)
$\phi_{A8,A9}$	0.44 (0.05)	0.59 (0.16)	0.45 (0.05)
$\phi_{A8,G1}$	0.08 (0.03)	0	0.07 (0.03)
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.46 (0.08)
$\phi_{B1,B2}$	1	0.67 (0.27)	0.89 (0.10)
$\phi_{F1,G1}$	0	0	0
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.52 (0.01)
ψ_{A1}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{A2}	0.89 (0.03)	0.84 (0.11)	0.89 (0.03)
ψ_{B1}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.11 (0.03)	0.16 (0.11)	0.11 (0.03)
P_{A2a}	[pooled]	[pooled]	[pooled]
P_{A2b}	[pooled]	[pooled]	[pooled]
P_{A2}	0.23 (0.02)	0.33 (0.03)	0.27 (0.02)
P_{A3}	0.31 (0.03)	0.80 (0.03)	0.49 (0.02)
P_{A4}	1.00 (< 0.01)	1	1.00 (< 0.01)
P_{A5}	1	1	1
P_{A6}	1	1	1
P_{A7}	0.94 (0.02)	0.92 (0.08)	0.94 (0.02)
P_{A8a}	[pooled]	0.88 (0.12)	0.94 (0.02)
P_{A8b}	[pooled]	0.78 (0.14)	0.90 (0.03)
P_{A8}	1	0.97 (0.03)	0.99 (< 0.01)
P_{A9a}	1	1	1
P_{A9b}	1	1	1
P_{A9}	1	1	1
P_{B1}	1	1	1

Table A5-2. (Continued)

Parameter	Release Occasion 1	Release Occasion 2	Population Estimate
P_{B2a}	1	[pooled]	1
P_{B2b}	0.83 (0.15)	[pooled]	1.00 (< 0.01)
P_{B2}	1	1	1
P_{F1a}	0.88 (0.12)	1	0.90 (0.09)
P_{F1b}	0.78 (0.14)	1	0.82 (0.12)
P_{F1}	0.97 (0.03)	1	0.98 (0.02)
P_{G1a}	[pooled]	1	0.96 (0.04)
P_{G1b}	[pooled]	1	0.92 (0.05)
P_{G1}	0.93 (0.07)	1	1.00 (< 0.01)
P_{G2a}	1		1
P_{G2b}	1		1
P_{G2}	1		1

Table A5-3. Parameter estimates (standard errors in parentheses) from reduced survival model for tagged juvenile Chinook Salmon released in 2012, including predator-type detections. Parameters without standard errors were estimated at fixed values in the model. Population-level estimates are from pooled release groups. Some parameters were not estimable because of sparse data.

	Release Occasion		
Parameter	1	2	Population Estimate
S_{A2}	0.87 (0.06)	0.62 (0.04)	0.77 (0.04)
S_{A3}	0.77 (0.04)	0.59 (0.03)	0.65 (0.02)
S_{A4}	0.98 (0.01)	0.90 (0.02)	0.95 (0.01)
S_{A5}	0.81 (0.02)	0.49 (0.04)	0.70 (0.02)
S_{A6}	0.86 (0.03)	0.73 (0.07)	0.82 (0.03)
S_{A7}	0.50 (0.04)	0.26 (0.06)	0.44 (0.03)
$S_{A7,G2}$	0.07 (0.02)	0	0.06 (0.01)
$S_{A8,G2}$	0.16 (0.04)	0	0.14 (0.03)
$S_{B2,G2}$	0.17 (0.15)	0	0.11 (0.11)
$S_{F1,G2}$	0	0	0
$\phi_{A1,A2}$	0.93 (0.05)	1.03 (0.06)	1.00 (0.04)
$\phi_{A1,A3}$	0.81 (0.04)	0.64 (0.03)	0.77 (0.03)
$\phi_{A8,A9}$	0.43 (0.05)	0.49 (0.14)	0.44 (0.05)
$\phi_{A8,G1}$	0.08 (0.03)	0	0.07 (0.03)
$\phi_{A9,G1}$	0.49 (0.09)	0.33 (0.19)	0.46 (0.08)
$\phi_{B1,B2}$	1	1	1
$\phi_{F1,G1}$	0	0	0
$\phi_{G1,G2(A)}$	0.54 (0.10)	0	0.52 (0.10)
ψ_{A1}	0.98 (0.01)	0.98 (0.01)	0.98 (0.01)
ψ_{A2}	0.88 (0.03)	0.86 (0.09)	0.88 (0.03)
ψ_{B1}	0.02 (0.01)	0.02 (0.01)	0.02 (0.01)
ψ_{F2}	0.12 (0.03)	0.14 (0.09)	0.12 (0.03)
P_{A2a}	[pooled]	[pooled]	[pooled]
P_{A2b}	[pooled]	[pooled]	[pooled]
P_{A2}	0.23 (0.02)	0.34 (0.03)	0.28 (0.02)
P_{A3}	0.31 (0.03)	0.80 (0.03)	0.49 (0.02)
P_{A4}	1.00 (< 0.01)	1	1.00 (< 0.01)
P_{A5}	1	1	1
P_{A6}	1	1	1
P_{A7}	0.94 (0.02)	0.93 (0.07)	0.94 (0.02)
P_{A8a}	[pooled]	0.87 (0.12)	[pooled]
P_{A8b}	[pooled]	0.64 (0.15)	[pooled]
P_{A8}	1	0.95 (0.05)	1
P_{A9a}	1	1	1
P_{A9b}	1	1	1
P_{A9}	1	1	1
P_{B1}	1	1	1

Table A5-3. (Continued)

Parameter	Release Occasion		Population Estimate
	1	2	
P_{B2a}	1	[pooled]	1
P_{B2b}	0.83 (0.15)	[pooled]	0.56 (0.17)
P_{B2}	1	1	1
P_{F1a}	0.86 (0.13)	1	0.89 (0.10)
P_{F1b}	0.60 (0.15)	1	0.67 (0.14)
P_{F1}	0.94 (0.06)	1	0.96 (0.04)
P_{G1a}	[pooled]	1	0.96 (0.04)
P_{G1b}	[pooled]	1	0.92 (0.05)
P_{G1}	0.93 (0.07)	1	1.00 (< 0.01)
P_{G2a}	1		1
P_{G2b}	1		1
P_{G2}	1		1

Appendix B. Errata from 2011 VAMP Report

In Table H-2 (page 283) of the 2011 VAMP report (SJRGA 2013), the definition for parameter $\phi_{A8,G2}$ should read "Overall survival from STN to Chipps Island (CHPE/CHPW)."

Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010

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California Department of Fish and Game

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NOTE TO READERS

Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010 presents important data for the improvement of Central Valley salmon management. Until 2007, only experimental releases of fall-run Chinook salmon from Central Valley hatcheries were marked and coded-wire tagged (low, inconsistent numbers), resulting in a lack of data for harvest management, evaluation of hatchery rearing and release practices, hatchery impacts to natural-origin fish, and the success of habitat improvement programs.

The Central Valley Constant Fractional Marking Program (CFM) was initiated in 2007 to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed in the Central Valley. Beginning with Brood Year 2006 fall-run Chinook, the program has marked and coded-wire tagged a minimum of 25 percent of releases from the Central Valley hatcheries each year (Buttars 2007, 2008, 2009, 2010). The program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In 2010, almost 27,000 Code Wire Tags were recovered from ad-clipped Chinook sampled in Central Valley natural area spawning surveys, at Central Valley hatcheries, Central Valley river creel surveys, and California commercial and recreational ocean fisheries. Almost all of the fall run Chinook Code Wire Tags recovered in the Central Valley were tagged as part of the CFM program, since most Central Valley fish return at ages two, three, or four, and age five Chinook made up a very small fraction (0.01%) of the total Central Valley fall escapement in 2010.

This report evaluates the 2010 Central Valley fall, spring, and late fall runs Chinook Code Wire Tags recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this first full year of recovery data from the CFM program:

- What are the proportions of hatchery and natural-origin fish in spawning returns to Central Valley hatcheries and natural areas, and in ocean harvest?
- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Straits?
- What are the relative recovery rates for fish acclimated in net pens and released in the bay compared to salmon released directly into the waters of the Carquinez Straits?
- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

As with all of its products, Fisheries Branch is interested in comments on the utility of this document, particularly regarding its application to monitoring and management decision processes. Therefore, we encourage you to provide us with your comments. Comments should be directed to Ms. Alice Low, Fisheries Branch, 830 S Street, Sacramento, CA 95814, (916) 323-9583, alow@dfg.ca.gov.

Stafford Lehr
Chief, Fisheries Branch

Introduction

Each year, approximately 32 million fall-run Chinook salmon are produced at five hatcheries in California's Central Valley (CV): Coleman National Fish Hatchery (CNFH), Feather River Hatchery (FRH), Nimbus Fish Hatchery (NFH), Mokelumne River Hatchery (MOK), and Merced River Fish Facility (MER). Production from these hatcheries contributes to major sport and commercial fisheries in ocean and inland areas. Prior to 2007, only small experimental releases (generally <100,000 fish) of CV fall-run Chinook were consistently released with microscopic (≤ 1 mm) coded-wire tags (CWT) inserted in their snouts. Each CWT contains a binary or alpha-numeric code that identifies a specific release group of salmon (e.g., agency, species, run, brood year, hatchery or wild stock, release size, release date(s), release location(s), number tagged and untagged). Any CV salmon containing a CWT is also externally marked with a clipped adipose fin (ad-clipped) to allow for visual identification. Although FRH did mark and tag a portion of their fall-run Chinook during 2000 through 2006, tagging rates were not consistent or representative of the 6-8 million fish produced annually by FRH. Almost all of the fall-run Chinook production releases at the other CV hatcheries were untagged during this time.

In 2004, the CALFED Ecosystem Restoration Program (ERP) funded a study to design a constant fractional marking and coded-wire tagging program for CV fall-run Chinook production at all CV hatcheries. The primary goal of this program was to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed throughout the CV. The study recommended the implementation of a system-wide marking and tagging program for production releases. Planning studies indicated an optimum marking and tagging rate of 25% for all CV fall-run Chinook production releases (Hicks et al. 2005).

Beginning with brood year 2006, at least 25% of fall-run Chinook production releases at CNFH (12-13 million), FRH (9-10 million), NFH (5-6 million), and MOK (4-5 million) have been marked and tagged each spring-run (Buttars 2007, 2008, 2009, 2010). This Constant Fractional Marking (CFM) program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In addition, 100% of the fall-run Chinook produced at the MER (approximately 50,000-300,000 annually) are marked and coded-wire tagged. Almost 100% of the spring-run Chinook reared at FRH and the late fall-run Chinook reared at CNFH have also been marked and coded-wire tagged. It should be noted that due to their extremely low production numbers, MOK marked and tagged 100% of their fall-run Chinook releases for brood years 2008 and 2009.

During 2010, almost 27,000 CWTs were recovered from ad-clipped Chinook sampled in CV natural area spawning surveys, at CV hatcheries, in CV river creel surveys, and in California ocean commercial and recreational fisheries. Almost all of the fall-run Chinook CWTs recovered in the CV were tagged as part of the CFM program since most CV fish return at ages two, three, or four. Age five Chinook made up a very small fraction (0.01%) of the total CV fall-run escapement in 2010. This report evaluates the 2010 CV fall, spring, and late fall runs Chinook CWT recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this first essentially complete year of recovery data:

- What are the proportions of hatchery and natural-origin fish in spawning returns to CV hatcheries and natural areas, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?

- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Straits? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released.

- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Straits?

- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

Data and Methods

Inland Escapement Monitoring

During 2010, monitoring of Chinook escapement occurred at all five salmon hatcheries and on major rivers and tributaries throughout the CV. In addition, creel surveys were conducted on river fisheries in the Feather, American, and Sacramento River basins. Returning salmon were counted and 100% sampled at CV hatcheries while sample rates and methods (e.g., carcass surveys, weir counts, redd counts) varied among natural spawner surveys (Table 1).

Approximately 26,500 ad-clipped salmon were observed and 25,700 heads collected by various CV projects. Monitoring agencies include DFG, DWR, EBMUD, FWS, and PSMFC. Most heads were processed by DFG at the Santa Rosa CWT lab (15,839 heads) and by FWS staff at CNFH (9,531 heads). Remaining heads were processed by individual projects and their data submitted to the Santa Rosa CWT Lab. Almost 97% (24,838) of these heads contained valid CWTs, 2% of heads had shed their CWTs prior to processing, and 1% contained CWTs that either were lost during processing or too damaged to read.

Total escapement estimates and the number of salmon sampled for ad-clips in this report were provided by individual CV projects or hatcheries. These data, along with their respective CWT recovery data, were uploaded to the Regional Mark Processing Center (RMPC) and are readily accessible at www.rmpc.org.

Ocean Harvest Monitoring

Since 1962, the DFG's Ocean Salmon Project (OSP) has monitored California's ocean salmon fisheries at approximately 20 ports between Point Conception and the California-Oregon border. The goal of OSP is to sample at least 20% of all Chinook landed and to collect the heads from all ad-clipped salmon observed during monitoring. In 2010, the seasons for California sport and commercial ocean salmon fisheries were relatively constrained (Table 2) to protect both

Sacramento River fall-run Chinook and Klamath River fall-run Chinook. Field staff sampled 13,344 salmon and collected 2,211 heads that were processed by the Santa Rosa CWT lab. About 90% (1,987) of these heads contained valid CWTs, 10% were missing CWTs and <1% contained CWTs that were too damaged to read. Although it is generally agreed that CWTs missing from inland head recoveries is the result of salmon "shedding" these tags prior to release, this can not be assumed for heads recovered from mixed-stock ocean fisheries. Oregon and Washington hatcheries have recently begun to "mass-mark" (i.e., ad-clipped salmon that do not contain a CWT) Chinook to support small mark-selective fisheries in the northwest. During the last several years, OSP has noticed a gradual increase in the number of ocean heads collected that do not contain CWTs, especially in California's northern ports, and assume that this is due to the increased production of mass-marked salmon in Oregon and Washington.

CWT Data Analysis

A "Master" release database of CWT codes was created to determine species, brood year, run, stock origin (hatchery or natural), release site, release date(s), number of salmon CWT tagged, total number of salmon released and any other pertinent release information (e.g., trucked, net pen acclimation, disease) for all 2010 CWT recoveries. All west coast CWT release data for broods 2006 through 2009 were downloaded from the RMPC. Approximately 105 million CV Chinook were released for these five brood years, of which, 37 million fish were marked and tagged utilizing 500 unique CWT codes. Although a few natural origin salmon are trapped, marked, and tagged each year, salmon produced by hatcheries make up more than 95% of all releases. In 2010, there were 319 individual CWT codes recovered in the CV, primarily from age two-, three-, and four-year old Chinook. The CWT master file was updated with any additional information obtained for these CV Chinook releases (e.g., number of untagged salmon associated with 2008 fall-run CNFH production CWT releases) and the production factor calculated for each CWT code. The production factor, $F_{prod,}$ is the total number of fish released (tagged and untagged) represented by each CWT recovery. $F_{prod,}$ was calculated for each CWT code and is defined as,

$$F_{prod} = (Ad.CWT + Ad.noCWT + noAd.CWT + noAd.noCWT) / Ad.CWT ,$$

where Ad.CWT is the number of fish released with ad-clips and CWTs, Ad.noCWT is the number of fish released with ad-clips but without CWTs (i.e., shed tags), noAd.CWT is the number of fish released without ad-clips but with CWTs, and noAd.noCWT is the number of fish released without ad-clips and without CWTs. F_{prod} allows expansion to total hatchery production from observed recoveries of CV CWTs.

For this analysis, each CV CWT release was further classified into "release types" based on the following criteria: run, stock, hatchery or natural, production or experimental, release location, and holding strategy. All CV CWT codes were assigned by brood year into one of 16 fall-run Chinook release types, 4 spring-run Chinook release types, or 2 late fall-run Chinook release types:

Sacramento River Basin Fall-run Chinook Release Types

CFHFe	Coleman National Fish Hatchery fall-run experimental releases
CFHFh	Coleman National Fish Hatchery fall-run in-basin (at hatchery) releases
CFHFn	Coleman National Fish Hatchery fall-run net pen releases

FRHFe	Feather River Hatchery fall-run experimental releases
FRHFn	Feather River Hatchery fall-run net pen releases
FRHFt	Feather River Hatchery fall-run trucked releases (no net pen acclimation)
FRHFtn	Feather River Hatchery fall-run Tiburon net pen releases (held 3-4 months; released in fall)
FeaFw	Feather River fall-run wild
YubFw	Yuba River fall-run wild
NIMF	In-basin releases
NIMFn	Nimbus Fish Hatchery fall-run net pen releases
NIMFtib	Nimbus Fish Hatchery fall-run Tiburon net pen releases (held 3-4 months; released in fall)

San Joaquin River Basin Fall-run Chinook Release Types

MOKF	Mokelumne River Hatchery fall-run in-basin releases
MOKFn	Mokelumne River Hatchery fall-run net pen releases
MOKFt	Mokelumne River Hatchery fall-run trucked releases (no net pen acclimation)
MokFw	Mokelumne River fall-run wild
MERF	Merced River Fish Facility fall-run releases (primarily in-basin)

Central Valley Spring-run Chinook Release Types

FRHS	Feather River Hatchery spring-run in-basin releases
FRHSn	Feather River Hatchery spring-run net pen releases
FRHSt	Feather River Hatchery spring-run trucked releases (no net pen acclimation)
YubSw	Yuba River spring-run wild

Central Valley Late fall-run Chinook Release Types

CFHLe	Coleman National Fish Hatchery late fall-run experimental releases
CFHLh	Coleman National Fish Hatchery late fall-run in-basin (at hatchery) releases

It should be noted that not all release types occurred every brood year and release sites sometimes varied within a given release type (Table 3). There were also several problem CWT releases where stock origin did not match hatchery origin (e.g., American River fall-run Chinook salmon raised at MOK), stocks or runs were mixed prior to CWT tagging and released utilizing various strategies (e.g., American and Mokelumne fall-run Chinook accidentally mixed and tagged together at MOK, FRH fall-run and spring-run Chinook spawned together and released as experimental "hybrid" salmon for Delta studies), or a percentage of the salmon trucked for net pen acclimation were actually released directly into the waters of the Carquinez Strait.

To estimate the total escapement (or harvest) associated with each CWT recovery, each tag recovery was expanded by its respective F_{prod} and sample expansion factor, F_{samp}, which is defined as,

$$F_{samp} = 1 / (f_e \times f_a \times f_d),$$

where f_e is the fraction of the total salmon escapement sampled and examined for ad-clipped fish, f_a is the fraction of heads from ad-clipped salmon collected and processed, and f_d is the fraction of observed CWTs that were successfully decoded (Tables 4 and 5). A few heads were collected opportunistically during redd counts and snorkel surveys but are not included in this analysis since they are not representative of the escapement.

To help delineate between raw CWT recoveries, CWT recoveries expanded for production, CWTs expanded for sampling, and CWTs expanded for production and sampling, the following nomenclature will be used:

CWT = Raw count CWT recoveries
CWT_{prod} = CWT recoveries expanded only by their respective production factor, F_{prod}
CWT_{samp} = CWT recoveries expanded only by their respective sample expansion factor, F_{samp}
CWT_{total} = CWT recoveries expanded by both F_{prod} and F_{samp}

Determining hatchery and natural-origin proportions in CV escapement

To determine the contribution of hatchery and natural-origin Chinook for each natural-area escapement survey or hatchery, all hatchery CWT_{total} were summed to produce the total number of hatchery fish. The contribution of natural-origin fish was then determined by subtracting the total number of hatchery fish from the total escapement estimate, as follows:

$$\text{Estimate of natural-origin Chinook} = \text{Total Escapement Estimate} - \sum_{i=1}^{m} CWT_{total,i} \ ,$$

where m = total number of CWT release groups identified in an escapement survey or hatchery.

Determining recovery rates of various release types in CV escapement and ocean harvest

To determine the relative CV recovery rate, R_{cwt}, of each unique CWT release group (i.e., code), all recoveries were expanded by their location-specific F_{samp}, summed over all recovery locations, and then divided by the total number of fish tagged and released with this CWT. Since expanded recoveries for several individual CWT groups were less than 0.001% of the numbers released, recovery rates are reported in recoveries per 100,000 CWT salmon released, as follows:

$$R_{cwt} = \sum_{j=1}^{l} CWT_{samp,j} \text{ recoveries } / \text{ (CWT release group size / 100,000)},$$

where *j (=1,2,3,,,l)* denotes recovery location.

Data from all CWT release groups belonging to the same brood year and release type were combined and an overall release type-specific CV recovery rate, R_{type}, was calculated as:

$$R_{type} = \sum_{j=1}^{l} \sum_{k=1}^{n} CWT_{samp,j,k} \ / \ (\sum_{k=1}^{n} \text{release group size of CWT } k \ / \ 100{,}000),$$

where: *k* (= 1,2,3,,,n) denotes release group and *j (=1,2,3,,,l)* denotes recovery location.

Determining stray proportions of various release groups in CV escapement

Basin of origin is defined here as the drainage of any major river as it pertains to the geographic region of the CV where a hatchery is located. For this report the CV was segregated into five primary hatchery basins: Battle Creek (including the mainstem of the upper Sacramento River), Feather River (including the Yuba River), American River, Mokelumne River, and the Merced River. Hatchery-origin Chinook returning to streams not included in these five primary basins were considered to be strays. Through discussion with regional biologists it was determined that CNFH stocks are often considered to be analogous to Chinook that originate from the mainstem of the upper Sacramento River and thus are not considered to be strays. Alternatively, FRH stocks are often considered to be strays when they return to the Yuba River, a major tributary in the basin. As a result of differing opinions of what constitutes a stray throughout the CV any CWTs recovered outside of these defined basins of origin based on their reported stock or hatchery were considered strays. Further evaluation of these definitions is warranted as future CFM recovery data become available.

To determine the CV stray proportion, S_{cwt}, for each CWT code, the sum of all CWT_{samp} recoveries collected out of the basin of origin was divided by total CV CWT_{samp} recoveries for that release group, as follows:

$$S_{cwt} = \sum_{p=1}^{o} CWT_{samp,p} \text{ (out-of-basin locations) } / \sum_{p=1}^{q} CWT_{samp,p} \text{ (all CV locations)},$$

where p denotes recovery location, o denotes the number of out-of-basin recovery locations, and q denotes the total number of recovery locations.

Data from all CWT releases belonging to the same brood year and release group were then combined and release type-specific CV stray proportion, $S_{type,}$ was calculated as:

$$S_{type} = \sum_{p=1}^{o}\sum_{k=1}^{n} CWT_{samp,p,k} \text{ (out-of-basin) } / \sum_{p=1}^{o}\sum_{k=1}^{n} CWT_{samp,p,k} \text{ (all CV locations)}$$

Results

General Overview of 2010 CV inland recoveries and California ocean harvest

All but two of the 24,838 valid CWTs recovered in the CV during 2010 were CV Chinook releases; most CWTs originated from brood year 2006 through 2008 releases (Table 6). More than 84% of all expanded CWT recoveries were fall-run Chinook, followed by spring-run (10%) and late fall-run (6%) releases. No Sacramento River winter-run Chinook CWTs were recovered. The majority of fall-run CWTs were age-3 (67%) and age-2 (31%) fish. It should be noted that a few age-1 fall-run CWTs were also sampled which is relatively rare in the CV. Age-3 (92%) fish dominated the spring-run return while age-4 (59%), age-3 (20%), and age-5 (16%) made up most of the late fall-run return. A few age-6 late fall-run fish were also recovered.

All but 141 of the 1,987 valid CWT recoveries from the California ocean harvest in 2010 were CV Chinook releases; most CWTs were brood year 2006 through 2008 releases (Table 7). Approximately 62% of all expanded CWTs in the ocean harvest were fall-run Chinook, followed by late fall-run (30%), spring-run (3%), and winter-run (<1%). The majority of fall-run Chinook CWTs were age-3 (86%) and age-2 (12%) fish. Age-3 (93%) fish dominated the spring-run Chinook harvest while age-4 (62%), age-3 (21%), and age-5 (17%) made up most of the late-fall Chinook catch. A few age-6 late fall-run Chinook were also caught. The remaining 5% of ocean CWT recoveries originated from non-CV rivers, including the Klamath, Trinity, Smith, Chetco and Columbia rivers; most were age-3 (51%) and age-4 (49%) fish.

1. Proportion of hatchery- and natural-origin fish in CV escapement

The proportion of hatchery-origin fish on the natural area spawning grounds varied throughout the CV and by run. The lowest hatchery proportion (1%) was observed in the Butte Creek spring-run

Chinook mark-recapture survey while the highest proportion (78%) was observed in the Feather River fall/spring-run Chinook mark-recapture survey (Figure 1).

The hatchery proportion of fall-run Chinook returning to CV hatcheries ranged from 79% to 95% (Figure 2). The spring-run Chinook return to FRH was 82% hatchery-origin fish whereas the late fall-run return to CNFH was almost 100% hatchery-origin fish.

Overall, there were 23 individual CWT release types contributing to CV escapement in 2010. To facilitate the breakout of the hatchery proportion by stock and release strategy, all release types from the same hatchery/basin were given the same color scheme (Figure 3) in Figures 4 through 9. All net pen releases contain black dots while most trucked, experimental, or Tiburon net pen releases are designated by black stripes when possible (i.e., release types did not overlap for a particular basin).

Upper Sacramento River Basin

Ten escapement surveys were conducted in the Upper Sacramento River Basin: fall and late fall runs Chinook counts at CNFH, fall and late fall runs Chinook mark-recapture surveys in the mainstem Sacramento River, a fall-run Chinook mark-recapture survey in Clear Creek, and spring-run and fall-run Chinook mark-recapture surveys in Butte Creek. Spring and fall runs Chinook redd count surveys were conducted in Mill Creek and a spring-run Chinook snorkel survey (maximum count) was conducted in Deer Creek. Representative sampling for ad-clipped salmon did not occur in Mill and Deer Creek. Returns to CNFH were predominantly hatchery-origin fish released from this facility while escapement into natural areas was primarily natural-origin fish (Figures 4 and 5):

- Fall-run returns at CNFH were 89% hatchery-origin fish (96% CFHFh)
- Fall-run spawners in the mainstem Sacramento River were 20% hatchery-origin fish (48% FRHFn, 19% CFHFh, 17% FRHSn)
- Fall-run spawners in Clear Creek were 4% hatchery-origin fish (45% FRHFn, 32% CFHFh)
- Late fall-run returns at CNFH were almost 100% hatchery-origin fish (99% CFHLh)
- Late fall-run spawners in the mainstem Sacramento River were 6% hatchery-origin fish (73% CFHLh)
- Spring-run spawners in Butte Creek were 1% hatchery-origin fish (63% FRHSn)
- Fall-run spawners in Butte Creek were 11% hatchery-origin fish (89% FRHFn)

Feather River Basin

Four escapement surveys were conducted in the Feather River Basin: spring and fall runs Chinook counts at FRH, a combined fall/spring run Chinook mark-recapture survey in the Feather River, and a combined fall/spring run Chinook mark-recapture survey in the Yuba River. Spring and fall runs Chinook returns to FRH and in the natural areas were predominantly of hatchery-origin (Figure 6):

- Spring-run returns at FRH were 82% hatchery-origin (50% FRHS, 39% FRHSn)
- Fall-run returns at FRH were 95% hatchery-origin (87% FRHFn)
- Fall/spring-run spawners in the Feather River were 78% hatchery-origin (88% FRHFn)
- Fall/spring-run spawners in the Yuba River were 71% hatchery-origin (48% FRHFn, 22% FRHS, 21% FRHSn)

American River Basin

Three escapement surveys were conducted in the American River Basin: fall-run Chinook counts at NFH, a fall-run Chinook mark-recapture survey on the American River and a single late fall-run Chinook carcass count on the American River. In addition, dead salmon were recovered from the NFH weir, which is located just upstream from the hatchery and was installed on September 15th to force returning salmon into NFH. Salmon that migrated upstream beyond the hatchery prior to installation of the weir were trapped in the upstream area. Many of those salmon washed back onto the weir upon death. There is minimal spawning habitat above the weir. Spawner returns to natural areas and those from the NFH weir fish were predominantly of natural-origin while returns to NFH were predominantly of hatchery-origin (Figure 7):

- Fall-run returns to NFH were 79% hatchery-origin (81% NIMFn)
- Fall-run spawners in the American River were 32% hatchery-origin (48% NIMFn, 24% FRHFn, 19% CFHFn)
- Late fall-run spawners in the American River were 24% hatchery-origin (97% CFHLe)
- Salmon recovered on the NFH Weir were 38% hatchery-origin (40% NIMFn, 36% FRHFn)

Mokelumne River Basin

Three escapement surveys were conducted in the Mokelumne River Basin: fall-run Chinook counts at MOK, a video weir count at Woodbridge Dam of all fall-run Chinook escapement into Mokelumne River, and a daily collection of salmon carcasses from the MOK weir, which is installed to prevent salmon from bypassing the MOK fish ladder. This barrier was originally installed on October 8th but removed on October 15th to allow for increased water releases from Camanche Reservoir designed to produce attraction flows for upstream migrating Chinook. The weir was then reinstalled on October 19th when flows returned to a rate that would not damage the weir. Any salmon above the weir when it was installed were trapped and many washed back onto the weir after their death.

All adult Chinook salmon migrating upstream into the Mokelumne River to spawn were counted by the video fish counting device operated by EBMUD at Woodbridge Dam. These counts also included the number of ad-clipped salmon entering the system. By subtracting the 5,520 Chinook that returned to MOK and that were collected on the MOK weir from the total video count of 7,196 Chinook, it was assumed that the remaining 1,676 Chinook remained in the Mokelumne River. Utilizing the same logic, it was also assumed that there were 820 ad-clipped Chinook remaining in the river since only 2,866 of the 3,686 ad-clipped Chinook counted in the video monitoring were recovered at MOK and on the weir. After reviewing the CWT codes recovered from 59 heads collected during sporadic surveys on the Mokelumne River, we found that the proportions of the 12 individual CWT codes collected were very similar to the proportion of these codes recovered at MOK and on the weir; however there were 45 additional CWT codes recovered at the hatchery and weir. Because 100% of Chinook salmon observed at MOK and the weir were sampled, we felt that the MOK recoveries best represented the entire run and thus expanded the estimated 820 ad-clips in the Mokelumne River based on their proportions, including heads that lacked a CWT (approx 1.5%). This approach is based on the methodology used by the Klamath River Technical Team (KRTT) to determine the hatchery composition of fall-run Chinook above Willow Creek Weir on the Trinity River (e.g.,KRTT 2011).

Spawner returns to the Mokelumne River Basin were dominated by hatchery-origin fish (Figure 8):

- Fall-run returns at MOK were 90% hatchery-origin (34% MOKFt, 18% MOKFn, 32% NIMFn)
- Salmon carcasses recovered on the MOK weir were 74% hatchery-origin (50% MOKFt, 18% MOKFn, 27% NIMFn)
- Fall-run spawners in the Mokelumne River were 73% hatchery-origin (50% MOKFt, 18% MOKFn, 31% NIMFn)

San Joaquin River Basin Tributaries
Four additional escapement surveys were conducted in tributaries of the San Joaquin River: fall-run Chinook counts at MER, as well as fall-run Chinook mark-recapture surveys conducted on the Stanislaus, Tuolumne, and Merced rivers. Fall-run Chinook returns to the Merced River were dominated by hatchery-origin fish while the Stanislaus and Tuolumne rivers were almost equally split between hatchery- and natural-origin spawners (Figure 9):

- Fall-run returns at MER were 79% hatchery-origin (37% MOKFt, 18% NIMFn, 12% NIMFtib, 11% CFHFn, 10% MERF)
- Fall-run spawners in the Merced River were 78% hatchery-origin (31% NIMFn, 20% FRHFn, 16% MOKFn, 14% MOKFt)
- Fall-run spawners in the Stanislaus River were 50% hatchery-origin (31% NIMFn, 26% MOKFn, 23% MOKFt)
- Fall-run spawners in the Tuolumne River were 49% hatchery-origin (29% CFHFn, 23% MERF, 19% FRHFn)

2. Relative recovery and stray proportions for hatchery-origin Chinook released in-basin versus hatchery-origin Chinook trucked and released into the waters of the Carquinez Strait (includes Chinook salmon acclimated in net pens and released into San Pablo Bay).

Release strategies vary widely among hatcheries from year to year. This variability has often been in response to fluctuating abundances of certain stocks or differing policies among mitigating agencies with respect to “best” release practices. Lack of consistency and “problem releases” among CV hatcheries has limited the number of release groups available for direct comparison of differing release strategies. For these reasons, there are only six release groups recovered in 2010 that allows in-basin releases to be compared directly to trucked/net pen releases.

Table 8 summarizes the recovery rates R_{type} (in-basin, stray, and ocean) for all release groups with representative recoveries from the CV in 2010. Figures 10 and 11 provide a graphical representation of R_{type} for the Sacramento River fall-run Chinook and other CV stocks, respectively. In general, Chinook that were trucked and released directly into the waters of Carquinez Strait or acclimated in bay area net pens had higher relative recovery rates than their respective in-basin releases. These releases also had higher stray proportions than their paired in-basin counterparts.

Coleman National Fish Hatchery Releases - Fall-run Chinook Broods 2007 and 2008
For brood 2008 CNFH fall-run Chinook releases, the CV age-2 recovery rate for net pen CNFHn releases (161.5) was 2.3 times greater than in-basin CFHFh releases (70.9). However, while

CNFHh releases were only recovered in-basin, the proportion of CFHFn recoveries out-of-basin was very high at 89%.

There were three different CNFH release types for brood 2007 fall-run Chinook. The CV age-3 recovery rate for experimental CFHFe releases (164.0) was more than 3.0 times greater than in-basin CFHFh (54.6) and net pen CFHFn (41.2) releases. Less than 1% of CFHFh were recovered out-of-basin compared to straying proportions of 98% and 25% for CFHFn and CFHFe, respectively.

Feather River Hatchery Releases – Spring-run Chinook Broods 2006, 2007, and 2008
For brood 2008 FRH spring-run releases, the CV age-2 recovery rate for net pen FRHSn releases (32.2) was slightly higher than in-basin FRHS (28.0) releases. Approximately 10% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2007 FRH spring-run releases, the CV age-3 recovery rate for net pen FRHSn releases (440.4) was 1.3 times higher than in-basin FRHS (348.4) releases. Approximately 15% of age-3 FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2006 FRH spring-run releases, the CV age-4 recovery rate for net pen FRHSt releases (19.4) was 3.0 times higher than in-basin FRHS (6.4) releases. Approximately 18% of both FRHSt and FRHS CWTs were recovered out-of-basin.

Nimbus Fish Hatchery Release – Fall-run Chinook Brood 2008
For brood 2008 NFH fall-run releases, the CV age-2 recovery rate for net pen NIMFn releases (86.9) was 2.6 times greater than in-basin NIMF releases (33.5). However, while NIMF releases were only recovered in-basin, the proportion of NIMFn recoveries out-of-basin was very low at 6%.

Feather River Hatchery Releases – Fall-run Chinook Brood 2008
Although FRH did not have any in-basin releases for broods 2006, 2007 or 2008, they did have experimental FRHFe, net pen FRHFn and trucked FRHFt releases that can be compared.

For brood 2008 FRH fall-run releases, the CV age-2 recovery rate for experimental FRHFe releases (135.6) was slightly higher than net pen FRHFn (117.6) releases. The FRHFe releases were actually “hybrid” fish (FRH fall-run x FRH spring-run Chinook). Approximately 5% of both FRHFe and FRHFn were recovered out-of-basin.

For brood 2006 FRH fall-run releases, the CV age-4 recovery rate for net pen FRHFn releases (17.2) was 3.1 times higher than experimental FRHFe (5.6) releases. Recoveries of trucked FRHFt (0.7) releases were too low for comparison purposes. Approximately 10% of FRHFn and 9% of FRFHe releases were recovered out-of-basin. It should be noted that many of the FRHFn releases had some fish released directly into the bay so it is impossible to separate true net pen releases from trucked/direct bay ones.

3. Relative CV recovery and stray rates of bay releases acclimated in net pens and released directly without acclimatization

The same issues related to release practices that limited the available recovery comparisons in the previous section also limited the comparison of net pen releases and direct releases in the Carquinez Strait area. As a result there is only one release type comparison possible.

Feather River Hatchery Release – Fall-run Chinook Brood 2007

For brood 2007 FRH fall-run releases, the CV age-3 recovery rate for net pen FRHFn releases (478.4) was 3.9 times higher than trucked/direct bay FRHFt (122.9) releases. Approximately 19% of FRHFt fish were recovered out-of-basin compared to 8% of FRHFn releases.

4. Relative recovery rate and contribution of CV release groups to ocean harvest

The relative recovery rate of CV hatchery releases in the 2010 ocean salmon fisheries (sport and commercial combined) varied by age and release group (Figure 12). Of the 4,755 CV CWT_{samp} collected in the fisheries, most were age-3 (84%), followed by age-2 (12%), age-4 (4%) and age-5 (<1%) fish.

The majority of age-2 CV Chinook harvested were in the sport fishery due to its lower size limit (20”-24” total length) compared to the commercial fishery (27” total length). For all age-2 CV releases, trucked MOKFt (42.7) had the highest recovery rate per 100,000 fish released, followed by net pen CFHFn (23.6), San Joaquin basin MERF (11.3), and net pen FRHFn (7.9) releases (Table 8).

Net pen releases had the highest recovery rates for age-3 CV fall and spring runs Chinook. The recovery rate for net pen FRHFn (81.2) was more than twice that of NIMFn (37.7) CFHFn, (32.1), FRHSn (29.4) and MOKFn (22.8). There were only in-basin releases of CV late fall-run CFHLh (24.4) for age-3 fish.

Relatively few age-4 or age-5 CWT recoveries were made compared to age-2 and age-3 CV fish. In-basin CV late fall-run Chinook CFHLh had the highest recovery rate for age-4 (16.0) and age-5 (0.6) CV releases.

Contribution of CV release groups to sport ocean harvest

In 2010, anglers harvested an estimated 14,697 Chinook in the California sport ocean salmon fishery. Based on the expanded CWT_{total} collected in the fishery, including non-CV Chinook release types, hatchery-origin fish contributed 31%-63% of the total harvest, depending on major port area (Figure 13). Of the hatchery-origin fish, fall-run net pen FRHFn releases dominated the sport catch in all port areas: Monterey (43%), San Francisco (38%), Fort Bragg (22%), and Eureka/Crescent City (27%). Other CV releases contributing to all sport fisheries were net pen NIMFn (4-8%), in-basin CFHFh (5-10%) and net pen CFHFn (3-5%); however there were no recoveries of CFHFh and CFHFn in the Eureka/Crescent City port area. Non-CV stocks also made up a higher proportion (3%) in this northern area.

Contribution of CV release groups to commercial ocean harvest

Commercial trollers landed an estimated 15,098 Chinook in the California commercial ocean salmon fishery; most salmon (83%) were caught in the Fort Bragg port area. Based on the expanded CWT_{total} collected in the fishery, hatchery-origin fish contributed 22%-74% of the total harvest, depending on major port area (Figure 14). Of the hatchery release types, fall-run net pen FRHFn dominated the commercial catch in all port areas: Monterey (50%), San Francisco (14%), and Fort Bragg (22%). The Eureka / Crescent City port area was completely closed to commercial fishing in 2010. Other CV releases contributing to the California commercial fishery were net pen NIMFn (3%-10%) and in-basin CFHFh (3%-8%). In addition, non-CV stocks contributed at a higher overall proportion in the commercial fishery (6%) than in the sport fishery (1%), especially in Fort Bragg (7%) where most of the commercial season occurred in 2010.

Discussion

Estimates of hatchery contributions that are presented in this report should be viewed simply as a "single year (2010) snapshot" of CV Chinook escapement and the California ocean harvest. This was the first year that the majority of all CWT recoveries from CV releases were representatively marked and tagged at a minimum 25% level. Although there were definite differences observed in recovery rates and straying proportions among runs, brood years, and CV release groups, this is just the first step in many needed to statistically analyze the contribution of hatchery and natural-origin salmon to natural areas throughout the CV, evaluate hatchery release strategies, improve California ocean and river salmon fisheries management, and determine if other goals of the CFM program are being met. It is also important to note that most of the CV CWT release groups in this study were produced, released and/or recovered during a time when Sacramento River fall-run Chinook were at historically low levels. Thus these salmon were not susceptible to "normal" ocean or river salmon fisheries since these fisheries were either completely closed or very constrained during the last three years.

The effect of interannual variation in survival and year-class strength of both hatchery-origin and natural-origin stocks should be considered when evaluating the status of CV Chinook stocks. At this time neither year class strength or age structure of CV natural-original Chinook are known. Scale-aging work done on 2006, 2007, and 2008 CV Chinook escapement by OSP has indicated that there may be different maturation rates for hatchery and natural-origin fish by stock and basin. It is premature to compare hatchery and natural-origin proportions without having complete brood- and/or stock-specific population estimates. While it may appear that total escapement by hatchery fish in the CV may exceed that of natural-origin fish in any given year, comparing age-specific total escapement (hatchery and natural) once broods complete their life cycle may indicate differences in hatchery and natural ratios for specific age groups and stocks. Such analyses may provide the basis for changing hatchery practices to better mimic wild population parameters. They may also further clarify the effects of specific environmental stressors unique to natural-origin fish and/or specific hatchery CWT release groups.

Strategies for CV fall-run production releases in any given year are often a result of two conflicting objectives. Increasing survival rates to allow for greater harvest and escapement often favors release strategies that bypass the Sacramento-San Joaquin Delta. Alternatively, in-basin release practices are aimed at maximizing homing rates back to the hatchery of origin to reduce impacts on natural stocks. It is impossible to make a thorough comparison of hatchery release practices at this time due to the large variability that existed among CWT release types within the same CV hatchery broods examined in this study. Most release types included individual CWT codes that were released at numerous locations at different times and under various conditions (e.g., river water flows and temperatures, bay tidal flows for trucked and net pen releases). While some individual CWT codes were recovered at a relatively high rate, others within the same release type were not recovered at all. The recovery rate R_{cwt} for individual CWT codes should be examined on a release type basis and the release strategies (in-basin, trucked, net-pen acclimation) that produce the greatest resource value (i.e., highest recovery rate, lowest straying proportion) adopted for future release strategy evaluation. Coordinated and paired hatchery release types will allow for direct comparisons to be made between them and will enrich the available data set used for subsequent evaluation of the hatchery program in the future. The CDFG Fisheries Branch has performed some very preliminary statistical testing to evaluate the significance of differences noted between the performance of individual pairs of release types (Ferreira 2011).

Prior to the CFM program, the primary purpose of CV Chinook escapement monitoring was to provide basic status information (e.g., grilse and adult escapement counts) by individual stocks and basins for California hatchery and ocean harvest management needs. The marking, tagging, or collection of CV CWT fish was not a high priority. CV escapement monitoring has expanded to provide data for a broad range of management applications related to recovery planning for listed stocks. These applications include assessing recovery efforts, including habitat restoration work, improving ocean and river fisheries management, and evaluating CV salmon hatchery programs to ensure both mitigation and conservation goals are being met. To meet the needs of these various assessment efforts, a review of current methodologies being employed among CV inland escapement monitoring programs was undertaken by DFG in 2008. The goal of this review was to identify needed changes and/or additions to survey protocols that will ensure both statistically valid estimates of escapement and the collection of biological data, including CWTs and scales, needed for assessment efforts. In 2012, DFG completed the Central Valley Chinook Salmon Escapement Monitoring Plan that recommends methods for estimating escapement and collecting biological data necessary for improved stock assessment in the CV (Bergman et al. 2012). Survey modifications included changes in the current mark-recapture models being utilized, changes in sampling protocols to ensure representative sampling and proper accounting, and the use of counting devices in place of some mark-recapture programs. This monitoring plan is now being implemented among CV surveys to provide the basis for sound CV Chinook assessment and subsequent management. The OSP and DFG Fisheries Branch CWT laboratories in Santa Rosa and Sacramento respectively, have both been expanded and additional staff hired to process the 40,000-60,000 tagged Chinook expected to be recovered annually during CV escapement and California ocean salmon fisheries monitoring. The OSP lab has also expanded its scale-aging capability utilizing state-of-the-art digital imaging. If these data are going to be used in a timely manner to manage CV salmon production and ocean/river fisheries, all CWT data and stock-specific age composition of CV escapement will be needed by February each year.

The CV CFM program has been successful in marking and tagging the target numbers of salmon each year at each of the CV hatcheries, and has just begun recovering CWTs in a statistically valid manner throughout the CV. The results from this program, in conjunction with future aging work will provide the best opportunity to manage CV Chinook salmon based on scientifically defensible data. The CFM program should be continued with the current design for several years to provide comparable, consistent data needed for harvest and hatchery management. Current funding for both CFM CWT recovery/processing and scale-aging programs expires in July 2013. Identifying future funding for these programs is essential for the continued enhancement of Chinook management in California's Central Valley.

Literature Cited

Bergman, J., Nielson, R., and Low, A. 2012. Central Valley Chinook Salmon In-River Escapement Monitoring Plan. California Department of Fish and Game. Fisheries Branch Administrative Report Number: 2012-1. January 2012

Buttars, B. 2007. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2007 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2008. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2008 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2009. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2009 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2010. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2010 Marking Season. Pacific States Marine Fisheries Commission.

Ferreira, J. 2011. Coded Wire Tag Recovery Analysis for Central Valley Chinook. California Department of Fish and Game, Fisheries Branch.

Hicks, A.C., Newman, K.B., and Hankin D.G. 2005. A second analysis of a marking, tagging, and recovery program for Central valley hatchery Chinook salmon. Unpublished report to Central Valley Salmon Team.

Klamath River Technical Team 2011. Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2010 Run. 24 February 2011

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List of Acronyms and Abbreviations

Ad-clipped	clipped adipose fin
BOR	U.S. Bureau of Reclamation
CFM	Constant Fractional Marking
CNFH	Coleman National Fish Hatchery
CV	California Central Valley
CWT	coded-wire tag
DFG	California Department of Fish and Game
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
ERP	Ecosystem Restoration Program
FRH	Feather River Hatchery
FWS	U.S. Fish and Wildlife Service
MER	Merced River Hatchery
MOK	Mokelumne River Hatchery
NFH	Nimbus Fish Hatchery
OSP	Ocean Salmon Project
PSMFC	Pacific States Marine Fisheries Commission
RMPC	Regional Mark Processing Center
YARMT	Yuba Accord River Management Team

Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 1 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Hatchery Spawners		
Coleman National Fish Hatchery (CNFH) Fall and Late Fall	Direct count. All fish examined for fin-clips, tags, marks. Hatchery takes a one month break in between the fall and late fall run spawning periods. Fish that arrive during this 'break' are counted and excised. Those fish that contain a fall cwt code or have their adipose fin present are later counted as a part of the fall run. Fish containing a late fall CWT code are later counted as late fall. Systematic random bio-sample[a/] of all fish with adipose fin absent. Grilse cutoff: 760 mm.	FWS
Feather River Hatchery (FRH) Spring and Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish arriving at the hatchery April-June tagged with two uniquely-numbered floytags. All fish marked with floytags returning to FRH during August and September are spawned as spring run. All other fish are spawned as fall run. All spring Chinook are bio-sampled. Systematic random bio-sample ~10% of aggregate fall run fish with adipose fin present and absent. All fall run fish with adipose fin absent are bio-sampled. All spawned fall run fish are bio-sampled. Grilse cutoff: 650 mm.	CDFG
Nimbus Fish Hatchery (NFH) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG
Nimbus Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Mokelumne River Hatchery (MOK) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 males.	CDFG
Mokelumne Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Merced River Fish Facility (MER) Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG

Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 2 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Natural Spawners		
Upper Sacramento River Mainstem Fall and Late Fall	Superpopulation modification of the Jolly-Seber mark-recapture estimate applied using large females with adipose fin present within survey area (Keswick Dam to Balls Ferry). Chinook removed during the survey for CWT recovery are added to the J-S estimate. Total escapement estimate (Keswick Dam to Princeton) is derived using expansions for: Fish spawning outside of the survey area (Balls Ferry to Princeton) through aerial redd surveys, large male Chinook based on the sex ratio at CNFH, and grilse based on the rate encountered during the mark recapture survey. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG, FWS
Clear Creek Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG, FWS
Butte Creek Spring and Fall	Modified Schaefer mark-recapture estimate for spring run. Peterson mark-recapture estimate for fall run. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFG
Feather River Fall	Modified Schaefer mark recapture-estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring run Chinook are included. Grilse cutoff: 650 mm.	DWR
Yuba River Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring Chinook are included in estimate. Grilse cutoff: 650	CDFG, YARMT
American River Fall	Modified Schaefer mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm.	CDFG
Mokelumne River Fall	Video count at Woodbridge Irragation District Dam. Additionally, in river survey conducted to collect bio-samples from all fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 males.	EBMUD
Stanislaus River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Tuolumne River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG
Merced River Fall	Pooled-Petersen mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled.	CDFG

Table 1. Estimation and sampling methods used for the 2010 Central valley Chinook run assessment. (page 3 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Recreational Harvest		
Upper Sacramento River Fall	Open October 9th to October 31st from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Feather River Fall	Open July 31st to August 29th below the Thermolito Afterbay Outlet. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
American River Fall	Open October 30th to November 28th from the mouth to the SMUD power line crossing at Ancil Hoffman Park. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Lower Sacramento River Fall	Open September 4th to October 3rd from the Carquinez Bridge to the Highway 113 Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG
Upper Sacramento River Late Fall	Open November 1st to December 12th from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFG

a/ Biological samples ("bio-samples" or "bio-data") of live fish or carcasses generally include: sex, fork length, scales, tags or marks, and CWT recovery from ad-clipped fish.

Table 2. 2010 California ocean sport and commerial salmon fishery seasons by major port area.

	Sport		Commercial		
Major Port Area	Season	Size Limit[a/]	Season	Size Limit[a/]	Quota
Crescent City/Eureka	May 29-Sep 6	24" TL	closed	--	--
Fort Bragg	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6	24" TL	July 15-29	27" TL	18,000
			Aug 1-31	27" TL	9,375
San Francisco	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6 (closed Tue/Wed)	24" TL			
Monterey/Morro Bay	Apr 3-30	20" TL	July 1-4, 8-11	27" TL	none
	May 1-Sep 6 (closed Tue/Wed)	24" TL			

a/ Size limit in total length (TL).

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release type, brood years 2006-2009. (page 1 of 2)

Age 2 CWT releases

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2008	FRH	Fea R	Spr	5	1,016,835	1,015,717	100%	Basin	Boyds Pump Ramp
FRHSn	2008	FRH	Fea R	Spr	5	1,007,177	1,005,727	100%	Bay pens	San Pablo Bay net pens
CFHFh	2008	CNFH	Sac R	Fall	27	12,529,146	3,128,111	25%	Basin	CNFH
CFHFn	2008	CNFH	Sac R	Fall	3	1,427,439	371,685	26%	Bay pens	Mare Island net pens, San Pablo Bay net pens
FRHFn	2008	FRH	Fea R	Fall	11	7,760,969	2,061,211	27%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFe	2008	FRH	Fea R	Hybrid	30	498,341	481,853	97%	CV exper	Fall x Spr hybrid releases: Benicia, Discovery Pk, Elkhorn Boat Launch, Miller Park, Sac River at Garcia Bend and Pittsburg
FRHFtib	2008	FRH	Fea R	Fall	2	91,631	89,859	98%	Tiberon pens	Held 3-4 mos Tiberon net pens, released as yearlings
FeaFw	2008	wild	Fea R	Fall	37	292,423	289,830	99%	Basin	Feather River Hatchery, Thermalito Bypass
NIMF	2008	NIM	Ame R	Fall	1	267,003	264,006	99%	Basin	American River
NIMFn	2008	NIM	Ame R	Fall	4	3,924,440	976,955	25%	Bay pens	Mare Island net pens
MOKFt	2008	MOK	Mok R	Fall	4	250,969	250,300	100%	Trucked	Sherman Island
MokFw	2008	wild	Mok R	Fall	5	24,911	20,680	83%	Basin	Woodbridge, Mok R Vino farms
MERF	2008	MER	Mer R	Fall	2	34,532	32,978	95%	Basin	Jersey Pt (San Joaquin River)
CFHLh	2009	CNFH	Sac R	Late	16	1,134,119	1,115,378	98%	Basin	CNFH (includes spring surrogate releases)
			Total age 2 releases:		152	30,259,935	11,104,290	37%	1% wild releases	

Age 3 CWT releases

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2007	wild	Butte Ck	Spr	30	317,706	311,061	98%	Basin	Baldwin Construction Yard
FRHS	2007	FRH	Fea R	Spr	8	1,414,343	1,378,941	97%	Basin	Boyds Pump Ramp (on Feather River)
FRHSn	2007	FRH	Fea R	Spr	2	1,271,761	1,242,480	98%	Bay pens	San Pablo Bay net pens, Wickland Oil net pens
CFHFe	2007	CNFH	Sac R	Fall	8	200,619	196,993	98%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2007	CNFH	Sac R	Fall	14	11,232,241	2,801,459	25%	Basin	CNFH
CFHFn	2007	CNFH	Sac R	Fall	3	1,266,949	314,681	25%	Bay pens	San Pablo Bay net pens (Conoco Phillips, Mare Island); 75% truck mortality noted for one release
FRHFe	2007	FRH	Fea R	Fall	19	623,567	619,085	99%	CV exper	Elkhorn Boat Ramp,Isleton, Lighthouse Marina, West Sacramento
FRHFn	2007	FRH	Fea R	Fall	9	9,422,521	2,347,396	25%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFt	2007	FRH	Fea R	Fall	4	102,225	101,712	99%	Trucked	Benicia
FeaFw	2007	wild	Fea R	Fall	19	208,717	206,683	99%	Basin	Thermalito Bypass
NIMFn	2007	NIM/MOK	Ame R	Fall	7	6,879,664	1,714,858	25%	Bay pens	Raised at both NIM and MOK; San Pablo Bay net pens
NIMFtib	2007	MOK	Ame R	Fall	1	51,600	51,600	100%	Tiberon pens	Raised at MOK; held 3-4 mos Tiberon net pens, released as yearlings
MOKF	2007	MOK	Mok R	Fall	1	406,593	101,458	25%	Basin	New Hope Landing
MOKFn	2007	MOK	Mok R	Fall	2	2,203,488	550,668	25%	Bay pens	San Pablo Bay net pens
MokFw	2007	wild	Mok R	Fall	1	315	315	100%	Basin	Mokelumne River
CFHLh	2008	CNFH	Sac R	Late	14	1,106,673	1,072,854	97%	Basin	CNFH (includes spring surrogate releases)
			Total age 3 releases:		142	36,708,982	13,012,244	35%	1% wild releases	

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release type, brood years 2006-2009. (page 2 of 2)

Age 4 CWT releases

Release type*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2006	wild		Spr	27	283,749	279,936	99%	Basin	Baldwin Construction Yard
FRHS	2006	FRH	Fea R	Spr	1	1,043,284	1,004,683	96%	Basin	Fea R Hatchery
FRHSt	2006	FRH	Fea R	Spr	9	1,036,931	1,026,561	99%	Trucked	Wickland Oil Terminal (no pens)
YubSw	2006	wild	Yub R	Spr	16	182,730	179,853	98%	Basin	Yuba River
CFHFe	2006	CNFH	Sac R	Fall	8	201,812	196,108	97%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2006	CNFH	Sac R	Fall	8	12,113,781	3,032,082	25%	Basin	CNFH
FRHFe	2006	FRH	Fea R	Fall	34	573,386	564,904	99%	CV exper	Elkhorn Boat Ramp,Isleton, Lighthouse Marina, West Sacramento, Yolo Bypass
FRHFn	2006	FRH	Fea R	Fall	8	8,154,003	1,995,912	24%	Bay pens, Trucked	Wickland Oil net pens - proportion of trucked fish placed in pens, varies from 35%-100%; remainder dumped directly into bay
FRHFt	2006	FRH	Fea R	Fall	9	1,018,073	305,755	30%	Trucked	Benicia, Wickland Oil Terminal (no pens)
FeaFw	2006	wild	Fea R	Fall	17	188,293	186,478	99%	Basin	Thermalito Bypass
YubFw	2006	wild	Yub R	Fall	14	62,426	61,295	98%	Basin	Yuba River
NIMFn	2006	NIM	Ame-Mok	Fall	5	6,128,032	1,527,846	25%	Coastal & Bay pens, Trucked	Amer-Moke fish accidentally mixed, released into multiple net pens: 18% coastal (Avila, Santa Cruz), 82% Bay net pens. American stock trucked to Wickland Oil net pens (approx 87% placed into pens)
MOKF	2006	MOK	Mok R	Fall	7	3,706,436	925,826	25%	Basin	New Hope Landing
MOKFn	2006	MOK	Mok R	Fall	2	227,412	55,427	24%	Coastal & Bay pens	Coastal and ocean net pens (Port San Luis,Santa Cruz, Moss Landing & Selby/Wickland net pens)
MOKFt	2006	MOK	Mok R	Fall	1	1,127,138	281,582	25%	Trucked	Wickland Oil Terminal (no pens)
MokFw	2006	wild	Mok R	Fall	2	13,903	10,968	79%	Basin	Mok R
MERF	2006	MER	Mer R	Fall	12	312,294	304,121	97%	Basin	Hatfield State Area, MER
CFHLe	2007	CNFH	Sac R	Late	17	309,829	299,292	97%	CV exper	Sac R (Colusa to RBDD), Georgianna Slough, Port Chicago, Ryde-Koket
CFHLh	2007	CNFH	Sac R	Late	9	738,638	723,091	98%	Basin	CNFH (includes spring surrogate releases)
			Total age 4 releases:		206	37,422,150	12,961,720	35%	2% wild releases	

***CV CWT release types:**

Sacramento River Basin Fall Chinook CWT release groups

CFHFe	Coleman National Fish Hatchery (CNFH) fall experimental releases
CFHFh	Coleman National Fish Hatchery fall hatchery releases
CFHFn	Coleman National Fish Hatchery fall net pen releases
FRHFe	Feather River Hatchery fall experimental (2008 brdyr includes spring x fall hybrids)
FRHFn	Feather River Hatchery fall net pen releases
FRHFt	Feather River Hatchery fall trucked releases (no net pens)
FRHFtn	Feather River Hatchery fall Tiburon net pen releases (released as yearlings following fall)
FeaFw	Feather River fall wild
YubFw	Yuba River fall wild
NIMFn	Nimbus Fish Hatchery fall net pens
NIMFtib	Nimbus Fish Hatchery fall Tiburon net pens (released as yearlings following fall)

Sacramento River Basin Late Fall Chinook CWT release groups

CFHLe	Coleman National Fish Hatchery late fall experimental releases
CFHLh	Coleman National Fish Hatchery late fall hatchery releases

San Joaquin Basin Fall Chinook CWT release groups

MOKF	Mokelumne Hatchery fall basin releases
MOKFn	Mokelumne Hatchery fall net pen releases
MOKFt	Mokelumne Hatchery fall trucked releases
MokFw	Mokelumne River fall wild
MerF	Merced Hatchery fall releases

Central Valley Spring Chinook CWT release groups

FRHS	Feather River Hatchery spring basin releases
FRHSn	Feather River Hatchery spring net pen releases
FRHSt	Feather River Hatchery spring trucked releases
ButSw	Butte Creek spring wild
YubSw	Yuba River spring wild

Table 4. Escapement estimates and sample data for 2010 CV escapement.

Escapement Survey	Run	Total Escapement	Chinook Sampled[a/]	Observed Ad-Clips	Valid CWTs	Sample Fractions[b/] fe	fa	fd	Sample Expansion
Hatcheries									
Feather River Hatchery	Spring	1,661	1,661	1,279	1,234	1.000	1.000	0.998	1.00
Coleman National Fish Hatchery	Fall	17,238	17,238	4,140	4,040	1.000	1.000	0.990	1.01
Feather River Hatchery	Fall	19,972	19,972	6,373	6,049	1.000	1.000	0.969	1.03
Nimbus Fish Hatchery	Fall	9,095	9,095	2,060	2,025	1.000	1.000	0.997	1.00
Nimbus Weir	Fall	7,115	7,115	999	948	1.000	1.000	0.999	1.00
Mokelumne River Hatchery	Fall	5,276	5,276	2,747	2,707	1.000	1.000	1.000	1.00
Mokelumne Weir	Fall	244	244	119	115	1.000	1.000	1.000	1.00
Merced River Fish Facility	Fall	146	146	83	81	1.000	1.000	0.988	1.01
Coleman National Fish Hatchery	Late Fall	5,505	5,505	5,391	5,258	1.000	1.000	0.995	1.00
Natural Areas									
Mill Creek	Spring	482	482	1	1	1.000	1.000	1.000	1.00
Butte Creek	Spring	1,979	1,113	21	16	0.562	1.000	1.000	1.78
Sacramento River-Above Red Bluff	Fall	16,372	1,415	130	117	0.086	0.992	1.000	11.66
Mill Creek	Fall	144	144	1	1	1.000	1.000	1.000	1.00
Deer Creek	Fall	166	166	2	2	1.000	1.000	1.000	1.00
Clear Creek	Fall	7,192	1,496	19	19	0.208	1.000	1.000	4.81
Butte Creek	Fall	370	83	3	3	0.224	1.000	1.000	4.46
Feather River	Fall	44,914	5,077	1,388	1,276	0.113	0.964	0.998	9.20
Yuba River	Fall	13,097	789	341	330	0.060	1.000	1.000	16.60
American River	Fall	7,573	1,435	142	134	0.189	1.000	0.985	5.36
Mokelumne River	Fall	1,920	1,920	820	808 [c/]	1.000	1.000	0.999	1.00
Stanislaus River	Fall	1,086	155	38	36	0.143	1.000	1.000	7.01
Tuolumne River	Fall	540	85	27	24	0.157	1.000	1.000	6.35
Merced River	Fall	651	132	49	46	0.203	1.000	1.000	4.93
American River	Late Fall	162	162	37	37	1.000	1.000	1.000	1.00
Sacramento River-Above Red Bluff	Late Fall	4,282	811	47	43	0.189	0.979	0.977	5.52
Inland Sport Harvest									
Sacramento River-Above Feather Confluence	Fall	2,080	187	23	21	0.090	1.000	1.000	11.12
Feather River	Fall	1,194	111	26	26	0.093	1.000	1.000	10.76
Sacramento River-Below Feather Confluence	Fall	2,008	126	45	44	0.063	1.000	1.000	15.94
American River	Fall	248	14	7	6	0.056	1.000	1.000	17.71
Sacramento River-Above Feather Confluence	Late Fall	1,117	144	87	86	0.129	1.000	0.989	7.85
	Total	**173,829**	**82,299**	**26,445**	**24,838**				

a/ Number of salmon visually checked for an ad-clip.

b/ Sample Fractions:

fe = fraction of total salmon escapement sampled and examined for ad-clipped fish.
fa = fraction of heads from ad-clipped salmon collected and processed.
fd = fraction of observed CWTs that were successfully decoded.

c/ Mokelumne River natural area includes expanded CWTs based on ad-clip count at Woodbridge dam weir.

Table 5. Catch estimates and sample data for 2010 ocean salmon sport and commercial fisheries by major port area.

Major Port Area	Total Harvest Estimate	Chinook Sampled[a/]	Observed Ad-Clips	Valid CWTs	Sample Fractions[b/] fe	fa	fd	Sample Expansion
Commercial								
Fort Bragg	12,577	7,563	1,018	858	0.601	0.993	1.000	1.67
San Francisco	1,086	856	81	69	0.788	1.000	1.000	1.27
Monterey	1,435	677	158	152	0.472	0.987	1.000	2.15
Sport								
Eureka/Crescent	720	168	36	25	0.233	1.000	1.000	4.29
Fort Bragg	1,702	499	95	89	0.293	0.989	1.000	3.45
San Francisco	5,927	2,149	478	454	0.363	0.985	0.998	2.81
Monterey	6,348	1,432	358	340	0.226	0.992	0.997	4.48
Total	**29,795**	**13,344**	**2,224**	**1,987**				

a/ Number of salmon visually checked for ad-clip

b/ Sample fractions:

fe = fraction of the total salmon sampled and examined for ad-clipped fish.
fa = fraction of heads from ad-clipped salmon collected and processed.
fd = fraction of observed CWTs that were successfully decoded.

Table 6. Raw and expanded CV coded-wire-tag (CWT) recoveries by stock and age, brood years 2004-2010.

Fall	2009	2008	2007	2006	2005	2004		
Age	1	2	3	4	5	6	Total CV CWTs	Total CV %
Raw CWT Recoveries	36	7,087	8,022	272	2		15,419	62%
	(< 1%)	(46%)	(52%)	(2%)	(< 1%)			
Expanded CWT$_{total}$	**137**	**29,451**	**63,868**	**2,197**	**2**		95,655	84%
	(< 1%)	(31%)	(67%)	(2%)	(< 1%)			

Spring	2009	2008	2007	2006	2005	2004		
Age	1	2	3	4	5	6	Total CV CWTs	Total CV %
Raw CWT Recoveries		306	3,340	91	1		3,738	15%
		(8%)	(89%)	(2%)	(< 1%)			
Expanded CWT$_{total}$		**608**	**10,582**	**308**	**1**		11,499	10%
		(5%)	(92%)	(3%)	(< 1%)			

Late Fall	2010	2009	2008	2007	2006	2005		
Age	1	2	3	4	5	6	Total CV CWTs	Total CV %
Raw CWT Recoveries		153	781	3,824	918	5	5,681	23%
		(3%)	(14%)	(67%)	(16%)	(< 1%)		
Expanded CWT$_{total}$		**334**	**1,358**	**4,093**	**1,122**	**5**	6,912	6%
		(5%)	(20%)	(59%)	(16%)	(< 1%)		

All Runs								
Age	1	2	3	4	5	6	Total CV CWTs	Total CV %
Raw CWT Recoveries	36	7,546	12,143	4,187	921	5	24,838	100%
	(< 1%)	(30%)	(49%)	(17%)	(4%)	(< 1%)		
Expanded CWT$_{total}$	**137**	**30,392**	**75,809**	**6,597**	**1,125**	**5**	114,066	100%
	(< 1%)	(27%)	(66%)	(6%)	(1%)	(< 1%)		

Table 7. Raw and expanded ocean coded-wire-tag (CWT) recoveries by stock and age, brood years 2004-2009.

Fall	2008	2007	2006	2005	2004	Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries	183	1,282	34			1,499	75%
	(12%)	(86%)	(2%)				
Expanded CWTtotal	**1,603**	**11,704**	**250**			13,557	62%
	(12%)	(86%)	(2%)				

Spring	2008	2007	2006	2005	2004	Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries	10	162	3			175	9%
	(6%)	(93%)	(1%)				
Expanded CWTtotal	**35**	**575**	**9**			619	3%
	(6%)	(93%)	(1%)				

Late Fall	2009	2008	2007	2006	2005	Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries		111	56	1	2	170	9%
		(65%)	(33%)	(< 1%)	(1%)		
Expanded CWTtotal		**1,358**	**4,093**	**1,122**	**5**	6,578	30%
		(21%)	(62%)	(17%)	(< 1%)		

Winter	2008	2007	2006	2005	2004	Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries	1	1				2	< 1%
	(50%)	(50%)					
Expanded CWTtotal	**4**	**2**				6	< 1%
	(67%)	(33%)					

Non CV Rivers	2008	2007	2006	2005	2004	Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries		84	56		1	141	7%
		(60%)	(40%)		(< 1%)		
Expanded CWTtotal		**523**	**509**		**2**	1,034	5%
		(51%)	(49%)		(< 1%)		

All Runs						Total CV CWTs	Total CV %
Age	2	3	4	5	6		
Raw CWT Recoveries	194	1,640	149	1	3	1,987	100%
	(10%)	(83%)	(7%)	(< 1%)	(< 1%)		
Expanded CWTtotal	**1,642**	**14,162**	**4,861**	**1,122**	**7**	21,794	100%
	(8%)	(65%)	(22%)	(5%)	(< 1%)		

Table 8. 2010 CWT recovery rate (recoveries per 100,000 CWTs released) by release type, brood year, and recovery location. (page 1 of 2)

Age 2 CV recoveries

Release	Brood	Run	# CWT	**Central Valley CWT$_{samp}$ recoveries by location**								**CV CWT$_{samp}$ totals**			**Ocean**	**Recovery Rate per 100,000 released**				**CV Stray**
type	year	type	tagged	Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	**CWT$_{samp}$**	Basin	Stray	CV total	Ocean	**Proportion**
FRHS	2008	Spr	1,015,717				284					284	284		12	28.0		28.0	1.2	0.00
FRHSn	2008	Spr	1,005,727		23		291	8	1			323	291	33	23	28.9	3.2	32.2	2.3	0.10
CFHFh	2008	Fall	3,128,111	2,196	23							2,219	2,219		102	70.9		70.9	3.3	0.00
CFHFn	2008	Fall	371,685	44	23	14	213	221	44	7	33	600	68	533	88	18.2	143.3	161.5	23.6	0.89
FRHFn	2008	Fall	2,061,211	17	12		2,297	70	13	1	13	2,423	2,297	126	163	111.4	6.1	117.6	7.9	0.05
FRHFe	2008	Fall	481,853				623	30				653	623	30	27	129.3	6.3	135.6	5.6	0.05
FRHFtib	2008	Fall	89,859	7			48	11				67	48	18	5	53.6	20.5	74.1	5.1	0.28
FeaFw	2008	Fall	289,830				12					12	12			4.2		4.2		0.00
NIMF	2008	Fall	264,006					88				88	88			33.5		33.5		0.00
NIMFn	2008	Fall	976,955		12		3	800	33	1		849	800	49	34	81.9	5.0	86.9	3.5	0.06
MOKFt	2008	Fall	250,300	2		4	3	151	2,176	111	158	2,606	2,176	430	107	869.4	171.8	1041.2	42.7	0.17
MokFw	2008	Fall	20,680						4			4	4		2	18.7		18.7	7.4	0.00
MERF	2008	Fall	32,978	4		6	36	23	100	31	78	278	31	247	4	93.5	749.6	843.0	11.3	0.89
CFHLh	2009	Late	1,115,378	130				1		2		133	130	3		11.7	0.3	12.0		0.02

Age 3 CV recoveries

Release	Brood	Run	# CWT	**Central Valley CWT$_{samp}$ recoveries by location**								**CV CWT$_{samp}$ totals**			**Ocean**	**Recovery Rate per 100,000 released**				**CV Stray**
type	year	type	tagged	Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	**CWTs**	Basin	Stray	CV total	Ocean	**Proportion**
ButSw	2007	Spr	311,061			5						5	5			1.7		1.7		0.00
FRHS	2007	Spr	1,378,941				4,804					4,804	4,804		195	348.4		348.4	14.1	0.00
FRHSn	2007	Spr	1,242,480	11	501	24	4,650	245	22		19	5,471	4,650	822	365	374.2	66.1	440.4	29.4	0.15
CFHFe	2007	Fall	196,993	68	175	5	55	20	1			323	243	81	30	123.1	40.9	164.0	15.2	0.25
CFHFh	2007	Fall	2,801,459	1,392	117	20						1,529	1,508	20	311	53.8	0.7	54.6	11.1	0.01
CFHFn	2007	Fall	314,681	2			33	73	15	6		130	2	128	101	0.6	40.5	41.2	32.1	0.98
FRHFe	2007	Fall	619,085		12		203	8				223	203	20	22	32.8	3.2	36.0	3.6	0.09
FRHFn	2007	Fall	2,347,396	18	373	39	10,339	390	39	25	6	11,230	10,339	891	1905	440.4	38.0	478.4	81.2	0.08
FRHFt	2007	Fall	101,712		12		101	10	3			125	101	24	15	99.1	23.8	122.9	14.7	0.19
FeaFw	2007	Fall	206,683				29					29	29			14.0		14.0		0.00
NIMFn	2007	Fall	1,714,858	2	12		6	1,159	457	43	48	1,727	1,159	568	646	67.6	33.1	100.7	37.7	0.33
NIMFtib	2007	Fall	51,600				3	140	386	59	7	594	140	454		270.8	880.7	1151.5		0.76
MOKF	2007	Fall	101,458					1	21			22	21	1	3	20.3	1.0	21.3	2.6	0.05
MOKFn	2007	Fall	550,668	2			29	148	278	22	35	514	278	236	126	50.4	42.9	93.3	22.8	0.46
MokFw	2007	Fall	315																	
CFHLh	2008	Late	1,072,854	711	6				1			718	717	1	261	66.8	0.1	66.9	24.4	0.00

Table 8. 2010 CWT recovery rate (recoveries per 100,000 CWTs released) by release type, brood year, and recovery location. (page 2 of 2)

Age 4 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT$_{samp}$ recoveries by location								CV CWT$_{samp}$ totals			Ocean	Recovery Rate per 100,000 released				CV Stray
type	year	type	tagged	Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	CWTs	Basin	Stray	CV total	Ocean	Proportion
ButSw	2006	Spr	279,936			5						5	5		2	1.9		1.9	0.6	0.00
FRHS	2006	Spr	1,004,683		12		53					65	53	12	6	5.3	1.2	6.4	0.6	0.18
FRHSt	2006	Spr	1,026,561		12		164	23				199	164	35		16.0	3.4	19.4		0.18
YubSw	2006	Spr	179,853				33					33	33		3	18.5		18.5	1.6	0.00
CFHFe	2006	Fall	196,108	1			9					10	1	9	2	0.5	4.7	5.2	0.8	0.90
CFHFh	2006	Fall	3,032,082	82	12	5						98	93	5	8	3.1	0.2	3.2	0.3	0.05
FRHFe	2006	Fall	564,904				29	3				32	29	3		5.1	0.5	5.6		0.09
FRHFn	2006	Fall	1,995,912	1	12	5	308	17	1			343	308	35	45	15.4	1.8	17.2	2.2	0.10
FRHFt	2006	Fall	305,755				2					2	2		5	0.7		0.7	1.5	0.00
FeaFw	2006	Fall	186,478																	
YubFw	2006	Fall	61,295																	
NIMFn	2006	Fall	1,527,846					36	8			44	36	8	4	2.4	0.5	2.9	0.3	0.18
MOKF	2006	Fall	925,826																	
MOKFn	2006	Fall	55,427					1				1		1	2		1.8	1.8	2.9	1.00
MOKFt	2006	Fall	281,582				1		1			2	1	1	2	0.5	0.4	0.8	0.6	0.44
MokFw	2006	Fall	10,968																	
MERF	2006	Fall	304,121																	
CFHLe	2007	Late	299,292	7	6			16	4			32	13	20	12	4.2	6.6	10.8	3.8	0.61
CFHLh	2007	Late	723,091	3,770	72			1				3843	3842	1	115	531.3	0.1	531.4	16.0	0.00

Age 5 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT$_{samp}$ recoveries by location								CV CWT$_{samp}$ totals			Ocean	Recovery Rate per 100,000 released			CV Stray
type	year	type	tagged	Battle ck	Up Sac	Nat crks*	Fea/Yub	Amer	Moke	Merc	Stan	CV total	Basin	Stray	CWT$_{samp}$	Basin	Stray	Ocean	Proportion
FRHS	2005	Spr	762,021				1					1	1			0.1			
FRHFt	2005	Fall	1,000,606				1	1				2	1	1		0.1	0.1		0.49
CFHLe	2006	Late	264,277	8	61			24				93	69	24		26.0	9.1		0.26
CFHLh	2006	Late	854,496	858	94							952	952		5	111.4		0.6	

* - Natural creeks include Clear Creek, Butte Creek, and Deer Creek.

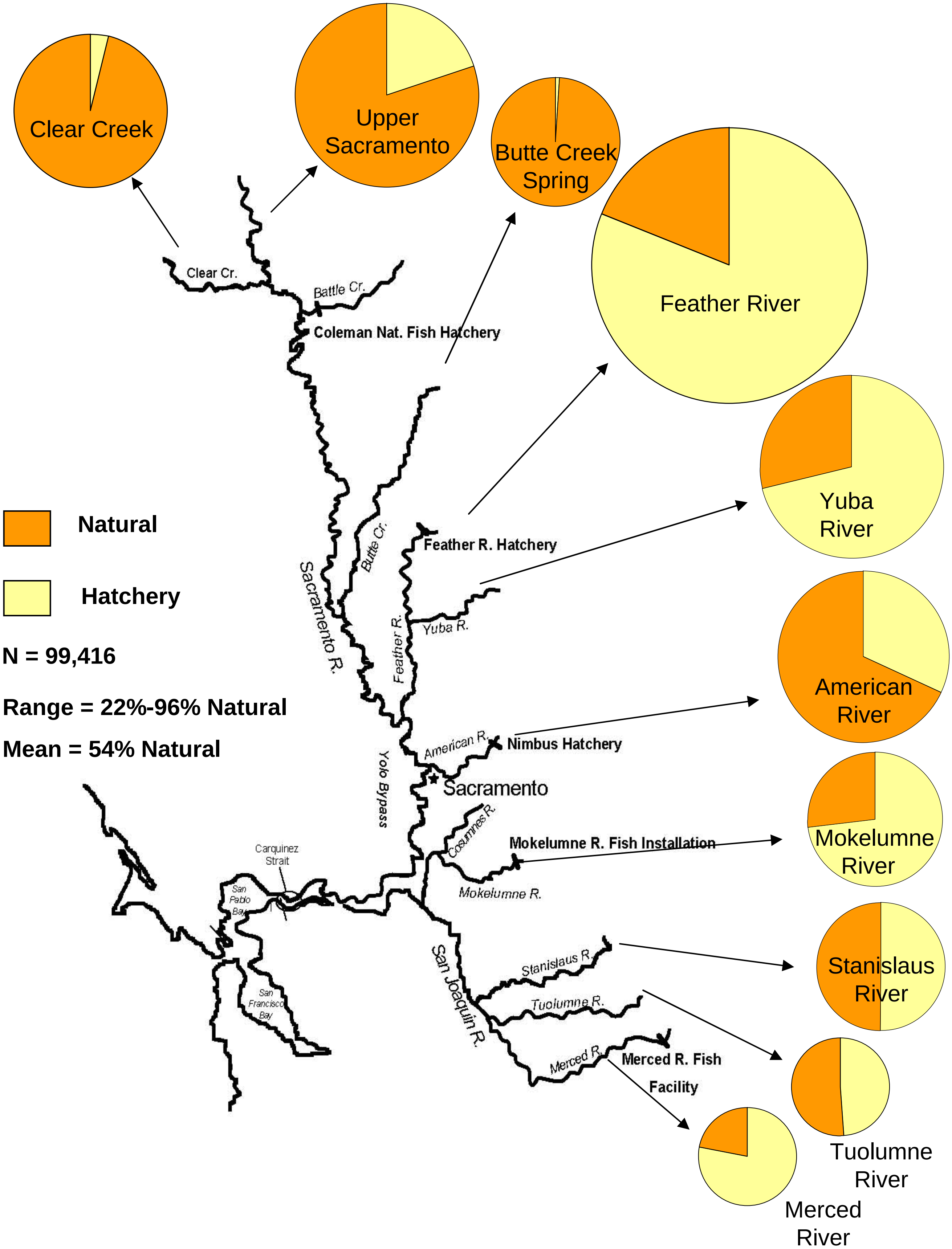


Figure 1. 2010 Fall Chinook Natural Area Escapement, Hatchery and Natural Proportions

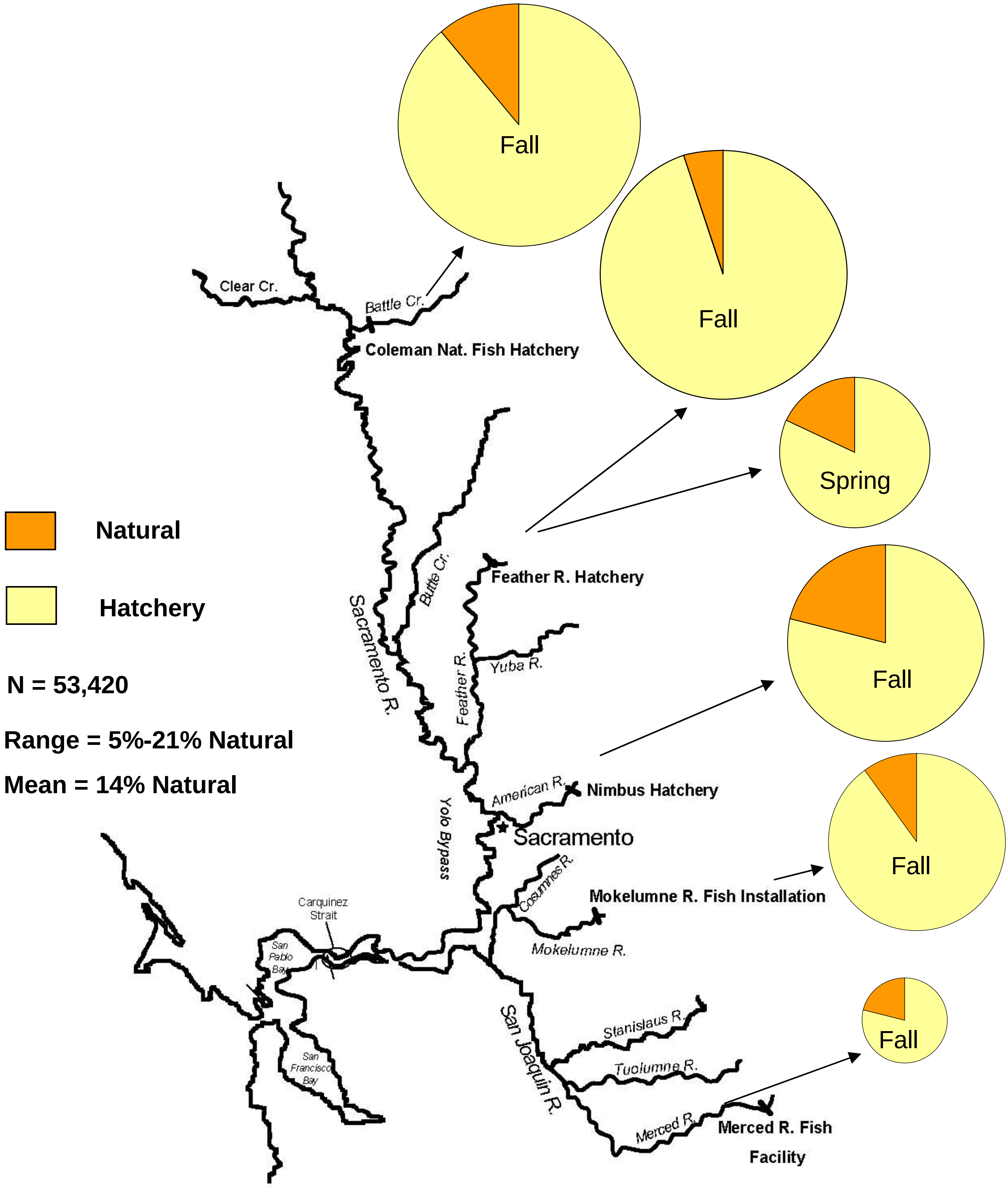


Figure 2. 2010 Fall Chinook Hatchery Escapement, Hatchery and Natural Proportions

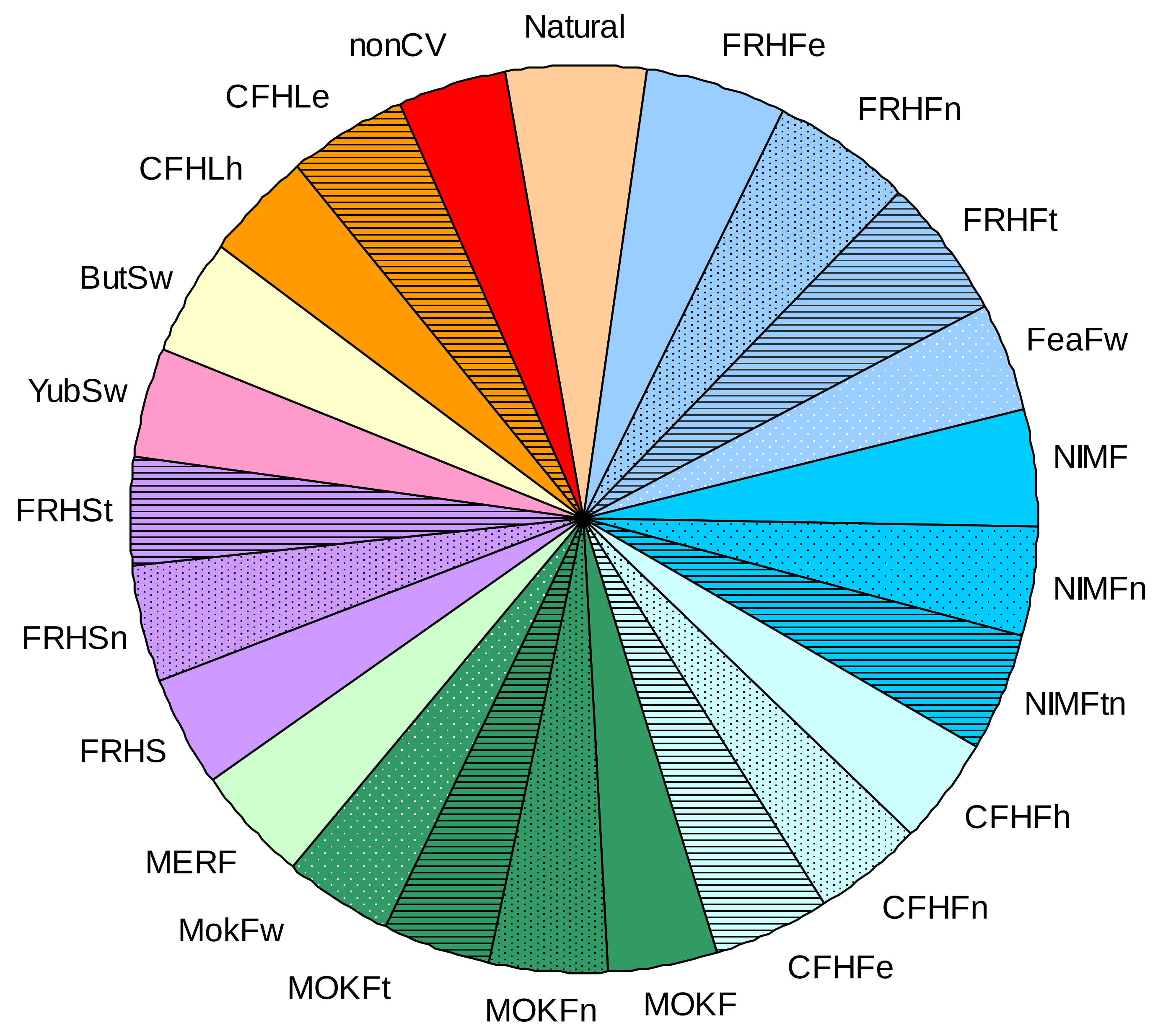


Figure 3. 2010 Central Valley hatchery release types color scheme.

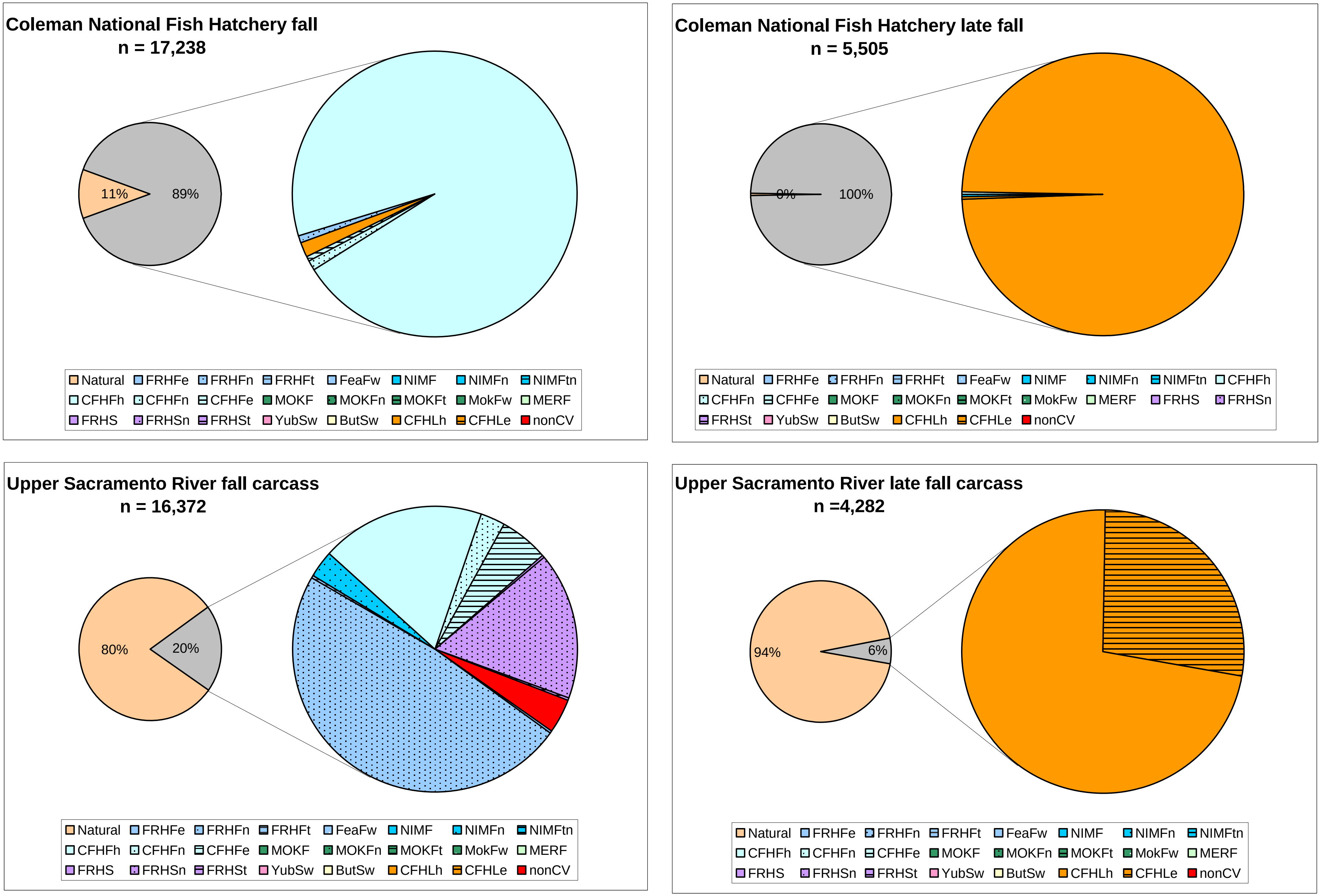


Figure 4. Proportion of hatchery and natural-origin fish in the Upper Sacramento River Basin.

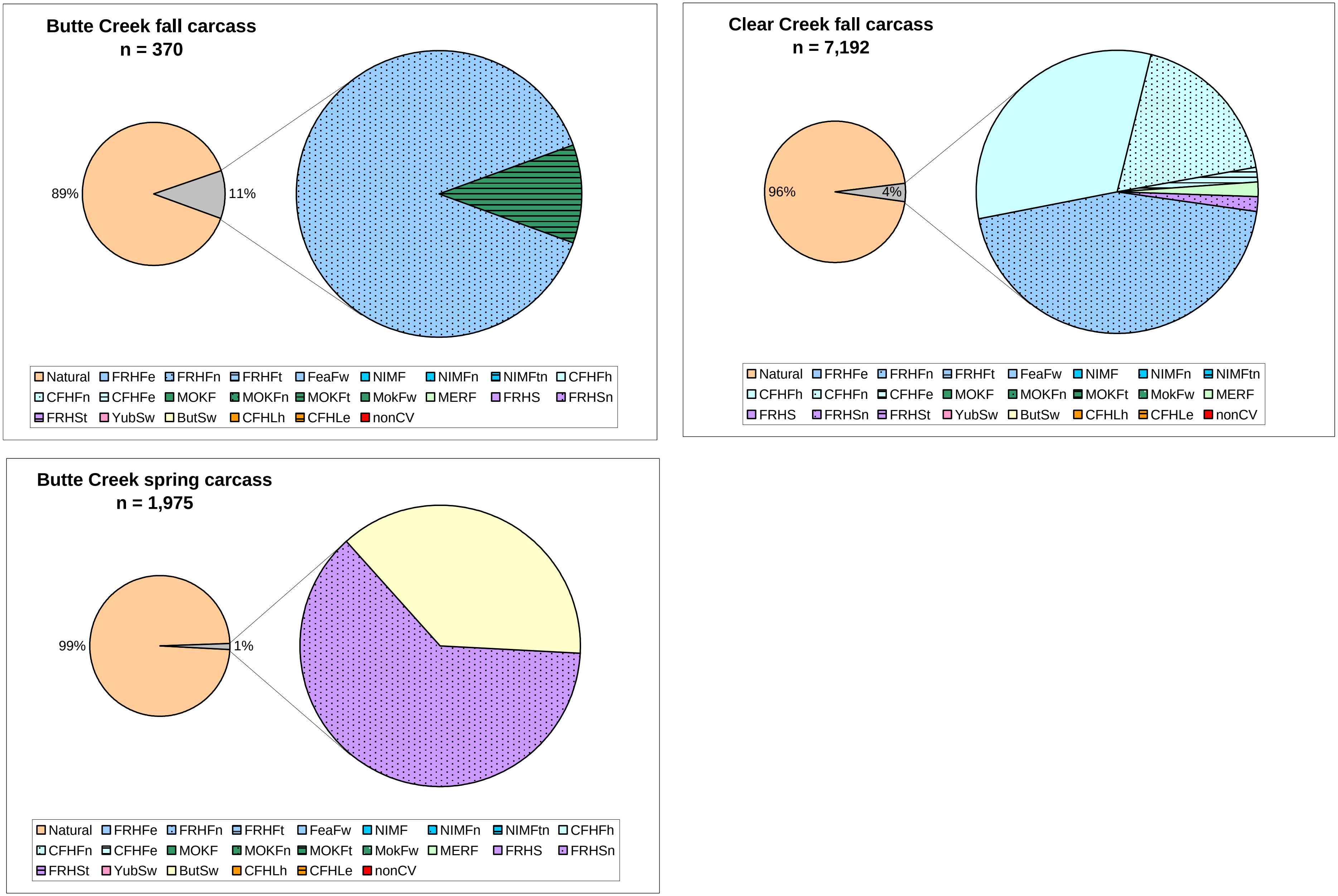


Figure 5. Proportion of hatchery and natural-origin fish in the Upper Sacramento River Basin.

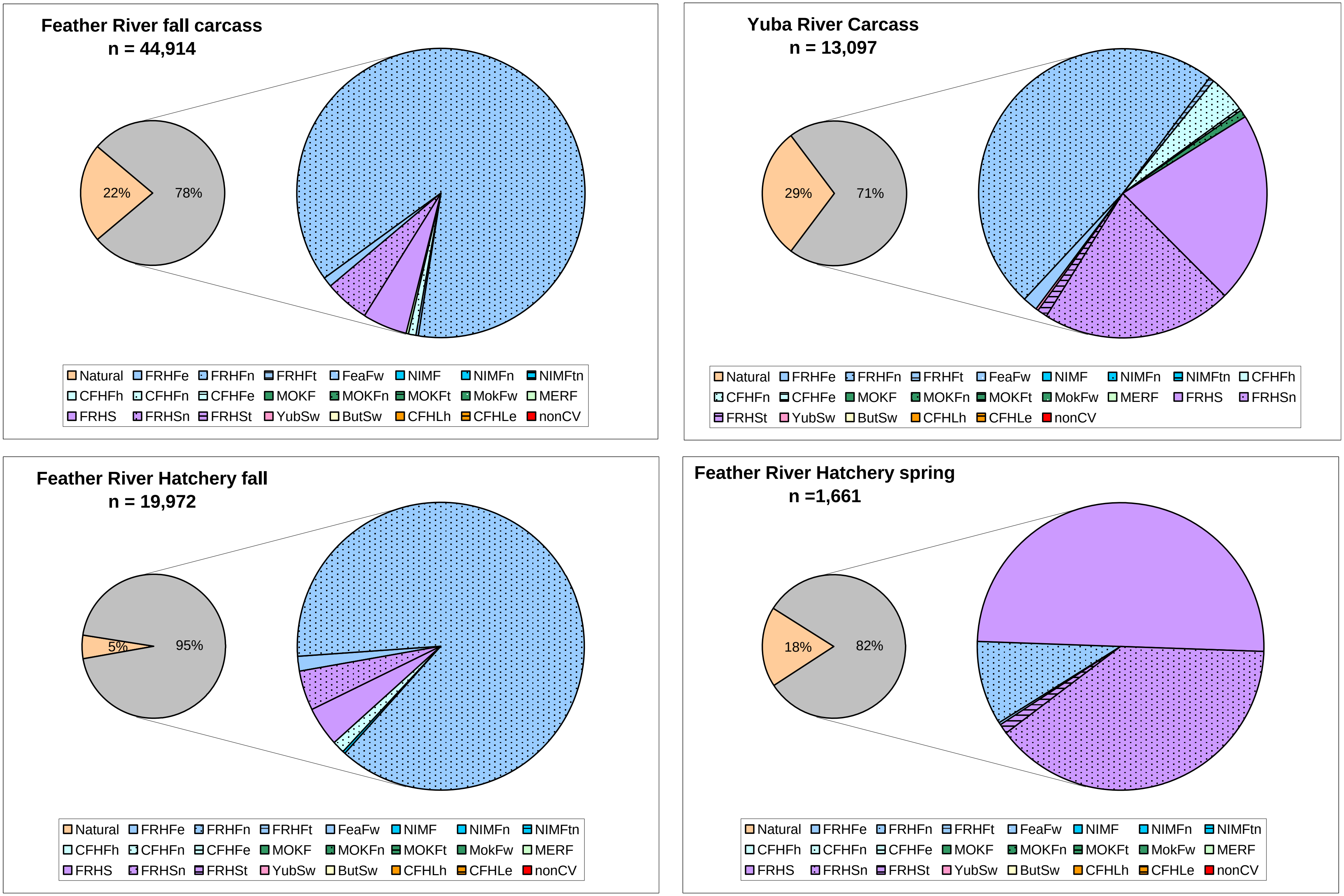


Figure 6. Proportion of hatchery and natural-origin fish in the Feather River Basin.

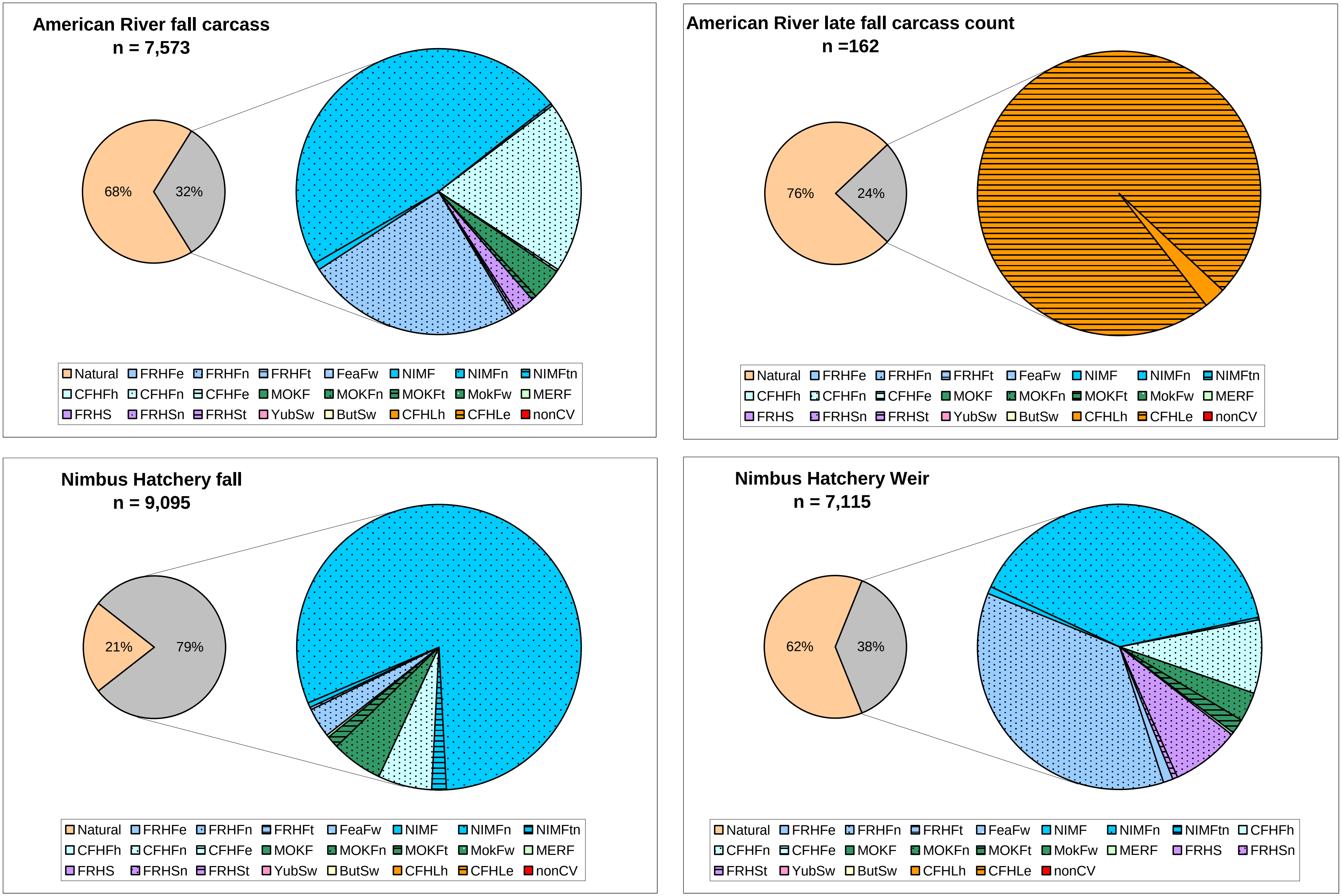
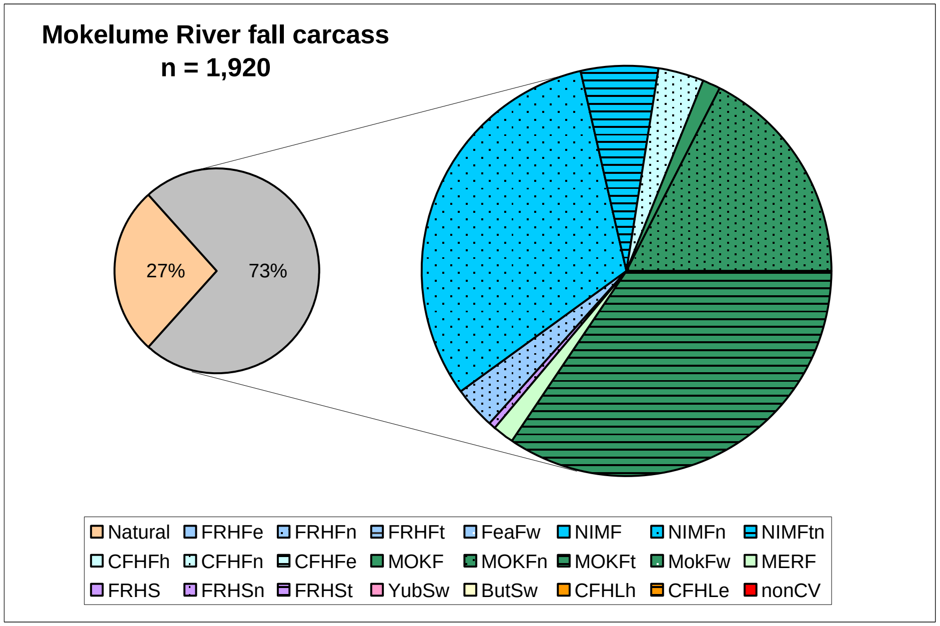
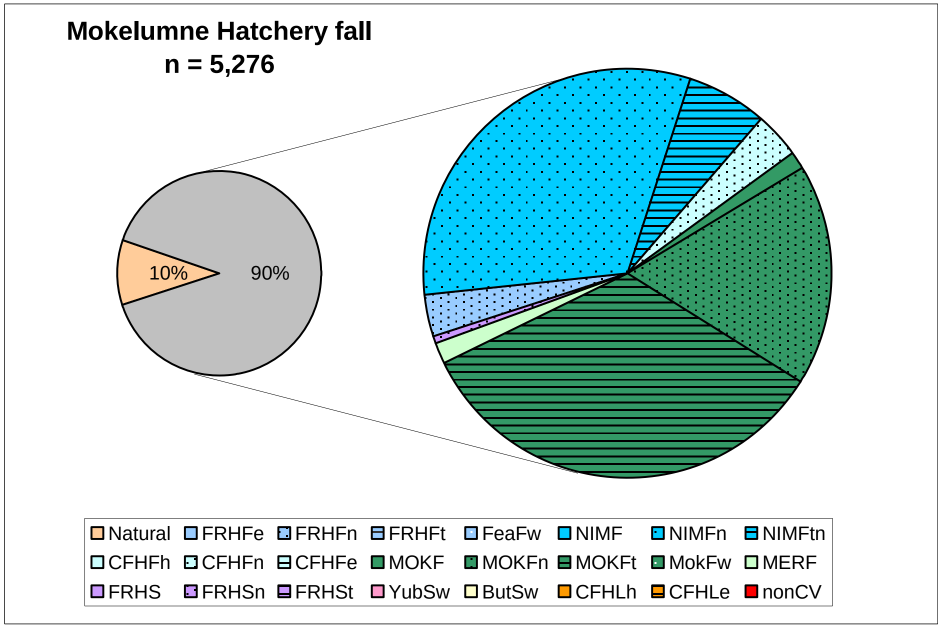


Figure 7. Proportion of hatchery and natural-origin fish in the American River Basin.





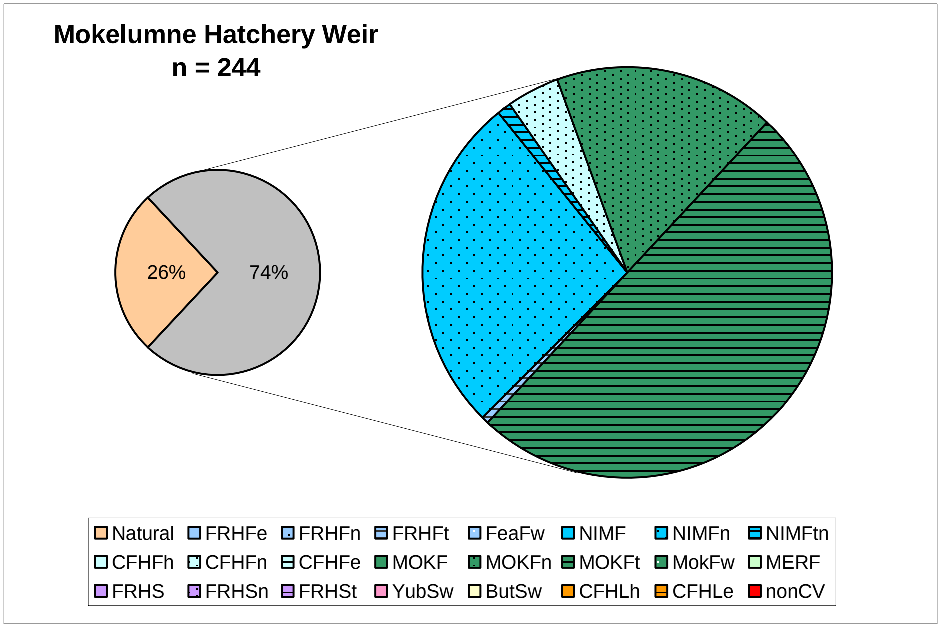


Figure 8. Proportion of hatchery and natural-origin fish in the Mokelumne River Basin.

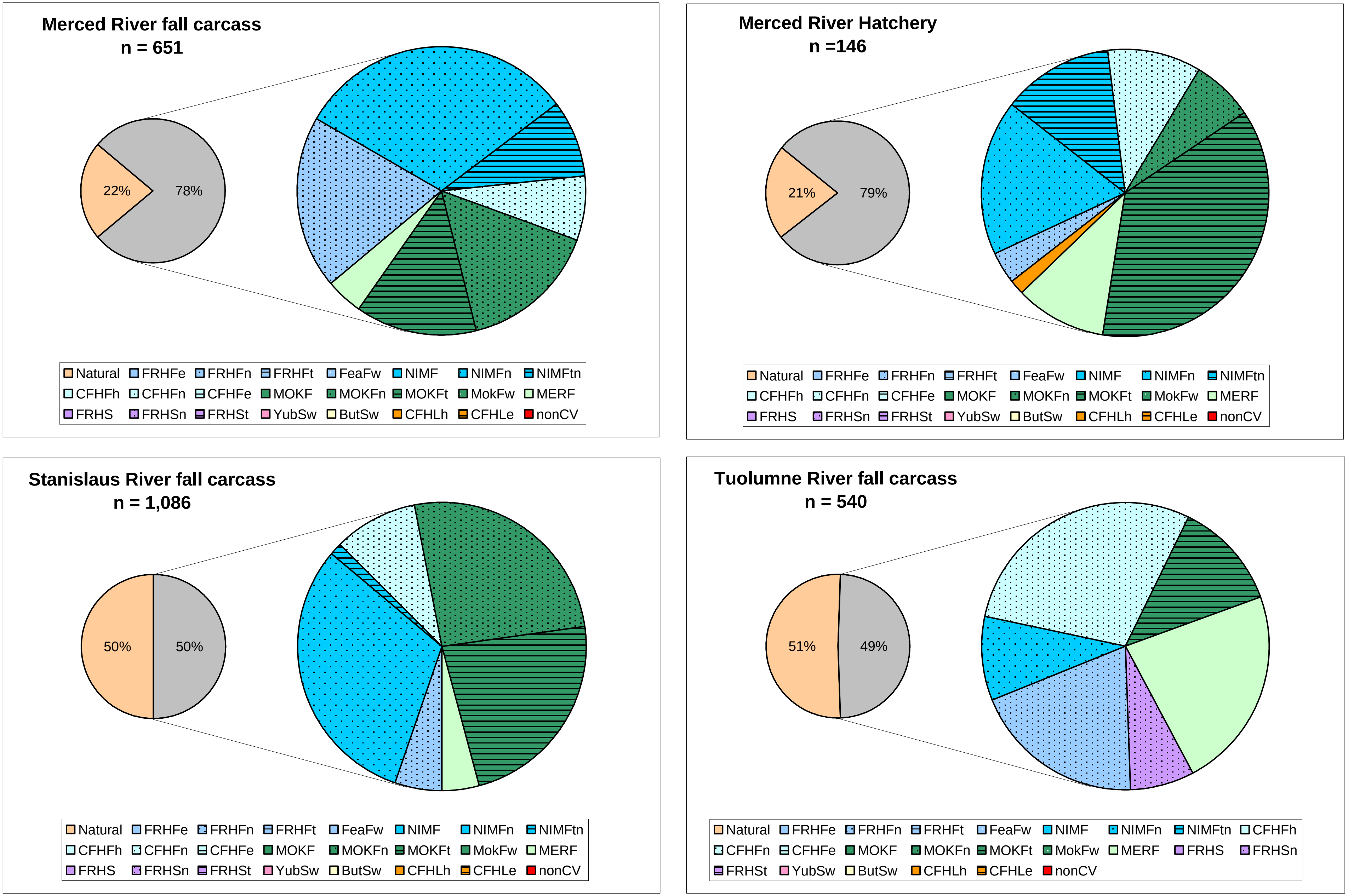
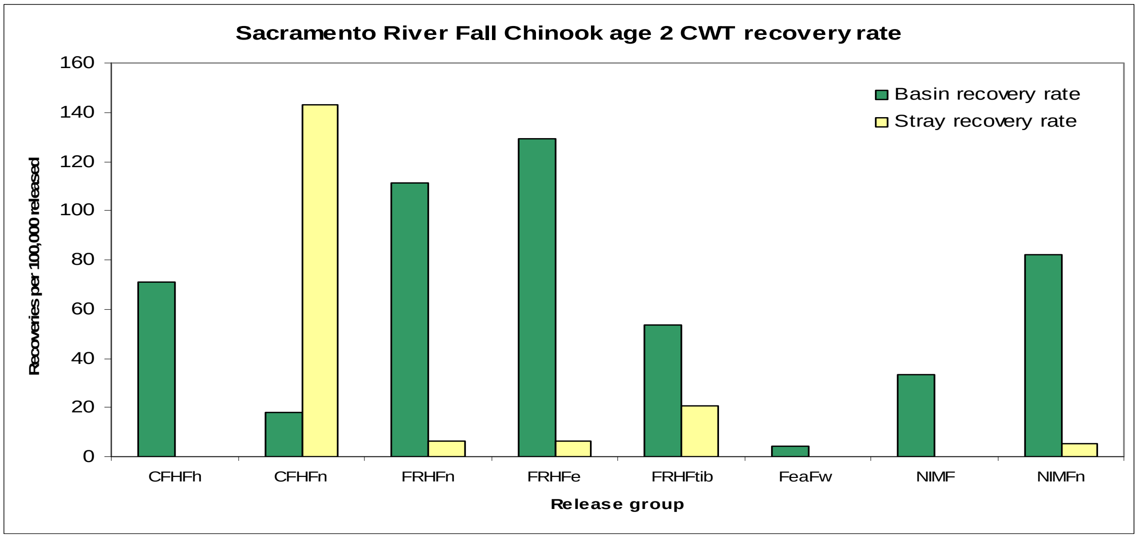
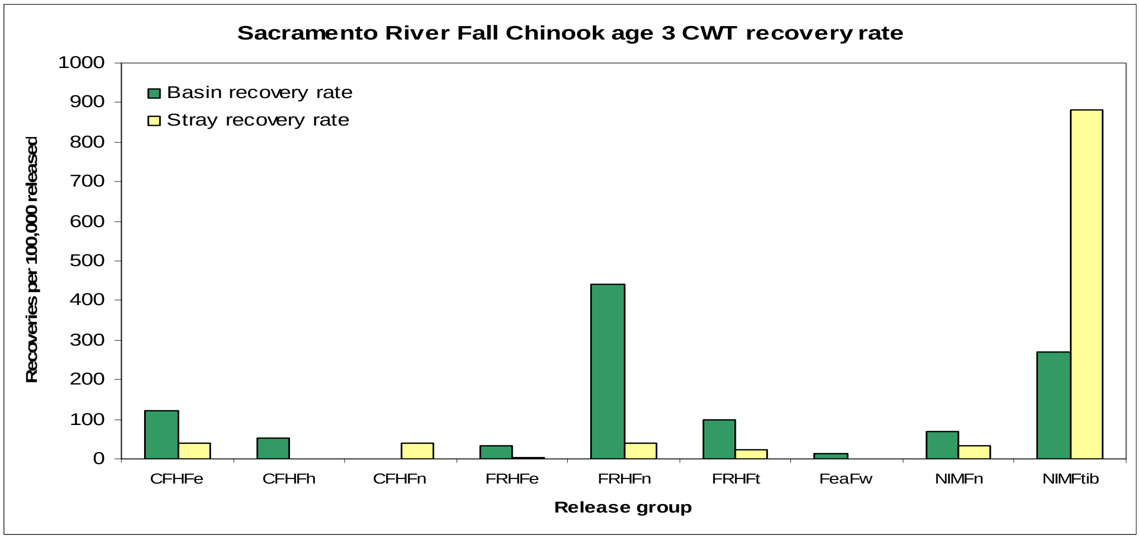


Figure 9. Proportion of hatchery and natural-origin fish in other San Joaquin River tributaries.





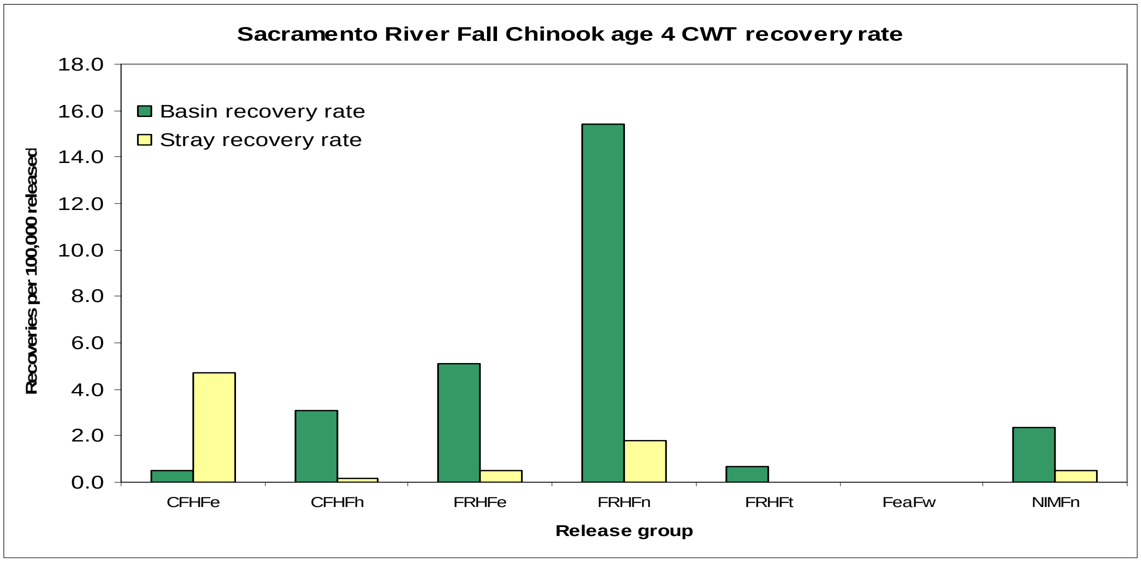
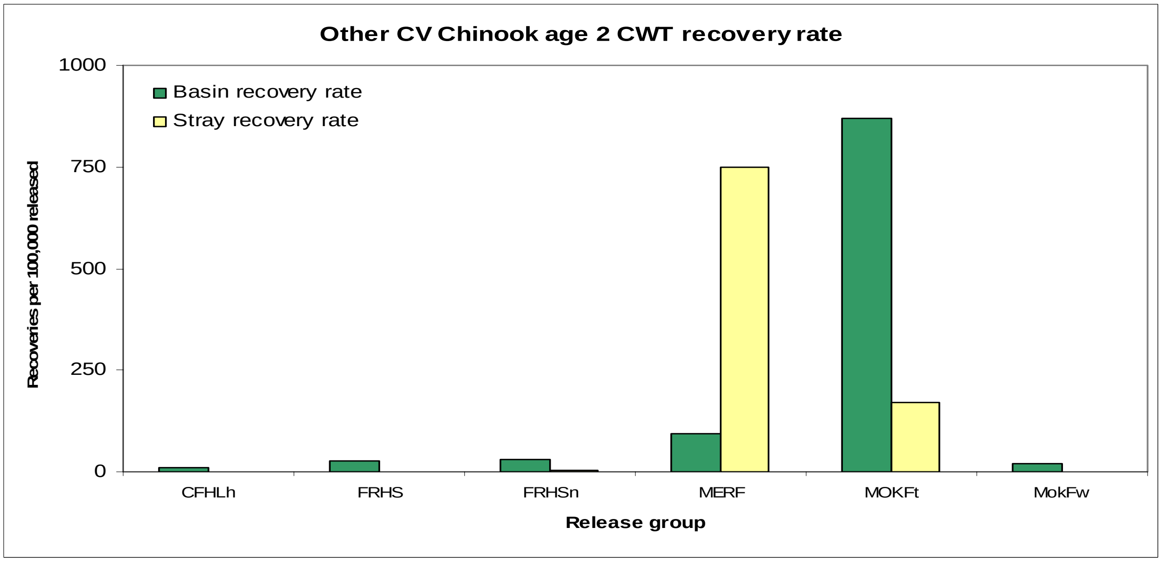
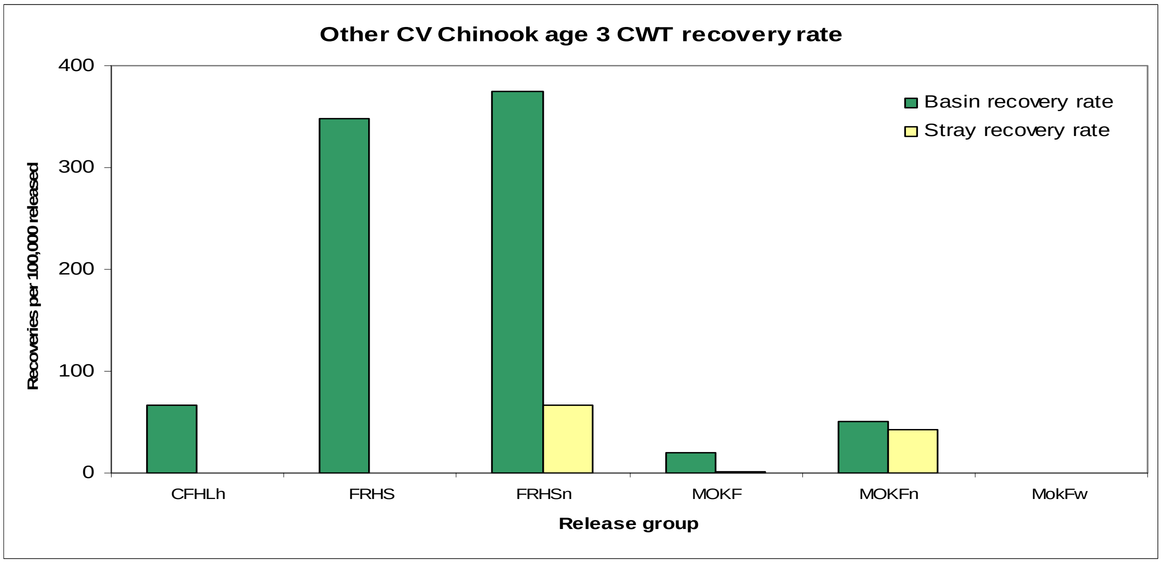


Figure 10. 2010 fall run Chinook recovery and stray rates in the Central Valley.





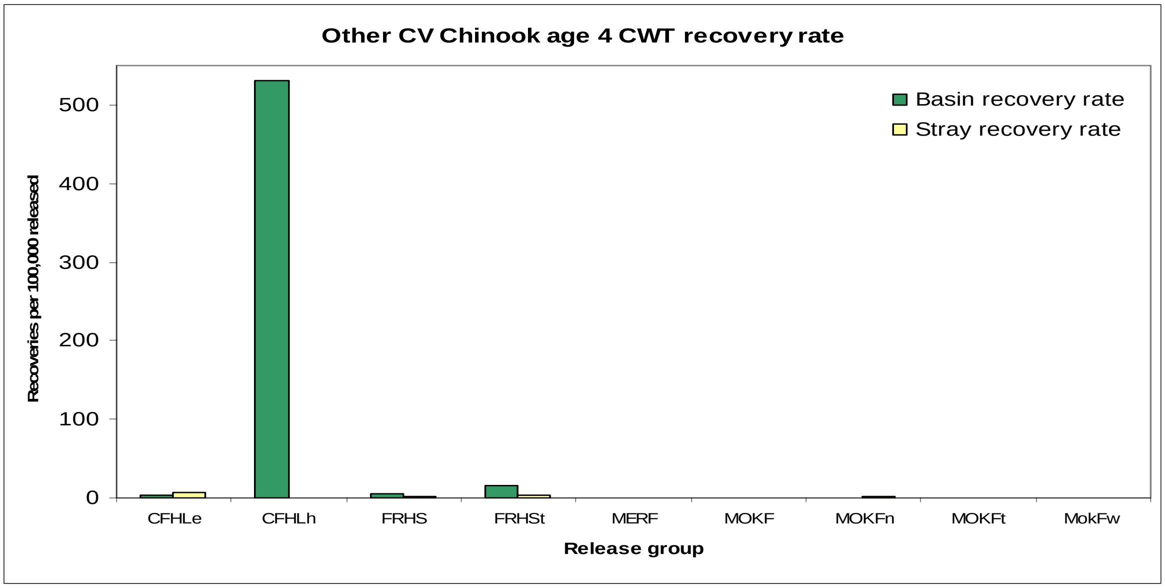
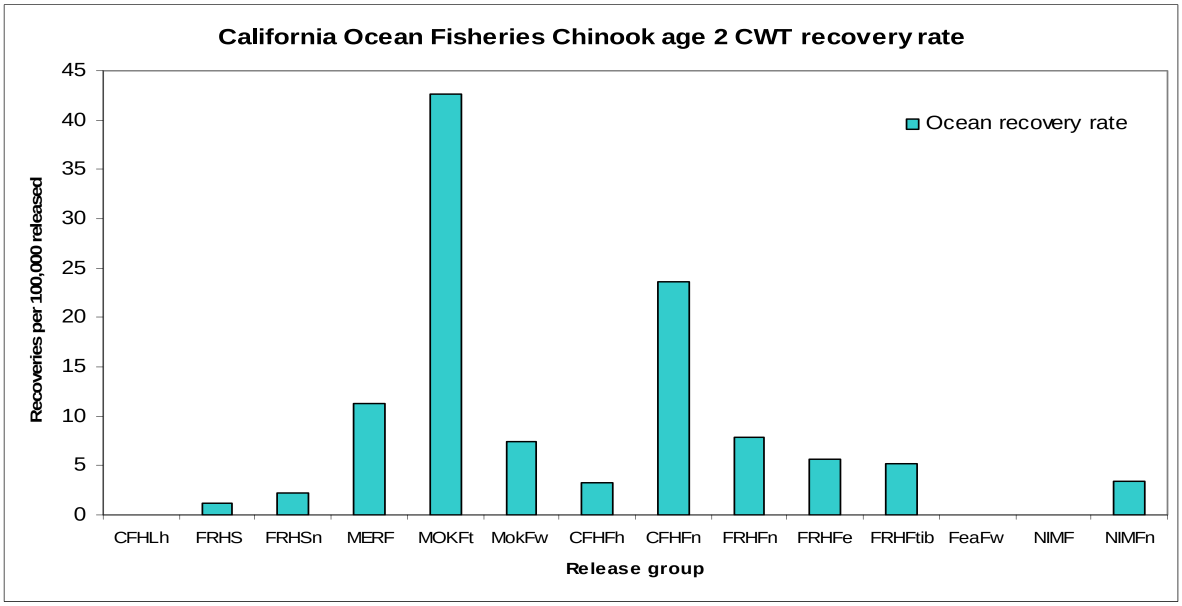
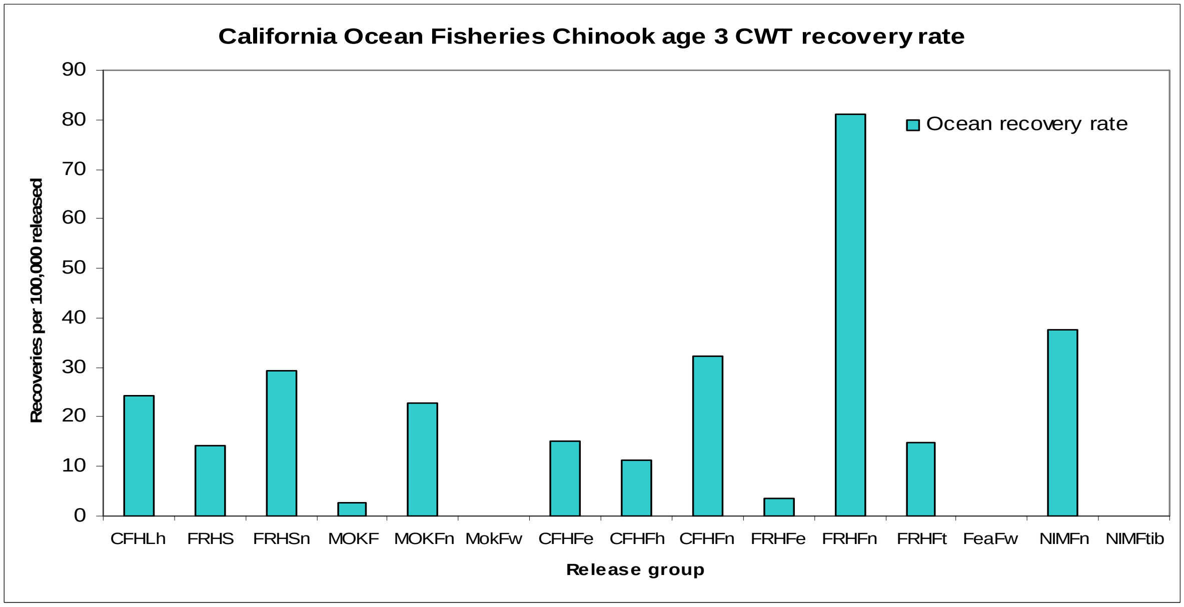


Figure 11. 2010 recovery and stray rates for other CV Chinook





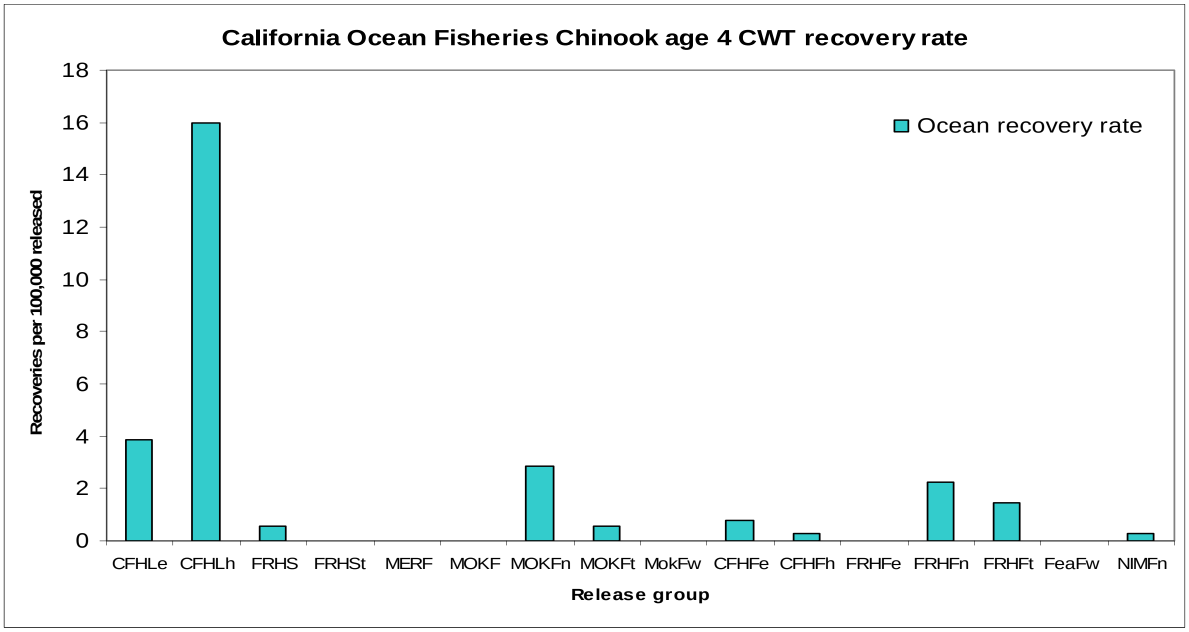


Figure 12. 2010 CV Chinook recovery rates in the ocean fishery.

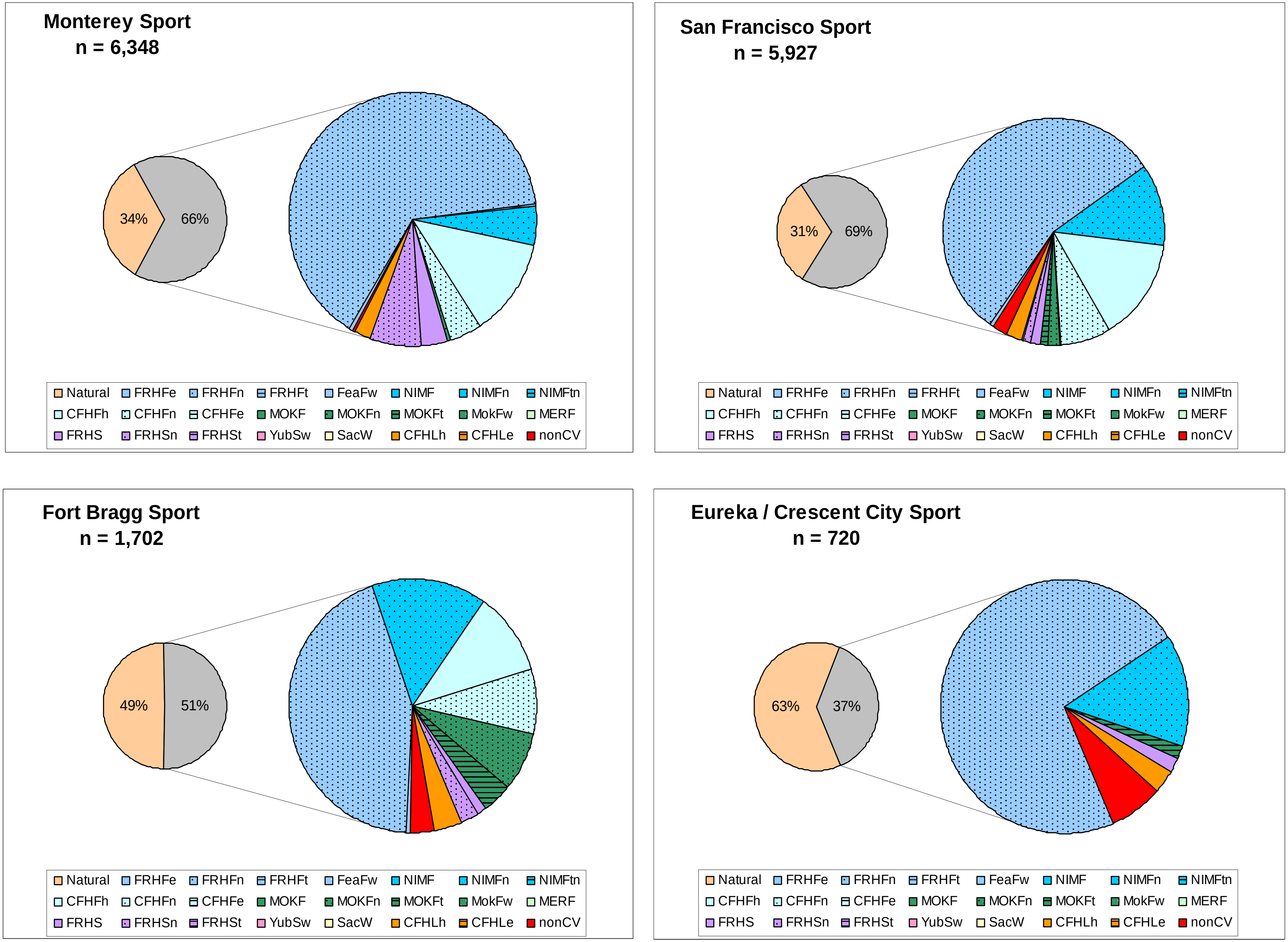


Figure 13. Proportion of hatchery and natural-origin fish in the 2010 ocean sport fishery.

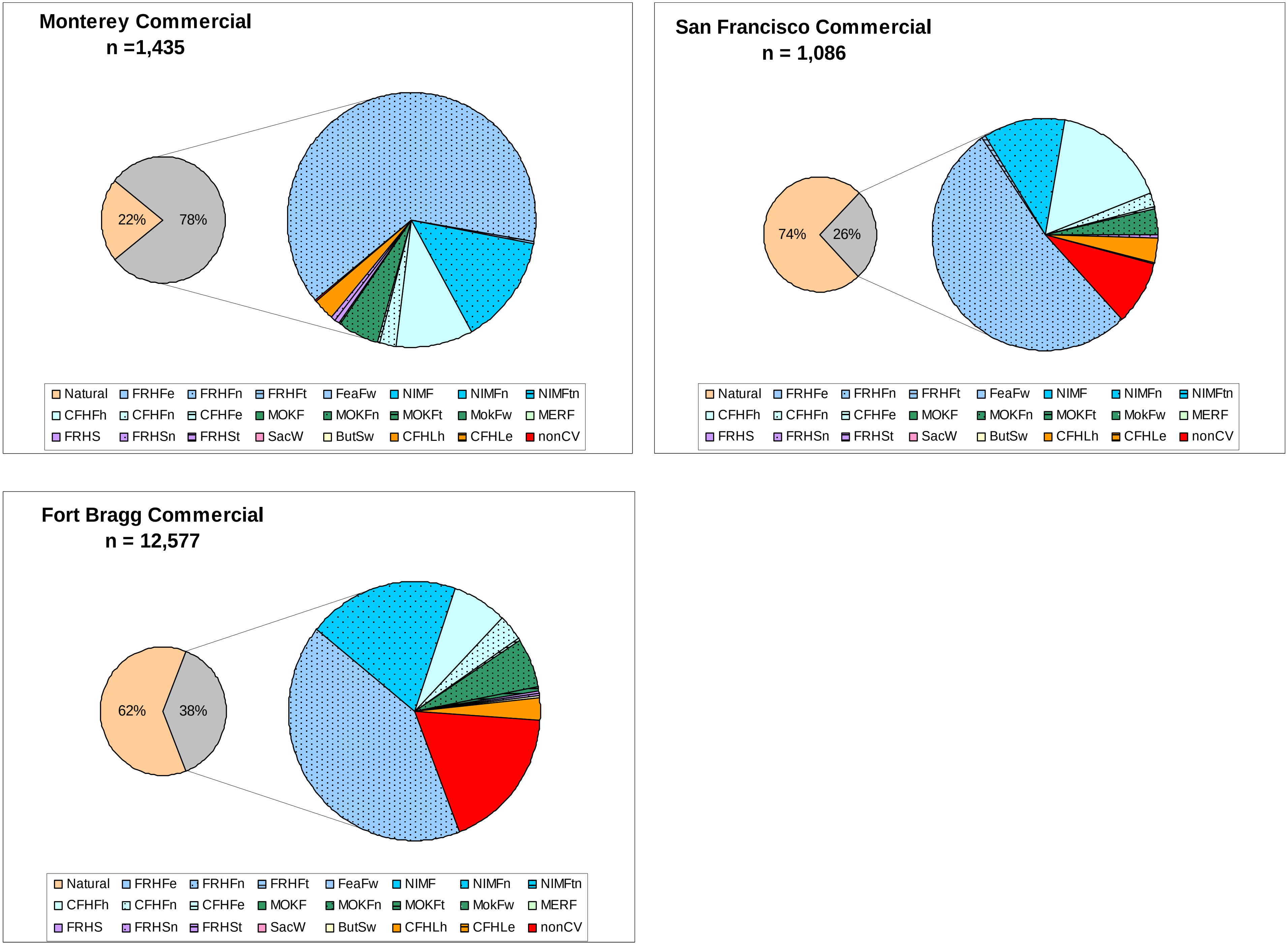


Figure 14. Proportion of hatchery and natural-origin fish in the 2010 ocean commercial fishery.

Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011

Melodie Palmer-Zwahlen[1] and Brett Kormos[1]
California Department of Fish and Wildlife

Fisheries Branch Administrative Report 2013-02

December 2013

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NOTE TO READERS

Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011 presents important data for the improvement of Central Valley salmon management. Until 2007, only experimental releases of fall-run Chinook salmon from Central Valley hatcheries were marked and coded-wire tagged (low, inconsistent numbers), resulting in a lack of data for harvest management, evaluation of hatchery rearing and release practices, hatchery impacts to natural-origin fish, and the success of habitat improvement programs.

The Central Valley Constant Fractional Marking Program (CFM) was initiated in 2007 to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed in the Central Valley. Beginning with Brood Year 2006 fall-run Chinook, the program has marked and coded-wire tagged a minimum of 25 percent of releases from the Central Valley hatcheries each year (Buttars 2007, 2008, 2009, and 2010). The program is a cooperative effort of the California Department of Fish and Game (DFG), the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service (FWS), the East Bay Municipal Utilities District (EBMUD), and the Pacific States Marine Fisheries Commission (PSMFC).

In 2011, more than 55,300 Code Wire Tags were recovered from ad-clipped Chinook sampled in Central Valley natural area spawning surveys, at Central Valley hatcheries, Central Valley river creel surveys, and California commercial and recreational ocean fisheries. All of the fall run Chinook Code Wire Tags recovered in the Central Valley were tagged as part of the CFM program.

This report evaluates the 2011 Central Valley fall, spring, and late fall runs Chinook Code Wire Tags recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this second complete year of recovery data:

- What are the proportions of hatchery- and natural-origin fish in spawning returns to CV hatcheries and natural areas, in inland harvest, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?

- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Strait? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released. In addition, salmon trucked to and held for several days in coastal net pens before release are also evaluated.

- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Strait?

- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

As with all of its products, Fisheries Branch is interested in comments on the utility of this document, particularly regarding its application to monitoring and management decision processes. Therefore, we encourage you to provide us with your comments. Comments should be directed to Dr. Russell J. Bellmer, Fisheries Branch, 830 S Street, Sacramento, CA 95814, (916) 327-8840, Russ.Bellmcr@ wildlife.ca.gov.

Stafford Lehr
Chief, Fisheries Branch

INTRODUCTION

Each year, approximately 32 million fall-run Chinook salmon (salmon) are produced at five hatcheries in California's Central Valley (CV): Coleman National Fish Hatchery (CNFH), Feather River Hatchery (FRH), Nimbus Fish Hatchery (NFH), Mokelumne River Hatchery (MOK), and Merced River Hatchery (MER). Production from these hatcheries contributes to major sport and commercial fisheries in ocean and inland areas. Prior to 2007, only small experimental releases (generally <100,000 fish) of CV fall-run salmon were consistently released with microscopic (≤ 1 mm) coded-wire tags (CWT) inserted in their snouts. Each CWT contains a binary or alpha-numeric code that identifies a specific release group of salmon (e.g., agency, species, run, brood year, hatchery or wild stock, release size, release date(s), release location(s), number tagged and untagged). Any CV salmon containing a CWT is also externally marked with a clipped adipose fin (ad-clipped) to allow for visual identification. Almost all of the fall-run salmon production releases from CV hatcheries were either untagged or tagged at inconsistent and relatively low rates prior to the Constant Fractional Marking (CFM) program.

In 2004, the CALFED Ecosystem Restoration Program (ERP), under the direction of the Central Valley Salmon Project Work Team (CVSPWT), funded a study to design a constant fractional marking and coded-wire tagging program for CV fall-run salmon production at all CV hatcheries. The primary goal of this program was to estimate in a statistically valid manner the relative contribution of hatchery production and to evaluate the various release strategies being employed throughout the CV. The study recommended the implementation of a system-wide marking and tagging program for production releases. Planning studies indicated an optimum marking and tagging rate of 33% for all CV fall-run salmon production releases (Hicks et al. 2005). Following subsequent review of the planning study recommendations, and communication with managers in the Northwest, the CVSPWT recommended a marking and tagging rate of 25% of fall-run production releases. The CVSPWT is an interagency group tasked with coordinating salmon and steelhead monitoring activities in the CV and they helped develop the CFM program. CVSPWT members included staff from the California Department of Fish and Wildlife (CDFW), California Department of Water Resources (DWR), East Bay Municipal Utility District (EBMUD), Metropolitan Water District, Central Valley Project Water Association, National Marine Fisheries Service (NMFS), Pacific States Marine Fisheries Commission (PSMFC), U.S. Bureau of Reclamation (BOR), and the U.S. Fish and Wildlife Service (FWS).

Beginning with brood year 2006, at least 25% of fall-run salmon production releases at CNFH (12-13 million), FRH (9-10 million), NFH (5-6 million), and MOK (4-5 million) have been marked and tagged each spring (Buttars 2007, 2008, 2009, 2010, 2011). This CFM program is a cooperative effort of the CDFW, DWR, BOR, FWS, EBMUD, and PSMFC. It should be noted that due to extremely low production numbers, MOK marked and tagged 100% of their fall-run salmon releases for brood years 2008 and 2009. In addition, almost all of the fall-run salmon production at MER (50,000-300,000 fish), spring-run salmon production at FRH (2 million fish), late-fall-run salmon production at CNFH (1 million fish), and winter-run salmon production reared at Livingston Stone National Fish Hatchery (100,000-200,000 fish) have been marked and coded-wire tagged each year.

During 2011, more than 55,300 CWTs were recovered from ad-clipped salmon sampled in CV fall-, spring-, and late-fall-run natural area spawning surveys, at CV hatcheries, in CV river creel surveys, and in California ocean commercial and recreational fisheries. All of the fall-run salmon CWTs recovered in 2011 were tagged as part of the CFM program. This report evaluates the 2011 CV fall-, spring-, and late-fall-run salmon CWT recovery data in accordance with program objectives. In particular, this report attempts to answer the following questions with this second complete year of recovery data:

- What are the proportions of hatchery- and natural-origin fish in spawning returns to CV hatcheries and natural areas, in inland harvest, and in ocean harvest? Of the hatchery proportions, what proportions originated from in-basin versus out-of-basin CWT recoveries?

- What are the relative recovery and stray rates for hatchery fish released in-basin versus salmon trucked to and released into the waters of the Carquinez Strait? The latter includes salmon acclimated in net pens that are pulled for several hours into San Pablo Bay before fish are released. In addition, salmon trucked to and held for several days in coastal net pens before release are also evaluated.

- What are the relative recovery rates for fish acclimated in net pens and released in the bay versus salmon released directly into the waters of the Carquinez Strait?

- What are the relative contribution rates of hatchery fish, by run and release type, to the ocean harvest?

DATA AND METHODS

Inland Escapement Monitoring

During 2011, monitoring of salmon escapement occurred at all five salmon hatcheries and on major rivers and tributaries throughout the CV. In addition, creel surveys were conducted on sport fisheries in the Feather, American, and Sacramento River basins. Returning salmon were counted and 100% of the ad-clipped salmon sampled at all CV hatcheries except CNFH, which sampled every other ad-clipped salmon (i.e., 50% sample rate) for fall-run escapement and 100% of ad-clipped salmon for the late-fall-run escapement. Similar to 2010, sample rates and methods (e.g., carcass surveys, weir counts, redd counts) varied among natural spawner surveys throughout the CV (Table 1).

Approximately 52,900 ad-clipped salmon were observed and 48,138 heads collected by various CV projects. Monitoring agencies include CDFW, DWR, EBMUD, FWS, and PSMFC. Most heads were processed by CDFW at their Santa Rosa and Sacramento CWT labs with the exception of approximately 9,500 heads collected from Clear Creek and CNFH that were processed by FWS staff at the Red Bluff FWS office. Additionally a few hundred heads were processed by individual projects, most notably at the Red Bluff and La Grange CDFW offices. Their respective data were submitted to the Santa Rosa CWT Lab for inclusion in the 2011 CV CWT recovery database. Almost 97% (46,596) of these heads contained valid CWTs, 2% of heads had shed their CWTs prior to processing, and less than 1% contained CWTs that were either too damaged to read or lost during processing.

Total escapement estimates and the number of salmon sampled for ad-clips in this report were provided by individual CV projects or hatcheries. These data, along with their respective CWT recovery data, were uploaded to the Regional Mark Processing Center (RMPC) and are readily accessible at www.rmpc.org.

Ocean Harvest Monitoring

Since 1962, the CDFW's Ocean Salmon Project (OSP) has monitored California's ocean salmon fisheries at approximately 20 ports between Point Conception and the California-Oregon border. The goal of OSP is to sample at least 20% of all salmon landed and to collect the heads from all ad-clipped salmon observed during monitoring. In 2011, the seasons for California sport and commercial ocean salmon fisheries were less constrained (Table 2) than in recent years due to an increase in the ocean abundance of both Sacramento River and Klamath River fall-run salmon. Field staff sampled more than 47,600 salmon and collected 9,768 heads that were processed by the Santa Rosa CWT lab. About 90% (8,717) of these heads contained valid CWTs, 10% were missing CWTs and <1% contained CWTs that were too damaged to read or lost during processing. Although it is generally agreed that CWTs missing from inland head recoveries is the result of salmon "shedding" these tags prior to release, this cannot be assumed for heads recovered from mixed-stock ocean fisheries. Oregon and Washington hatcheries have been "mass-marking" salmon (i.e., ad-clip only without a CWT) to support small mark-selective fisheries in the northwest. During the last several years, OSP has noticed a gradual increase in the number of ocean heads collected that do not contain CWTs, especially in California's northern ports, and assume that this is due to the increased production of mass-marked salmon in Oregon and Washington.

CWT Data Analysis

A "master" release database of CWT codes was created to determine species, brood year, run, stock origin (hatchery or natural), release site, release date(s), number of salmon CWT tagged, total number of salmon released and any other pertinent release information (e.g., trucked, net pen acclimation, disease) for all 2011 CWT recoveries. All west coast CWT release data for broods 2007 through 2010 were downloaded from the RMPC. Approximately 100.6 million CV salmon were released for these four brood years (BY), of which, 38.5 million fish were marked and tagged utilizing 444 unique CWT codes. Although a few natural-origin salmon are trapped, marked, and tagged each year, salmon produced by hatcheries make up more than 98% of all CWT releases. In 2011, there were 310 individual CWT codes recovered in the CV, primarily from age-2, age-3 and age-4 salmon. The CWT master file was updated with any additional information obtained for these CV salmon releases (e.g., number of untagged salmon associated with BY 2008 fall-run CNFH production CWT releases) and the production factor calculated for each CWT code. The production factor, $F_{prod,}$ is the total number of fish released (tagged and untagged) represented by each CWT recovery. F_{prod} was calculated for each CWT code and is defined as,

$$F_{prod} = (\text{Ad.CWT} + \text{Ad.noCWT} + \text{noAd.CWT} + \text{noAd.noCWT}) \ / \ \text{Ad.CWT}\ ,$$

where Ad.CWT is the number of fish released with ad-clips and CWTs, Ad.noCWT is the number of fish released with ad-clips but without CWTs (i.e., shed tags prior to release or CWT not correctly inserted), noAd.CWT is the number of fish released without ad-clips but with CWTs, and noAd.noCWT is the number of fish released without ad-clips and without CWTs. F_{prod} allows expansion to total hatchery production from observed recoveries of CV CWTs.

For this analysis, each CV CWT release was further classified into "release types" based on the following criteria: run, stock, hatchery or natural, production or experimental, release location, and holding strategy. All CV CWT codes were assigned by brood year into one of 17 fall-run release types, 3 spring-run release types, or 2 late-fall-run release types:

Sacramento River Basin fall-run Chinook salmon release types

CFHFe	Coleman National Fish Hatchery fall-run experimental releases
CFHFh	Coleman National Fish Hatchery fall-run in-basin (at hatchery) releases
CFHFn	Coleman National Fish Hatchery fall-run net pen releases
FRHFe	Feather River Hatchery fall-run experimental releases (includes fall x spring hybrid salmon)
FRHFn	Feather River Hatchery fall-run net pen releases
FRHFnc	Feather River Hatchery fall-run net pen coastal releases (Santa Cruz)
FRHFt	Feather River Hatchery fall-run trucked releases (no net pen acclimation)
FRHFtib	Feather River Hatchery fall-run Tiburon net pen releases (held 2-6 months)
FeaFw	Feather River fall-run wild
NIMF	Nimbus Fish Hatchery fall-run in-basin releases
NIMFn	Nimbus Fish Hatchery fall-run net pen releases
NIMFtib	Nimbus Fish Hatchery fall-run Tiburon net pen releases (held 3-4 months)

San Joaquin River Basin fall-run Chinook salmon release types

MOKF	Mokelumne River Hatchery fall-run in-basin releases
MOKFn	Mokelumne River Hatchery fall-run net pen releases
MOKFt	Mokelumne River Hatchery fall-run trucked releases (no net pen acclimation)
MokFw	Mokelumne River fall-run wild
MERF	Merced River Fish Facility fall-run releases (primarily in-basin)

Central Valley spring-run Chinook salmon release types

FRHS	Feather River Hatchery spring-run in-basin releases
FRHSn	Feather River Hatchery spring-run net pen releases
ButSw	Butte Creek spring-run wild

Central Valley Late-Fall-run Chinook salmon release types

CFHLe	Coleman National Fish Hatchery late-fall-run experimental releases
CFHLh	Coleman National Fish Hatchery late-fall-run in-basin (at hatchery) releases

It should be noted that not all release types occurred every brood year and release sites sometimes varied within a given release type (Table 3). There were also several problem CWT releases where stock origin did not match hatchery origin (e.g., BY 2007 American River fall-run salmon raised at MOK), stocks or runs were mixed prior to CWT tagging and released utilizing various strategies (e.g., known pairs of FRH fall- and spring-run salmon spawned and identified by CWT subsequently released as experimental "hybrid" salmon for Delta studies), or a high percentage of the salmon trucked for net pen acclimation actually died prior to release (e.g., 75% mortality reported in truckload of CNFH fall-run salmon being transported to San Pablo Bay net pens).

To estimate the total escapement (or harvest) associated with each CWT recovery, each tag recovery was expanded by its respective F_{prod} and sample expansion factor, F_{samp}, which is defined as,

$$F_{samp} = 1 / (f_e \times f_a \times f_d),$$

where f_e is the fraction of the total salmon escapement sampled and examined for ad-clipped fish, f_a is the fraction of heads from ad-clipped salmon collected and processed, and f_d is the fraction of observed CWTs that were successfully decoded (Tables 4 and 5). A few heads were collected opportunistically during redd counts or snorkel surveys; these CWTs were given an F_{samp} of 1.00 (i.e., no expansion) since they were not representative of the total escapement.

After the release of the 2010 report (Kormos et al. 2012), Mohr and Satterthwaite (in press) demonstrated how the potential misidentification of ad-clipped salmon in carcass surveys can significantly bias estimations of the total hatchery contribution since they frequently encounter both fresh and non-fresh (decayed) carcasses.

Salmon sampled in some CV carcass surveys are generally recorded as ‘fresh’ or ‘decayed’ based on criteria such as condition of the eyes (clear vs. opaque) or gills (pink vs. grey). Often the ad-clipped (marked) status of a decayed salmon can be uncertain due to the deteriorating condition of the carcass. Mohr and Satterthwaite (in press) identified four possible outcomes: 1) certain (all ad-clipped and non-marked salmon are correctly identified), 2) false negatives (ad-clipped salmon identified as not marked), 3) false positives (non-marked salmon identified as ad-clipped) or 4) false negatives/positives (ad-clipped salmon identified as non-marked and non-marked salmon identified as ad-clipped).

While condition criteria are somewhat ambiguous and classification may be inconsistent among surveys, differences in the ad-clip rate between fresh and decayed fish have been observed. During the 2010 upper Sacramento River fall-run salmon carcass survey, 21% of the fresh fish sampled were classified as ad-clipped compared to only 6% of decayed fish (i.e., false negative). The fresh carcass heads also contained a CWT more frequently than the heads collected from decayed carcasses (i.e., false positive). Furthermore, the sample sizes for these categories were also significantly different, with the number of decayed fish sampled (n=1,124) nearly four times greater than the fresh fish (n=291). The latter appears to be fairly common among CV carcass surveys currently collecting fish condition data.

Mohr and Satterthwaite (in press) demonstrated how the differences noted above negatively biased the hatchery contribution estimations for the 2010 upper Sacramento River fall-run salmon carcass survey as reported in Kormos et al. (2012). This was also shown to be true for the 2010 upper Sacramento late-fall-run survey. Furthermore, they cautioned that using only fresh CWT data may eliminate the occurrence of rare CWT codes in analyses due to the small sample sizes common with fresh carcasses in these surveys. Since both of these surveys contained false negatives and false positives, and sample sizes for decayed carcasses were much larger than those of fresh carcasses, we have adopted the following equation developed by Mohr and Satterthwaite (in press) to calculate F_{samp} for carcass surveys collecting fish condition data, thus reducing the potential bias associated with these surveys:

$$F_{samp} = (\,N \times p\_adc|fresh \times p\_cwt|fresh,adc) \,/\, n_{valid\ cwt}\ ,$$

where N = estimated total escapement, p_adc|fresh = proportion of fresh fish sampled that were ad-clipped, p_cwt|fresh,adc = proportion of ad-clipped fresh fish that contained a CWT, and $n_{valid\ cwt}$ = total number of valid CWTs collected from both fresh and decayed fish.

Table 6 shows the original and revised F_{samp} for the 2010 upper Sacramento River fall-run and late-fall-run carcass surveys. This new equation was also used to determine F_{samp} for the five CV salmon carcass surveys that collected fish condition sample data in 2011: upper Sacramento River fall-run, upper Sacramento late-fall-run, Clear Creek fall-run, Cottonwood Creek fall-run, and American River fall-run. We are hopeful that other CV carcass surveys will begin to collect fish condition information to reduce the known bias in CWT sample rate calculations and hatchery contribution estimations as demonstrated by Mohr and Satterthwaite (in press). We realize that the calculated hatchery contribution rates of the other carcass surveys in this report are most likely negatively biased.

To help delineate between raw CWT recoveries, CWT recoveries expanded for production, CWTs expanded for sampling, and CWTs expanded for production and sampling, the following nomenclature will be used:

CWT = Raw count CWT recoveries
CWT_{prod} = CWT recoveries expanded only by their respective production factor, F_{prod}
CWT_{samp} = CWT recoveries expanded only by their respective sample expansion factor, F_{samp}
CWT_{total} = CWT recoveries expanded by both F_{prod} and F_{samp}

Determining hatchery- and natural-origin proportions in CV escapement and harvest

To determine the contribution of hatchery- and natural-origin salmon, all CWT_{total} were summed to estimate the total number of hatchery fish in each survey. The contribution of natural-origin fish for each survey was then determined by subtracting the total number of hatchery fish from the total escapement estimate, as follows:

$$\text{Estimate of natural-origin salmon} = \text{Total escapement estimate} - \sum_{i=1}^{m} CWT_{total,i}\ ,$$

where m = total number of hatchery-origin CWT release groups identified in an escapement survey or hatchery.

Determining recovery rates of various release types in CV escapement and ocean harvest

To determine the relative CV recovery rate, R_{cwt}, of each unique CWT release group (i.e., code), all recoveries were expanded by their location-specific F_{samp}, summed over all recovery locations, and then divided by the total number of fish tagged and released with this CWT. Since expanded recoveries for several individual CWT groups were less than 0.001% of the total number released, recovery rates are reported in recoveries per 100,000 CWT salmon released, as follows:

$$R_{cwt} = \sum_{j=1}^{l} CWT_{samp,j} \text{ recoveries } / \text{ CWT release group size } / \text{ } 100{,}000,$$

where *j (=1,2,3,,,l)* denotes recovery location.

Data from all CWT release groups belonging to the same brood year and release type were combined and an overall release type-specific CV recovery rate, R_{type}, was calculated as:

$$R_{type} = \sum_{j=1}^{l} \sum_{k=1}^{n} CWT_{samp,k} \ / \sum_{k=1}^{n} \text{ release group size of CWT }_{k} / \text{ } 100{,}000,$$

where *k* (= 1,2,3,,,n) denotes release group.

Determining stray proportions of various release groups in CV escapement
To be consistent with Kormos et al. (2012), basin of origin is defined here as the drainage of any major river as it pertains to the geographic region of the CV where a hatchery is located. The CV was again segregated into five primary hatchery basins: upper Sacramento River (including Battle Creek), Feather River (including the Yuba River), American River, Mokelumne River, and the Merced River. Hatchery-origin salmon returning to streams not included in these five primary basins were considered to be strays. Any CWTs recovered outside of these defined basins of origin based on their reported stock or hatchery were considered strays.

Further evaluation of these definitions is warranted as future CFM recovery data become available and the definition of straying as it pertains to sub-basins of the CV is determined through hatchery program evaluation. To help facilitate this discussion, Appendix 1 presents alternative recovery and stray rates for CNFH and FRH CWT releases based on the assumption that recoveries in the upper Sacramento River and Yuba River, respectively, are strays.

To determine the CV stray proportion, S_{cwt}, for each CWT code, the sum of all CWT_{samp} recoveries collected out of the basin of origin was divided by total CV CWT_{samp} recoveries for that release group, as follows:

$$S_{cwt} = \sum_{p=1}^{o} CWT_{samp,p} \text{ (out-of-basin locations) } / \sum_{p=1}^{q} CWT_{samp,p} \text{ (all CV locations)},$$

where *p* denotes recovery location, *o* denotes the number of out-of-basin recovery locations, and *q* denotes the total number of recovery locations.

Data from all CWT releases belonging to the same brood year and release type were then combined and release type-specific CV stray proportion, $S_{type,}$ was calculated as:

$$S_{type} = \sum_{p}^{o} \sum_{k}^{n} CWT_{samp,p,\,k} \text{ (out-of-basin) } / \sum_{p}^{o} \sum_{k}^{n} CWT_{samp,p,k} \text{ (all CV locations)}$$

RESULTS

General Overview of 2011 CV inland recoveries and California ocean harvest

All but three of the 46,596 valid CWTs recovered in the CV during 2011 were CV salmon releases; most CWTs originated from brood year 2007 through 2009 releases (Table 7). More than 93% of all expanded salmon CWT recoveries were fall-run, followed by spring-run (3%) and late-fall-run (3%) releases. Data from the 2011 escapement survey of Sacramento River winter-run (SacW) salmon is not included in this report (USFWS report); however there were two SacW CWTs recovered at CNFH during fall-run spawning operations.

The majority of fall-run CWTs were age-2 (57%) and age-3 (36%) fish. Three age-1 fall-run CWTs were also sampled. The spring-run CWTs consisted primarily of age-3 (56%), age-2 (24%), and age-4 (20%) fish. Age-4 (51%), age-3 (30%), and age-5 (14%) made up most of the late-fall-run return. Only four age-6 fish were recovered in the CV; all were BY 2006 late-fall-run. It should be noted that there were also eight coho CWTs recovered from BY 2009 Lake Oroville releases; six were recovered during fall-run spawning at FRH while the other two were recovered in the Yuba River carcass survey above the Daguerre Point Dam (DPD) dam. Non-Chinook salmon CWTs were not included in any analyses.

Almost 90% of the 8,717 valid CWT recoveries from the California ocean harvest in 2011 were CV salmon releases; most CWTs were brood year 2007 through 2009 releases (Table 8). Approximately 86% of all expanded CWTs in the ocean harvest were fall-run, followed by late-fall-run (2%), spring-run (1%), and winter-run (<0.4%) salmon. The majority of fall-run salmon CWTs were age-3 (60%) and age-2 (35%) fish. Age-3 (85%) and age-4 (14%) made up most of the late-fall-run salmon catch while age-3 (72%) and age-2 (25%) fish dominated the spring-run salmon harvest. Almost all (99%) of the winter-run salmon were age-3. A few age-6 late-fall-run salmon were also caught. The remaining 10% of ocean CWT recoveries originated from non-CV hatcheries or waters, including the Klamath, Trinity, and Smith rivers in northern California as well as the Rogue, Chetco, Umpqua, Columbia, Snake and other Pacific Northwest rivers; most were age-3 (64%) and age-4 (34%) fish.

1. Proportion of hatchery- and natural-origin fish in CV escapement

In 2011, there were 22 individual CWT release types contributing to CV escapement and ocean fisheries. To facilitate the breakout of the hatchery proportion by stock and release strategy, all release types from the same hatchery/basin were given the same color scheme (Figure 1) in all pie chart figures. All net pen releases, except salmon released from net pens in Santa Cruz and Tiburon, contain black dots. Coastal and Tiburon net pen releases are designated with a crisscross pattern. Trucked and experimental releases are designated by black stripes. The revised hatchery and natural components of the 2010 upper Sacramento River fall-run and late-fall-run carcass surveys from Kormos et al. (2012) are shown in Figure 2.

The proportion of hatchery-origin fish on the natural area spawning grounds in 2011 varied throughout the CV and by run. The lowest hatchery proportion occurred in the Butte Creek spring-run salmon mark-recapture survey where no ad-clipped salmon were encountered (0%)

while the highest proportion (90%) was observed in the Feather River fall/spring-run salmon carcass mark-recapture survey (Figure 3).

It should be noted that since there has not been a carcass survey or CWT recovery program in Battle Creek since 2005, it is not possible to directly determine the hatchery contribution, recovery rate, or stray rate into the natural escapement of this tributary. Total natural escapement is estimated by subtracting the number of salmon returning to CNFH from the total video weir count into Battle Creek. The hatchery contribution to the natural area escapement in Battle Creek is considered equivalent to the hatchery return at CNFH (Robert Null, FWS, pers comm).

The hatchery proportion of fall-run salmon returning to CV hatcheries ranged from 77% to 98% (Figure 4). The spring-run salmon return to FRH was 94% hatchery-origin fish whereas the late-fall-run return to CNFH was almost 100% hatchery-origin fish. The percentage of hatchery and natural-origin contribution to the total escapement for all surveys by release type is shown in Table 9.

Upper Sacramento River Basin

Eight escapement surveys were conducted in the Upper Sacramento River Basin that allow for expansion of CWTs: fall-run and late-fall-run salmon counts at CNFH, fall-run and late-fall-run salmon mark-recapture carcass surveys in the mainstem Sacramento River, a fall-run salmon mark-recapture survey in Clear Creek, a video count and associated carcass survey in Cottonwood Creek, and spring- and fall-run salmon mark-recapture carcass surveys in Butte Creek. Four additional escapement surveys were conducted: video counts of fall-run salmon escapement with associated carcass surveys to opportunistically collect CWTs and other bio-data were conducted in Mill and Deer Creeks while redd surveys were conducted in Mill and Deer Creeks to estimate spring-run salmon escapement. Since representative sampling for ad-clipped salmon did not occur in any of these surveys, any CWT recovery in these creeks represents only itself (i.e., $F_{samp} = 1.00$) and the reported hatchery percentages represent their minimal hatchery contribution. Returns to CNFH were predominantly hatchery-origin fish released from this facility while escapement into natural areas was primarily natural-origin fish (Table 9, Figures 5 and 6):

- Fall-run returns at CNFH were 89% hatchery-origin fish
- Late-fall-run returns at CNFH were 100% hatchery-origin fish
- Fall-run spawners in the upper Sacramento River were 27% hatchery-origin fish
- Late-fall-run spawners in the upper Sacramento River were 44% hatchery-origin fish
- Fall-run spawners in Clear Creek were 8% hatchery-origin fish
- Fall-run spawners in Cottonwood Creek were 58% hatchery-origin fish
- Fall-run spawners in Butte Creek were 7% hatchery-origin fish
- Spring-run spawners in Butte Creek were 0% hatchery-origin fish

Feather River Basin

Five escapement surveys were conducted in the Feather River Basin: spring-run and fall-run salmon counts at FRH, a combined fall/spring-run salmon mark-recapture survey in the Feather River, a combined fall/spring-run salmon mark-recapture survey in the Yuba River below DPD, and a combined fall/spring-run salmon Vaki Riverwatcher count above DPD (with associated bio-sample). The Vaki Riverwatcher count also included the number of ad-clipped salmon entering the system. The 107 heads recovered in the bio-survey above DPD were expanded to the total 1,733 ad-clipped salmon counted at DPD. Hatchery contribution by release type was based on the proportion of valid CWT codes recovered. Spring-run and fall-run salmon returns to FRH and in the natural areas were predominantly of hatchery-origin (Table 9, Figures 7 and 8):

- Spring-run returns at FRH were 94% hatchery-origin
- Fall-run returns at FRH were 96% hatchery-origin
- Fall/spring-run spawners in the Feather River were 90% hatchery-origin
- Fall/spring-run spawners in the Yuba River below DPD were 34% hatchery-origin
- Fall/spring-run spawners in the Yuba River above DPD were 65% hatchery-origin

American River Basin

Two escapement surveys were conducted in the American River Basin: fall-run salmon counts at NFH and a fall-run salmon mark-recapture survey on the American River. In addition, dead salmon were recovered from the NFH weir, which is located just upstream from the hatchery and was installed on September 10th to force returning salmon into NFH. Salmon that migrated upstream beyond the hatchery prior to installation of the weir were trapped in the upstream area. Many of those salmon washed back onto the weir upon death. There is minimal spawning habitat above the weir. Spawner returns to natural areas and those from the NFH were predominantly of hatchery-origin while returns above the NFH weir were predominantly of natural-origin (Table 9, Figure 6):

- Fall-run returns to NFH were 77% hatchery-origin
- Fall-run spawners in the American River were 66% hatchery-origin
- Salmon recovered on the NFH Weir were 26% hatchery-origin

Mokelumne River Basin

Two escapement surveys were conducted in the Mokelumne River Basin: fall-run salmon counts at MOK and a video weir count at Woodbridge Dam of all fall-run salmon escapement into the Mokelumne River.

All adult salmon migrating upstream into the Mokelumne River to spawn were counted by the video fish counting device operated by EBMUD at Woodbridge Dam. These counts also included the total number of ad-clipped salmon above the Dam. By subtracting the 15,922 salmon that returned to MOK from the total video count of 18,589 Chinook, it was assumed that the remaining 2,667 salmon remained in the Mokelumne River. Utilizing the same logic, it was also assumed that there were 2,227 ad-clipped salmon remaining in the river since only 14,724 of the 16,951 ad-clipped salmon counted in the video monitoring were recovered at MOK. After reviewing the CWTs recovered from heads collected during sporadic surveys on the Mokelumne River, it was found that the proportions of the CWT codes collected were very similar to the proportion of the same codes recovered at MOK. Because 100% of Chinook salmon observed at MOK were sampled, including seven ad-clipped salmon recovered from the hatchery weir, we felt that the MOK CWT recoveries best represented the entire run and thus expanded the estimated 2,227 ad-clips in the Mokelumne River based on the proportion of valid CWTs recovered. This approach is based on the methodology used by the Klamath River Technical

Team (KRTT) to determine the hatchery composition of fall-run salmon above Willow Creek Weir on the Trinity River (KRTT 2012).

Spawner returns to the Mokelumne River Basin were dominated by hatchery-origin fish (Table 9, Figure 10):

- Fall-run returns at MOK were 98% hatchery-origin
- Fall-run spawners in the Mokelumne River were 88% hatchery-origin

San Joaquin River Basin Tributaries

Four escapement surveys were conducted in tributaries of the San Joaquin River that allow for expansion of CWTs: fall-run salmon counts at MER, as well as fall-run salmon mark-recapture surveys conducted on the Stanislaus, Tuolumne, and Merced rivers. One additional redd survey was conducted on the Calaveras River with an associated carcass survey to opportunistically collect CWTs and other bio-data. Fall-run salmon returns to the Merced, Stanislaus, and Tuolumne Rivers were dominated by hatchery-origin spawners (Table 9, Figure 11):

- Fall-run returns at MER were 88% hatchery-origin
- Fall-run spawners in the Merced River were 89% hatchery-origin
- Fall-run spawners in the Stanislaus River were 83% hatchery-origin
- Fall-run spawners in the Tuolumne River were 73% hatchery-origin

Inland Creel Survey

Five separate creel surveys were conducted in the Sacramento River and its tributaries: upper and lower Sacramento River fall, American River fall, Feather River fall, and a late-fall-run survey on the Sacramento River. The results of these surveys were not shown in 2010 due to extremely high sample expansions that caused hatchery contribution estimates to exceed estimated harvest totals in some cases. Although this over-estimation did not occur in 2011, sample expansions remained high for some of these surveys and thus estimates of hatchery contribution may also be biased high. All inland harvest was dominated by hatchery-origin salmon (Table 9, Figures 12 and 13):

- Upper Sacramento River fall-run harvest was 75% hatchery-origin
- Lower Sacramento River fall-run harvest was 81% hatchery-origin
- Feather River fall-run harvest was 83% hatchery-origin
- American River fall-run harvest was 95% hatchery-origin
- Sacramento River late-fall-run harvest was 68% hatchery-origin

2. Relative recovery and stray rates for hatchery-origin salmon released in-basin versus hatchery-origin salmon trucked and released into the waters of the Carquinez Strait (includes salmon acclimated in net pens and released in San Pablo Bay or Santa Cruz Harbor).

Release strategies vary among hatcheries from year to year. This variability has often been in response to fluctuating abundances of certain stocks or differing policies among mitigating agencies with respect to "best" release practices. Lack of consistency and "problem releases" among CV hatcheries has limited the number of release groups available for direct comparison of differing release strategies. In 2011, there were 11 release groups consisting of 22 individual brood specific release types recovered that allow in-basin releases to be compared directly to trucked/net pen releases.

Table 10 summarizes the recovery rates R_{type} (in-basin, stray, and ocean) for all release groups with representative recoveries from the CV and ocean in 2011. Recovery rates displayed there, in the following figures, and discussed below are scaled for comparison at total recoveries per 100,000 salmon released. Figures 14 and 15 provide a graphical representation of R_{type} for the Sacramento River fall-run salmon and other CV stocks, respectively, and include the total number of salmon released with CWTs for each release type. In general, salmon that were trucked and released directly into the waters of Carquinez Strait or acclimated in net pens had higher relative recovery rates than their respective in-basin releases. These releases also had higher stray proportions than their paired in-basin counterparts.

Coleman National Fish Hatchery releases - Fall-run salmon broods 2007, 2008, and 2009

For brood 2009 CNFH fall-run salmon releases, the overall age-2 inland and ocean recovery rate for net pen CNFHn releases (729) was 1.9 times greater than in-basin CFHFh releases (385). While the total CV recovery rate was equivalent (216) between these two release types, the CNFHn ocean recovery rate (513) was 3.0 times higher than that of CNFHh (170). However, the proportion of CNFHh out-of-basin recoveries was only 1%, while the proportion of CFHFn out-of-basin recoveries was very high at 95%.

For brood 2008 CNFH fall-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen CNFHn releases (1,387) was 3.5 times greater than in-basin CFHFh releases (399). The total CV recovery rate for CNFHn releases (296) was also more than double that of CNFHh (120) and the CNFHn ocean recovery rate (1,091) was 3.9 times higher than that of CNFHh (279). However, again the proportion of CNFHh out-of-basin recoveries was only 1%, while the proportion of CFHFn out-of-basin recoveries was very high at 95%.

For brood 2007 CNFH fall-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen CNFHn releases (97) was 3.7 times greater than in-basin CFHFh releases (26). The total CV recovery rate for CNFHn releases (27) was also double that of CNFHh (13) and the CNFHn ocean recovery rate (70) was 5.4 times higher than that of CNFHh (13). However, zero CNFHh recoveries came from out-of-basin, while the proportion of CFHFn out-of-basin recoveries was very high at 98%.

Feather River Hatchery releases – Spring-run salmon broods 2007, 2008, and 2009
For brood 2009 FRH spring-run releases, the overall age-2 inland and ocean recovery rate for net pen FRHSn releases (121) was 1.8 times higher than in-basin FRHS releases (66). The total CV recovery rate for FRHSn releases (110) was also higher than that of FRHS (58) by 1.9 times, and the FRHSn ocean recovery rate (11) was fairly equivalent to that of FRHS (8). Approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2008 FRH spring-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen FRHSn releases (238) was slightly lower than that of FRHS releases (249). The total CV recovery rate for FRHSn releases (207) was also slightly lower than that of FRHS (233), and the FRHSn ocean recovery rate (31) was fairly equivalent to that of FRHS (26). Approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

For brood 2007 FRH spring-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen FRHSn releases (67) was slightly higher than that of FRHS releases (50). The total CV recovery rate for FRHSn releases (66) was also slightly higher than that of FRHS (49), and the FRHSn ocean recovery rate (1) was identical to that of FRHS (1). Again, approximately 2% of FRHSn were recovered out-of-basin while all FRHS CWTs were recovered in-basin.

Feather River Hatchery releases – Fall-run salmon broods 2007, 2008, and 2009
Although FRH did not have any in-basin releases for broods 2007, 2008 or 2009, they did have experimental FRHFe, bay net pen FRHFn, coastal net pen FRHFnc, central bay net pen FRHFtib, and trucked direct bay FRHFt releases that can be evaluated.

For brood 2009 FRH fall-run salmon releases, the overall age-2 inland and ocean recovery rate for net pen FRHFn releases (578) was higher than that of central bay net pen FRHFtib releases (301), but lower than that of coastal net pen FRHFnc releases (644). The differences however, in recovery rates for CV and ocean areas are more revealing. The CV recovery rate for net pen FRHFn releases (349) was higher than that of central bay net pen FRHFtib releases (227), and much higher than that of the relatively few coastal net pen FRHFnc releases (60). The ocean recovery rate for net pen FRHFn releases (229) was much higher than that of central bay net pen FRHFtib releases (75), but much lower than that of coastal net pen FRHFnc releases (584). Approximately 4% and 5% of FRHFn and FRHFtib were recovered out-of-basin respectively, while 18% of FRHFnc CWTs were recovered out-of-basin.

For brood 2008 FRH fall-run salmon releases, the overall age-3 inland and ocean recovery rate for net pen FRHFn releases (754) was much higher than that of central bay net pen FRHFtib releases (433) and experimental FRHFe releases (401). The FRHFe releases were actually “hybrid” fish (FRH fall-run x FRH spring-run). The CV recovery rates for net pen FRHFn releases (358), central bay net pen FRHFtib releases (299), and experimental FRHFe releases (332) were fairly equivalent. The ocean recovery rate for net pen FRHFn releases (396) was much higher than that of central bay net pen FRHFtib releases (133) and experimental FRHFe releases (69). Approximately 4% of FRHFn and FRHFe were recovered out-of-basin, while 14% of FRHFtib CWTs were recovered out-of-basin.

For brood 2007 FRH fall-run salmon releases, the overall age-4 inland and ocean recovery rate for net pen FRHFn releases (165) was much higher that experimental FRHFe releases (8). Approximately 2% of FRHFe were recovered out-of-basin. A more in-depth comparison of the net pen FRHFn and trucked direct bay FRHFt releases from this brood are discussed in Section 3 below.

Nimbus Fish Hatchery releases – Fall-run salmon broods 2008 and 2009

For brood 2009 NFH fall-run salmon releases, the CV overall age-2 inland and ocean recovery rate for net pen NIMFn releases (315) was 1.8 times lower than that of NIMF releases (584). The total CV recovery rate for NIMFn releases (129) was 1.5 times lower than that of NIMF (196), and the NIMFn ocean recovery rate (185) was over 2 times lower than that of NIMF (388). Approximately 11% of NIMFn were recovered out-of-basin while only 2% of NIMF CWTs were recovered out-of-basin.

For brood 2008 NFH fall-run salmon releases, the CV overall age-3 inland and ocean recovery rate for net pen NIMFn releases (1,372) was 18.5 times higher than that of NIMF releases (74). The total CV recovery rate for NIMFn releases (247) was 7 times higher than that of NIMF (35), and the NIMFn ocean recovery rate (1,124) was nearly 29 times higher than that of NIMF (39). Approximately 4% of NIMFn were recovered out-of-basin while all NIMF CWTs were recovered in-basin.

Mokelumne Fish Hatchery releases – Fall-run salmon broods 2007 and 2009

For brood 2009 MOK fall-run salmon releases, the CV overall age-2 inland and ocean recovery rate for net pen MOKFn releases (947) was 4.2 times higher than that of MOKF releases (224). The total CV recovery rate for MOKFn releases (811) was 3.6 times higher than that of MOKF (224) The MOKFn ocean recovery rate was 135 while the MOKF ocean recovery rate was zero. Approximately 14% of MOKFn were recovered out-of-basin while only 1% of MOKF CWTs were recovered out-of-basin.

For brood 2007 MOK fall-run salmon releases, the CV overall age-4 inland and ocean recovery rate for net pen MOKFn releases (35) was much higher than that of MOKF releases (1). The total CV recovery rate for MOKFn releases (11) was also much higher than that of MOKF (1), The ocean recovery rate for MOKFn releases was 24 while there were no ocean recoveries for MOKF. Approximately 65% of MOKFn were recovered out-of-basin while the lone MOKF recovery was in-basin.

3. Relative CV recovery and stray rates of bay releases acclimated in net pens and released directly without acclimatization

The same issues related to release practices that limited the available recovery comparisons in the previous section also limited the comparison of net pen releases and direct releases in the Carquinez Strait area. As a result there is only one release type comparison possible.

Feather River Hatchery releases – Fall-run salmon brood 2007

For brood 2007 FRH fall-run salmon releases, the overall age-4 recovery rate inland and ocean for net pen FRHFn releases (165) was 3.5 times higher than that of trucked direct bay FRHFt releases (47). The CV recovery rate was 2.7 times higher for net pen FRHFn releases (97) compared to that of trucked direct bay FRHFt releases (36) and the ocean recovery rate for net pen FRHFn releases (68) was 6.8 times higher than that of trucked direct bay FRHFt releases (10). Approximately 11% of FRHFn were recovered out-of-basin while 66% of FRHFt CWTs were recovered out-of-basin.

4. Relative recovery rate and contribution of CV release groups to ocean harvest

The relative recovery rate of CV hatchery releases in the 2011 ocean salmon fisheries (sport and commercial combined) varied by age and release type (Figure 16). Of the 58,843 CV CWT_{samp} recovered in the fisheries, most were age-3 (60%), followed by age-2 (34%), age-4 (1%) and age-5 (<.01%) fish (Table 10). The majority of age-2 CV salmon were harvested in the sport fishery (Figure 16) due to its lower size limit (24" total length) compared to the commercial fishery (27" total length).

For all age-2 CV releases, coastal net pen FRHFnc (584) had the highest recovery rate, followed by net pen CFHFn (513), in-basin NIMF (388), and San Joaquin basin MERF (372) releases.

Net pen releases also had the highest recovery rates for age-3 CV salmon releases. The recovery rates for net pen NIMFn (1,124) and CFHFn (1,091) releases were similarly high, almost double that of trucked MOKFt releases (573), and nearly three times that of net pen FRHFn releases (396).

Relatively few age-4 or age-5 CWT recoveries were made compared to age-2 and age-3 CV fish. The central bay NIMFtib releases had the highest recovery rate for age-4 (144) and late-fall-run in-basin CFHLh had the highest recovery rate for age-5 (0.6).

Contribution of CV release groups to sport ocean harvest

In 2011, anglers harvested an estimated 49,822 salmon in the California sport ocean salmon fishery. The majority (65%) of the harvest occurred in San Francisco and Monterey port areas (Table 11). Based on the expanded CWT_{total} collected in the fishery, including non-CV salmon release types, hatchery-origin fish contributed 57%-77% of the total harvest, depending on major port area (Figure 17). Of all hatchery release types, fall-run net pen FRHFn contributed the most (18.2%) to the total sport harvest, followed by fall-run in-basin CFHFh (14.4%), net pen NIMFn (8.5%) and in-basin NIMF (7.2%). Non-CV releases contributed 3.2% to the total harvest.

Fall-run net pen FRHFn releases contributed the greatest to the sport harvest in Monterey (23%), San Francisco (20%), and Fort Bragg (16%). In Eureka-Crescent City, the fall-run in-basin CFHFh releases contributed the most (12%) to the hatchery sport catch. Other CV releases contributing to California sport fisheries were net pen NIMFn (6-14%), in-basin CFHFh (12-16%), in-basin NIMF (2-12%), and net pen CFHFn (4-9%). The contribution of non-CV stocks was highest (11%) in the Eureka-Crescent City port area, most likely due to its proximity to rivers and salmon hatcheries in northern California, Oregon and Washington.

Contribution of CV release groups to commercial ocean harvest

Commercial trollers landed an estimated 70,028 salmon in the California commercial ocean salmon fishery; most salmon (56%) were landed in the Fort Bragg port area (Table 11). Based on the expanded CWT_{total} collected in the fishery, hatchery-origin fish contributed 26%-57% of the total harvest, depending on major port area (Figure 18). Of all hatchery-origin release types, fall-run net pen NIMFn contributed the most (11.2%) to the total commercial harvest, followed by fall-run in-basin CFHFh (8.9%), net pen FRHFn (8.8%) and non-CV releases (7.4%).

The Monterey port area catch was dominated by fall-run net pen FRHFn releases (20%), while San Francisco and Fort Bragg port areas were dominated by fall-run net pen NIMFn releases (16% and 10%, respectively). The Eureka-Crescent City port area was dominated by non-CV releases (10%). The other CV release type contributing a relatively high percentage to the California commercial fishery was in-basin CFHFh (4%-13%). The contribution of non-CV stocks was highest (11.1%) in the Fort Bragg area, followed by Eureka-Crescent City (10.3%). Again this is most likely due to the proximity of these port areas to rivers and salmon hatcheries in northern California, Oregon and Washington.

DISCUSSION

Estimates of 2011 hatchery contributions and recovery rates by release type that are presented in this report should be viewed as the second “single year snapshot” of salmon escapement and harvest in the CV and California ocean fisheries. All CWT recoveries in 2011 were from CV releases that were representatively marked and tagged at the CFM minimum 25% level. Although there were definite differences observed in recovery rates and straying proportions among runs, brood years, and CV release groups, this effort continues the initial phase of the work needed to statistically analyze the contribution of hatchery- and natural-origin salmon to hatchery and natural areas throughout the CV, evaluate hatchery release strategies, improve California ocean and river salmon fisheries management, and determine if other goals of the CFM program are being met. Most of the CV CWT release groups in this study were produced, released and recovered during a time when Sacramento River fall-run salmon were at historically low levels or still in the stages of recovery. Although the 2011 ocean and river salmon fisheries were much less constrained than those in 2009-2010, salmon were still not susceptible to the historical levels of effort observed in ocean or river salmon fisheries prior to 2008.

Another critical factor to consider is that 2011 had the highest age-2 escapement of CV fall-run salmon on record. Thus the age-2 recoveries presented in this report are part of a very strong brood, compared to the weaker broods that preceded it. This apparent disparity in year class strength is important to note when comparing the relative recovery rates and hatchery contribution of various release types to harvest and escapement.

Again, the effects of interannual variation on survival and year-class strength for both hatchery- and natural-origin stocks should be considered when evaluating the status of CV salmon stocks. At this time, neither year class strength or age structure of CV natural-original salmon is known.

As noted in Kormos et al. (2012), scale-aging work done on 2006, 2007, and 2008 CV salmon escapement has indicated there may be different maturation rates between hatchery- and natural-origin fish by stock and basin. It remains premature to compare hatchery and natural-origin proportions without having complete brood- and/or stock-specific population estimates. While it may appear that total escapement of hatchery fish in the CV may exceed that of natural-origin fish in any given year, comparing age-specific total escapement (hatchery and natural) after broods complete their life cycle may identify differences in hatchery and natural ratios on a basin- and stock-specific basis. Such analyses may provide the basis for changing hatchery practices to better mimic wild population parameters. They may also further clarify the effects of specific environmental stressors unique to natural-origin fish or specific hatchery CWT release groups.

Strategies for CV fall-run production releases in any given year are often a result of two conflicting objectives. Increasing survival rates to allow for improved escapement and harvest often favors release strategies that bypass the Sacramento-San Joaquin Delta and acclimate salmon prior to release to reduce mortality from predators or other environmental factors. Alternatively, in-basin release practices are aimed at maximizing homing rates back to the hatchery of origin to reduce impacts on natural stocks. It is impossible to make a thorough comparison of hatchery release practices at this time due to the large variability that existed among CWT release types within the same CV hatchery broods examined in this study. Many release types included individual CWT codes that were released at numerous locations at different times and under various conditions (e.g., river water flows and temperatures, different net pen locations, incoming vs. outgoing bay tidal flows). While some individual CWT codes were recovered at a relatively high rate, others within the same release type were recovered at minimal levels if at all. The recovery rate R_{cwt} for individual CWT codes should be examined on a release type basis and the release strategies (e.g., in-basin, net pen acclimation) that produce the greatest resource value (i.e., high recovery rate with low straying) adopted for future release strategy evaluation. Coordinated and paired hatchery release types will allow for direct comparisons to be made between them and will enrich the available data set used for subsequent evaluation of the hatchery program in the future. Only FRH spring-run salmon in-basin and net pen releases have consistently allowed a true comparison during the last several broods.

There has been much debate among salmon biologists and managers on the definition of straying. Although it seems straight-forward to simply define any salmon not returning to the river of its hatchery location as a stray, decades of sharing broodstock and juvenile production among hatcheries, including different run-types, and releasing juvenile salmon at various sites and times throughout the CV have complicated this issue.

Years of sharing broodstock or progeny can confound the straying definitions in any system, especially when salmon return en masse to rivers where the shared broodstock or progeny originated. In addition, juvenile salmon production raised at other rearing facilities or released near the confluences of other rivers or within the delta system appear to exacerbate the problem of salmon straying to other systems. Although many of these practices have been recently terminated, it may take years before the long-term effects of these actions diminish and stray rates can be accurately determined and compared. In addition, preliminary analysis of individual

CWT codes within the same release type indicate that the timing of water releases within the CV during juvenile outmigration and adult escapement may also affect recovery and stray rates.

Another critical issue is the definition of straying when a mitigation hatchery is not located on the river being impacted. In 1942, CNFH was built specifically to mitigate for the loss of salmon spawning habitat in the upper Sacramento River basin caused by the construction of Shasta Dam. Because CNFH was built on Battle Creek, approximately 6 miles upstream of its confluence with the Sacramento River, the Keswick Fish Trap was constructed concurrently in the upper Sacramento River specifically to collect salmon broodstock for the hatchery (Black 1999). Historically, salmon taken at the Keswick Fish Trap contributed as much as 50 to 75 percent of the annual fall-run broodstock used at CNFH from the 1940s through the late 1970s (USFWS 2011) and this facility was utilized for fall-run broodstock collection until the late 1980s. Although the collection of fall-run broodstock at Keswick Fish Trap ceased completely in 1987, the introgression of CNFH hatchery- and natural-origin fall-run salmon continues naturally in the upper Sacramento River. Late-fall-run salmon are still collected at the trap for CNFH propagation purposes so that a genetically integrated hatchery stock can be maintained and the effects of domestication can be reduced (USFWS 2011). It is for these reasons that some salmon biologists continue to consider CNFH stocks to be analogous to salmon that originate from the mainstem of the upper Sacramento River.

Hatchery objectives for CNFH fall-run salmon unambiguously state that CNFH stocks are intended to escape to Battle Creek alone, and all other recoveries outside of that stream are strays. Tributaries of a larger river basin with an existing mitigation hatchery are also not intended to receive hatchery escapement, as is the case with the Yuba River. Hatchery objectives for FRH state that hatchery salmon originating there are intended to escape to only the Feather River. This is true despite many factors beyond the control of managers that affect salmon migration patterns such as dam operations, water temperatures and water diversions. Hatchery release location alone is the tool available to managers to mitigate the straying of hatchery stocks, and it often comes at a cost to the survival of hatchery production. In both the upper Sacramento River and Feather River basins, the rate of historical and present introgression of natural-origin stocks among their respective tributaries is unknown.

Given the issues identified above and to be consistent with Kormos et al. (2012), the same primary CV basins were used to define stray rates in this report; however to allow further evaluation and discussion of these issues, all CNFH and FRH CWT releases that were recovered in the upper Sacramento River and Yuba River, respectively, during 2011 are treated as strays in Appendix 1. It should be noted that differences in stray rates for FRH and CNFH under this alternative stray definition are relatively small as compared to the previous definition. A primary goal of this report is to provide information that will be useful in California salmon management, including the upcoming hatchery review process.

The advent of Santa Cruz coastal bay net pen release recoveries in the CV and ocean fisheries during 2011 also warrants some attention. These “enhancement” releases are intended to provide additional harvest to local ocean fisheries in the Monterey Bay area but they may also pose a potential risk to coastal salmon and steelhead stocks that may suffer from introgression or competition with hatchery stocks. As noted above, this release type should be evaluated after several broods have completed their respective life cycle so that their relative age-specific contribution to ocean fisheries and inland escapement can be determined. However, work is currently underway to monitor central California coastal streams to determine if this release type is straying into these areas. All coastal net pen releases are ad-clipped and contain a unique CWT code so identifying these fish should be relatively simple. If it appears that coastal net pen releases are competing or hybridizing via introgression with ESA-listed coastal salmon or steelhead stocks, then these programs should be seriously evaluated in the near term.

Prior to the creation of the CFM program, the primary purpose of CV salmon escapement monitoring was to provide basic status information (e.g., grilse and adult escapement counts) by individual stocks and major tributaries for California hatchery and ocean harvest management needs. The marking, tagging, or collection of CV CWT fish was not a high priority. CV escapement monitoring has since expanded to provide data for a broad range of management applications, including the recovery planning for ESA-listed salmonid stocks. These applications include assessing recovery efforts, including habitat restoration work, improving ocean and river fisheries management, and evaluating CV salmon hatchery programs to ensure both mitigation and conservation goals are being met. To meet the needs of these various assessment efforts, a review of current methodologies being employed among CV inland escapement monitoring programs was undertaken by CDFW in 2008. The goal of this review was to identify needed changes and/or additions to survey protocols that will ensure both statistically valid estimates of escapement and the collection of biological data, including CWTs and scales, needed for assessment efforts. In 2012, CDFW completed the "Central Valley Chinook Salmon Escapement In-River Monitoring Plan" that recommends methods for estimating escapement and collecting biological data necessary for improved stock assessment in the CV (Bergman et al. 2012). Survey modifications included changes in the current mark-recapture models being utilized, changes in sampling protocols to ensure representative sampling and proper accounting, and the use of counting devices in place of some mark-recapture programs. This monitoring plan is now being implemented among CV surveys to provide the basis for sound CV salmon assessment and subsequent management.

One critical item that was omitted from the recommended CV sampling protocol modifications was the need to account for the fresh versus decayed condition of fish sampled in CV carcass surveys. As identified by Mohr and Satterthwaite (in press) and discussed in this report, this information is needed to minimize the bias in determining the hatchery contribution by release type in natural areas. We know it is incorrect to assume that all sampled carcasses have the same ad-clip detection probability when a large disparity between fresh and decayed fish has been shown. Sample sizes related to these two conditions are also a factor when attempting to recover relatively small CWT releases (e.g., less than 200,000 ESA-listed Sacramento River winter-run salmon CWTs are released annually) or release types with typically low rates of contribution.

Overall, the CV CFM program has been successful in marking and tagging its targeted numbers of salmon each year at the five CV hatcheries. In addition, CWTs are now being recovered throughout the CV in a statistically valid manner. The CDFW CWT laboratories in Santa Rosa and Sacramento have both been expanded and are able to process the 50,000-70,000 heads recovered annually from ad-clipped salmon observed during CV escapement and California ocean and river fisheries monitoring.

The CFM program should be continued with the current design for several years to provide comparable, consistent data needed for harvest and hatchery management. Efforts continue to secure future funding for this program. The results from this program, in conjunction with the creation and funding of a permanent scale-aging program, should provide the best opportunity to manage CV salmon based on scientifically defensible data. Secure adequate funding will allow both CWT and scale-aging data to be available by February each year in order to manage CV salmon stocks, hatchery production, and California ocean and river fisheries in a real-time manner, similar to Klamath River fall-run salmon management. This work is essential for the continued enhancement of salmon management in California's Central Valley.

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LITERATURE CITED

Bergman, J., Nielson, R., and Low, A. 2012. Central Valley Chinook Salmon In-River Escapement Monitoring Plan. California Department of Fish and Game. Fisheries Branch Administrative Report Number: 2012-1. January 2012

Black, M. 1999. Shasta salmon salvage efforts: Coleman National Fish Hatchery on Battle Creek, 1895-1992. Prepared for the Battle Creek Technical Advisory Committee and the Battle Creek Work Group by Kier Associates Sausalito, California: 1-39.

Buttars, B. 2007. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2007 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2008. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2008 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2009. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2009 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2010. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2010 Marking Season. Pacific States Marine Fisheries Commission.

Buttars, B. 2011. Constant Fractional Marking/Tagging Program for Central Valley Fall Chinook Salmon, 2011 Marking Season. Pacific States Marine Fisheries Commission.

Hicks, A.C., Newman, K.B., and Hankin D.G. 2005. A second analysis of a marking, tagging, and recovery program for Central Valley hatchery Chinook salmon. Unpublished report to Central Valley Salmon Team.

Klamath River Technical Team 2011. Klamath River Fall Chinook Salmon Age-Specific Escapement, River Harvest, and Run Size Estimates, 2010 Run. 24 February 2011

Kormos, B., Palmer-Zwahlen, M., and Low, A. 2012. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2010. Fisheries Branch Administrative Report 2012-02.

Mohr, M. S. and W. H. Satterthwaite. In press. Coded wire tag expansion factors for Chinook salmon carcass surveys in California: estimating the numbers and proportions of hatchery-origin fish. San Francisco Estuary and Watershed Science.

U.S. Fish and Wildlife Service (USFWS). 2011. Biological Assessment of Artificial Propagation at Coleman National Fish Hatchery and Livingston Stone National Fish Hatchery: program description and incidental take of Chinook salmon and steelhead. July 2011.

LIST OF ACRONYMS AND ABBREVIATIONS

Ad-clipped	clipped adipose fin
BOR	U.S. Bureau of Reclamation
CFM	Constant Fractional Marking
CNFH	Coleman National Fish Hatchery
CV	California Central Valley
CWT	coded-wire tag
CDFW	California Department of Fish and Wildlife
DPD	Daguerre Point Dam
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utilities District
ERP	Ecosystem Restoration Program
FRH	Feather River Hatchery
FWS	U.S. Fish and Wildlife Service
MER	Merced River Hatchery
MOK	Mokelumne River Hatchery
NMFS	National Marine Fisheries Service
NFH	Nimbus Fish Hatchery
OSP	Ocean Salmon Project
PSMFC	Pacific States Marine Fisheries Commission
RMPC	Regional Mark Processing Center
YARMT	Yuba Accord River Management Team

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 1 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Hatchery Spawners		
Coleman National Fish Hatchery (CNFH) Fall and Late-Fall	Direct count. All fish examined for fin-clips, tags, marks. Hatchery takes a one month break in between the fall and late-fall run spawning periods. Fish that arrive during this 'break' are counted and excised. Those fish that contain a fall CWT code or have their adipose fin present are later counted as a part of the fall run. Fish containing a late-fall CWT code are later counted as late-fall. Systematic random bio-sample[a/] of all fish with adipose fin absent. Grilse cutoff: 700 mm.	FWS
Feather River Hatchery (FRH) Spring and Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish arriving at the hatchery April-June tagged with two uniquely-numbered floytags. All fish marked with floytags returning to FRH during August and September are spawned as spring run. All other fish are spawned as fall run. All spring Chinook are bio-sampled. Systematic random bio-sample ~10% of aggregate fall run fish with adipose fin present and absent. All fall run fish with adipose fin absent are bio-sampled. All spawned fall run fish are bio-sampled. Grilse cutoff: 650 mm.	CDFW
Nimbus Fish Hatchery (NFH) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 685 mm.	CDFW
Nimbus Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 685 mm.	CDFW
Mokelumne River Hatchery (MOK) Fall	Direct count. All fish examined for fin-clips, tags, marks. Systematic random bio-sample ~10% of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	CDFW
Mokelumne Weir Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	CDFW
Merced River Fish Facility (MER) Fall	Direct count. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 635 mm.	CDFW
Natural Spawners		
Upper Sacramento River Mainstem Fall and Late-Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate applied using all females within survey area (Keswick Dam to Balls Ferry). Total female escapement estimate (Keswick Dam to Princeton) is derived using expansions for females spawning outside of the survey area (Balls Ferry to Princeton) through aerial redd surveys. Male Chinook expanded based on the sex ratio at CNFH. Total estimate from Keswick to Princeton is then males and females. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 675 mm females, 755 mm males.	CDFW, FWS

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 2 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Clear Creek Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Bio-data collected from all fresh fish with adipose fin present and absent. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 675 mm females, 755 mm males.	CDFW, FWS
Cottonwood Creek Fall	Video weir count at mouth of creek to determine total escapement. Systematic carcass survey conducted to collect bio-samples from all fish with adipose fin present and absent. Grilse cutoff: 750 mm.	FWS, CDFW
Butte Creek Spring and Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate for spring run. Peterson mark-recapture estimate for fall run. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 610 mm.	CDFW
Feather River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark recapture-estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring run Chinook are included. Grilse cutoff: 650 mm.	DWR
Yuba River Fall	Above Daguerre Point Dam: Vaki Riverwatcher direct count. Additionally, systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Below Daguerre Point Dam: Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Spring Chinook are included in estimate. Grilse cutoff: 650 mm.	CDFW, YARMT
American River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. Systematic random bio-sample of aggregate fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm.	CDFW
Mokelumne River Fall	Video count at Woodbridge Irrigation District Dam. Additionally, in river survey conducted to collect bio-samples from all fish with adipose fin present and absent. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 710 mm males.	EBMUD
Stanislaus River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW
Tuolumne River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW
Merced River Fall	Superpopulation modification of the Cormack-Jolly-Seber mark-recapture estimate. All fish examined for fin-clips, tags, marks. All fish with adipose fin absent are bio-sampled. Grilse cutoff: 680 mm females, 760 mm males.	CDFW

Table 1. Estimation and sampling methods used for the 2011 CV Chinook run assessment. (page 3 of 3)

Sampling Location	Estimation and Sampling Methods	Agency
Recreational Harvest		
Upper Sacramento River Fall	Open July 16th to December 18th from Highway 113 Bridge to the Lower Red Bluff Boat Ramp. An additional river reach from the Red Bluff Diversion Dam to the Deschutes Road Bridge was open August 1st through December 18th.Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Feather River Fall	Open July 16th to December 11th from the mouth to 1,000 ft below the Thermolito Afterbay Outfall. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
American River Fall	Open July 16th to December 31st from the Jiboom Street Bridge to the base of Nimbus Dam with the following reach specific exceptions. The reach from the mouth to the Jiboom Street Bridge was open from July 16th to December 11th. The reach from the SMUD power line crossing to the USGS cable crossing was open from July 16th to October 31st, and the reach from the USGS cable crossing to the Hazel Avenue Bridge was open from July 16th to September 14th. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Lower Sacramento River Fall	Open July 16th to December 11th from the Carquinez Bridge to the Highway 113 Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW
Upper Sacramento River Late Fall	Open November 1st to December 18th from Highway 113 Bridge to Deschutes Road Bridge. Stratified-random sampling design (one weekday and one weekend sample per week per section during the open season per management zone) that included both roving and access interview components, and the collection of coded-wire tags from adipose fin-clipped salmon for stock identification. Bio-data collected during angler interviews.	CDFW

a/ Biological samples ("bio-samples" or "bio-data") of live fish or carcasses generally include: sex, fork length, scales, tags or marks, and CWT recovery from ad-clipped fish.

Table 2. 2011 California ocean sport and commerial salmon fishery seasons by major port area.

Major Port Area	Sport		Commercial		
	Season	size limit[a]	Season	size limit[a]	quota
Eureka/Crescent City	May 14 - Sep 5	24" TL	Jul 2-6, 9-13, 16-20	27" TL	1,400
			Aug 1 - 15	27" TL	1,000
Fort Bragg	Apr 2 - Oct 30	24" TL	Jul 23 - 27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
San Francisco	Apr 2 - Oct 30	24" TL	May 1 - 31	27" TL	
			Jun 25 - Jul 5	27" TL	
			Jul 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
			Oct 3-7, 10-14[b]	27" TL	
Monterey[c]	Apr 2 - Sep 18	24" TL	May 1 - 31	27" TL	
			Jun 25 - Jul 5	27" TL	
			Jul 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	
			Sep 1 - 30	27" TL	
South of Pt Sur[d]			May 1 - 31	27" TL	
			Jun 1 - 24	27" TL	
			Jun 25 - Jul 5	27" TL	
			July 9-13, 16-20, 23-27	27" TL	
			Jul 29 - Aug 29	27" TL	

a/ Size limit in inches total length (TL).

b/ Open only between Pt Reyes and San Pedro Pt.

c/ Recreational regulations apply from the Monterey area to the U.S./Mexico border

d/ Separate commercial regulations apply from Pt. Sur to the U.S./Mexico border

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release group, brood years 2007-2010. (page 1 of 2)

Age 2 CWT releases

Release group*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2009	FRH	Fea R	Spr	1	1,040,645	1,026,954	99%	Basin	Feather River (Boyds Pump Ramp)
FRHSn	2009	FRH	Fea R	Spr	6	1,085,409	1,058,635	98%	Bay pens	San Pablo Bay net pens
CFHFh	2009	CNFH	Sac R	Fall	25	10,209,934	2,543,157	25%	Basin	CNFH
CFHFn	2009	CNFH	Sac R	Fall	3	1,359,232	339,179	25%	Bay pens	Mare Island net pens
FRHFn	2009	FRH	Fea R	Fall	11	9,536,050	2,367,209	25%	Bay pens	San Pablo Bay net pens; Wickland Oil net pens
FRHFnc	2009	FRH	Fea R	Fall	1	122,334	118,879	97%	Coastal pens	Santa Cruz net pens; MBSTE project; held approx 1 week
FRHFtib	2009	FRH	Fea R	Fall	2	60,739	60,104	99%	Tibur. pens	Tiburon net pens, released as fingerlings (May) & yearlings (Oct)
FeaFw	2009	wild	Fea R	Fall	18	178,063	177,657	100%	Basin	Thermalito Bypass
NIMF	2009	NIM	Ame R	Fall	3	3,221,137	1,000,559	31%	Basin	American River (at Sunrise Launch Ramp & Discovery Park)
NIMFn	2009	NIM	Ame R	Fall	2	1,391,632	347,527	25%	Bay pens	Mare Island net pens
MOKF	2009	MOK	Mok R	Fall	1	99,157	99,048	100%	Basin	Mokelumne Hatchery
MOKFn	2009	MOK	Mok R	Fall	13	2,023,958	2,015,730	100%	Delta pens	Sherman Island net pens
MokFw	2009	wild	Mok R	Fall	2	1,529	1,113	73%	Basin	Mokelumne River (Woodbridge, Mok R Vino farms)
MERF	2009	MER	Mer R	Fall	6	165,213	154,685	94%	Basin	San Joaquin River (Jersey Pt)
CFHLh	2010	CNFH	Sac R	Late	26	2,036,844	1,984,094	97%	Basin	CNFH (includes spring surrogate releases)
Total age 2 releases:					120	32,531,876	13,294,530	41%	<1% wild releases	

Age 3 CWT releases

Release group*	Brood year	Hatchery / wild	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
FRHS	2008	FRH	Fea R	Spr	5	1,016,835	1,015,717	100%	Basin	Feather River (Boyds Pump Ramp)
FRHSn	2008	FRH	Fea R	Spr	5	1,007,177	1,005,727	100%	Bay pens	San Pablo Bay net pens
CFHFh	2008	CNFH	Sac R	Fall	27	12,530,336	3,128,111	25%	Basin	CNFH
CFHFn	2008	CNFH	Sac R	Fall	3	1,427,792	371,685	26%	Bay pens	Mare Island net pens, San Pablo Bay net pens
FRHFn	2008	FRH	Fea R	Fall	11	7,761,167	2,061,211	27%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFe	2008	FRH	Fea R	Hybrid	30	498,341	481,853	97%	CV exper	Fall x Spr hybrid releases: Benicia, Discovery Pk, Elkhorn Boat Launch, Miller Park, Sac River at Garcia Bend and Pittsburg
FRHFtib	2008	FRH	Fea R	Fall	2	91,801	89,859	98%	Tibur. pens	Held 3-4 mos Tiburon net pens, released as yearlings
FeaFw	2008	wild	Fea R	Fall	37	292,423	289,830	99%	Basin	Thermalito Bypass, Feather River
NIMF	2008	NIM	Ame R	Fall	1	270,000	264,006	98%	Basin	American River (Sunrise Launch Ramp)
NIMFn	2008	NIM	Ame R	Fall	4	3,924,887	976,955	25%	Bay pens	Mare Island net pens
MOKFt	2008	MOK	Mok R	Fall	4	250,969	250,300	100%	Trucked	Sherman Island
MokFw	2008	wild	Mok R	Fall	5	21,860	20,680	95%	Basin	Mokelumne River (Woodbridge, Mok R Vino farms)
MERF	2008	MER	Mer R	Fall	2	34,532	32,978	95%	Basin	San Joaquin River (Jersey Pt)
CFHLh	2009	CNFH	Sac R	Late	16	1,154,761	1,115,378	97%	Basin	CNFH (includes spring surrogate releases)
Total age 3 releases:					152	30,282,881	11,104,290	37%	1% wild releases	

Table 3. Central Valley coded-wire tag (CWT) Chinook releases by age, stock, run and release group, brood years 2007-2010. (page 2 of 2)

Age 4 CWT releases

Release group*	Brood year	Hatchery	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
ButSw	2007	wild	Butte Ck	Spr	33	330,672	323,916	98%	Basin	Butte Creek (Baldwin Construction Yard)
FRHS	2007	FRH	Fea R	Spr	8	1,414,343	1,378,941	97%	Basin	Boyds Pump Ramp (on Feather River)
FRHSn	2007	FRH	Fea R	Spr	2	1,271,761	1,242,480	98%	Bay pens	San Pablo Bay net pens, Wickland Oil net pens
CFHFe	2007	CNFH	Sac R	Fall	8	201,125	196,993	98%	CV exper	Clarksburg, Red Bluff Diversion Dam
CFHFh	2007	CNFH	Sac R	Fall	14	11,232,501	2,801,459	25%	Basin	CNFH
CFHFn	2007	CNFH	Sac R	Fall	3	1,266,949	314,681	25%	Bay pens	San Pablo Bay net pens (Conoco Phillips, Mare Island); 75% truck mortality noted for one release
FRHFe	2007	FRH	Fea R	Fall	19	623,567	619,085	99%	CV exper	Elkhorn Boat Ramp, Isleton, Lighthouse Marina, West Sacramento
FRHFn	2007	FRH	Fea R	Fall	9	9,422,521	2,347,396	25%	Bay pens	Mare Island net pens, San Pablo Bay net pens, Wickland Oil net pens
FRHFt	2007	FRH	Fea R	Fall	4	102,225	101,712	99%	Trucked	Benicia
FeaFw	2007	wild	Fea R	Fall	19	208,717	206,683	99%	Basin	Thermalito Bypass
NIMFn	2007	NIM/MOK	Ame R	Fall	7	6,879,664	1,714,858	25%	Bay pens	Raised at both NIM and MOK; San Pablo Bay net pens
NIMFtib	2007	MOK	Ame R	Fall	1	51,600	51,600	100%	Tiberon pens	Raised at MOK; held 3-4 mos Tiburon net pens, released as yearlings
MOKF	2007	MOK	Mok R	Fall	1	406,593	101,458	25%	Basin	Lower Mokelumne River (New Hope Landing)
MOKFn	2007	MOK	Mok R	Fall	2	2,203,488	550,668	25%	Bay pens	San Pablo Bay net pens
MokFw	2007	wild	Mok R	Fall	1	315	315	100%	Basin	Mokelumne River
CFHLh	2008	CNFH	Sac R	Late	14	1,108,540	1,072,854	97%	Basin	CNFH (includes spring surrogate releases)
				Total age 4 releases:	145	36,724,581	13,025,099	35%	1% wild releases	

Age 5 CWT releases

Release group*	Brood year	Hatchery	Stock origin	Run type	CWT codes	Total fish released	# CWT tagged	% CWT	Release strategy	Release locations / notes
CFHLe	2007	CNFH	Sac R	Late	17	310,099	299,292	97%	CV exper	Sac R (Colusa to RBDD), Georgianna Slough, Port Chicago, Ryde-Koket
CFHLh	2007	CNFH	Sac R	Late	10	751,208	732,952	98%		CNFH (includes spring surrogate releases)
				Total age 5 releases:	27	1,061,307	1,032,244	97%		

<u>*CV CWT release groups:</u>

Sacramento River Basin Fall Chinook CWT release groups

CFHFe	Coleman National Fish Hatchery fall experimental releases
CFHFh	Coleman National Fish Hatchery fall hatchery releases
CFHFn	Coleman National Fish Hatchery fall net pen releases
FRHFe	Feather River Hatchery fall experimental (2008 brdyr includes spring x fall hybrids)
FRHFn	Feather River Hatchery fall bay net pen releases
FRHFnc	Feather River Hatchery fall coastal net pen releases
FRHFt	Feather River Hatchery fall trucked releases (no net pens)
FRHFtib	Feather River Hatchery fall Tiburon net pen releases
FeaFw	Feather River fall wild
NIMF	Nimbus Fish Hatchery fall basin releases
NIMFn	Nimbus Fish Hatchery fall net pens
NIMFtib	Nimbus Fish Hatchery fall Tiburon net pens releases

San Joaquin Basin Fall Chinook CWT release groups

MOKF	Mokelumne Hatchery fall basin releases
MOKFn	Mokelumne Hatchery fall net pen releases
MOKFt	Mokelumne Hatchery fall trucked releases
MokFw	Mokelumne River fall wild
MERF	Merced Hatchery fall releases

Central Valley Spring Chinook CWT release groups

FRHS	Feather River Hatchery spring basin releases
FRHSn	Feather River Hatchery spring net pen releases
ButSw	Butte Creek spring wild

Sacramento River Basin Late Fall Chinook CWT release groups

CFHLe	Coleman National Fish Hatchery late fall experimental releases
CFHLh	Coleman National Fish Hatchery late fall hatchery releases

Table 4. Escapement estimates and sample data for 2011 CV escapement.

Escapement Survey	Run	Total Escapement	Chinook Sampled[a]	Observed Ad-Clips	Heads Processed	Valid CWTs	Sample rate (fe)	Ad-clips processed (fa)	Valid CWTs (fd)	CWT Sample Expansion
Hatchery Escapement										
Coleman National Fish Hatchery	Late-fall[b]	4,534	4,534	4,445	4,445	4,356	100%	100%	100%	1.00
Feather River Hatchery	Spring	1,969	1,969	1,424	1,424	1,329	100%	100%	99%	1.01
Coleman National Fish Hatchery	Fall	42,380	42,380	9,735	4,999	4,895	100%	51%	99%	1.96
Feather River Hatchery	Fall	32,616	32,616	10,302	10,302	9,983	100%	100%	99%	1.01
Nimbus Fish Hatchery	Fall	12,680	12,680	3,490	3,489	3,377	100%	100%	99%	1.01
Nimbus Fish Hatchery Weir	Fall	3,917	3,917	367	367	335	100%	100%	99%	1.01
Mokelumne River Hatchery	Fall	15,922	15,922	14,724	14,712	14,341	100%	100%	99%	1.01
Merced River Hatchery	Fall	437	437	349	349	337	100%	100%	99%	1.01
Total Hatchery Escapement		**114,455**	**114,455**	**44,836**	**40,087**	**38,953**				
fall		**107,952**	**107,952**	**38,967**	**34,218**	**33,268**				
Natural Area Escapement										
Upper Sacramento River (above RBDD)	Late-fall[b]	3,725	114	83	81	76	3%	98%	100%	20.21 [c]
Butte Creek	Spring	4,497	2,313	0	0	0	100%	100%	100%	-
Clear Creek	Fall	4,841	647	42	40	36	13%	95%	97%	3.50 [c]
Battle Creek	Fall	12,867	video							[d]
Cottonwood Creek	Fall	2,144	127	62	61	54	19%	98%	98%	5.94 [c]
Upper Sacramento River (above RBDD)	Fall	10,583	378	75	74	67	4%	99%	97%	12.12 [c]
Mill Creek	Fall	1,485	video	29	29	28				1.00 [e]
Deer Creek	Fall	662	video	1	1	1				1.00 [e]
Butte Creek	Fall	419	179	4	4	4	43%	100%	100%	2.34
Feather River	Fall	47,289	5,094	1,632	1,631	1,518	11%	100%	98%	9.48
Yuba River (above Daguerre Point dam)	Fall	7,723	video	1,733	1,733	1,620				1.00 [f]
Yuba River (below Daguerre Point dam)	Fall	1,398	216	27	27	25	15%	100%	96%	6.73
American River	Fall	21,320	921	480	473	440	4%	99%	98%	9.19 [c]
Mokelumne River	Fall	2,667	video	2,234	2,234	2,175				1.00 [f]
Calaveras River	Fall	465	redd	54	54	50				1.00 [e]
Stanislaus River	Fall	1,063	494	305	305	294	46%	100%	99%	2.18
Tuolumne River	Fall	878	444	249	249	241	51%	100%	100%	1.99
Merced River	Fall	1,615	401	284	284	270	25%	100%	98%	4.10
Total Natural Area Escapement		**125,641**	**11,328**	**7,294**	**7,280**	**6,899**				
fall		**117,419**	**8,901**	**7,211**	**7,199**	**6,823**				
CV Sport Harvest										
Sacramento River (above Feather River)	Fall	19,971	1,389	270	268	257	7%	99%	97%	14.94
Sacramento River (below Feather River)	Fall	14,900	600	170	168	163	4%	99%	99%	25.28
Feather River	Fall	4,218	231	54	52	49	5%	96%	98%	19.35
American River	Fall	21,411	585	165	163	158	3%	99%	99%	37.52
Sacramento River (above Feather River)	Late-fall[b]	1,730	186	123	120	117	11%	98%	99%	9.62
Total Sport Harvest		**62,230**	**2,991**	**782**	**771**	**744**				
Total		**302,326**	**128,774**	**52,912**	**48,138**	**46,596**				

a/ Number of salmon sampled and visually checked for an ad-clip.

b/ Late-fall hatchery and natural escapement occurred in late fall 2010; late-fall sport harvest occurred in late fall 2011.

c/ Sample expansion factor calculated based on the ad-clip rate and proportion of ad-clipped fish containing CWTs of fresh fish only and expanded to all CWTs (Mohr and Satterthwaite, in press).

d/ Battle creek fall Chinook natural escapement not sampled; escapement estimate based on total Battle Creek adult and jack video weir counts minus returns to Coleman National Fish Hatchery.

e/ Escapement estimates based on redd surveys or video counts; CWTs collected opportunistically and are not representative of total escapement.

Table 5. Catch estimates and sample data for 2011 Ocean Salmon Sport and Commercial Fisheries by major port area.

Port	Total Harvest Estimate	Chinook Sampled[a]	Observed Ad-Clips	Heads Processed	Valid CWTs	Sample Rate (fe)	Ad-clips Processed (fa)	Valid CWTs (fd)	CWT Sample Expansion
Commercial									
Eureka/Crescent	2,391	1,441	164	164	98	60%	100%	99%	1.68
Fort Bragg	39,311	17,087	2,536	2,530	1,943	43%	100%	100%	2.33
San Francisco	21,912	9,207	1,703	1,701	1,598	42%	100%	100%	2.38
Monterey	6,414	2,759	568	568	532	43%	100%	99%	2.35
Commercial total	**70,028**	**30,494**	**4,971**	**4,963**	**4,171**				
Sport									
Eureka/Crescent	9,987	2,510	558	555	472	25%	99%	100%	4.04
Fort Bragg	7,398	2,026	430	429	398	27%	100%	100%	3.70
San Francisco	19,734	9,171	2,716	2,694	2,637	46%	99%	100%	2.20
Monterey	12,703	3,400	1,093	1,072	1,039	27%	98%	100%	3.78
Sport total	**49,822**	**17,107**	**4,797**	**4,750**	**4,546**				
Ocean total	**119,850**	**47,601**	**9,768**	**9,713**	**8,717**				

a/ Number of salmon visually checked for an ad-clip

Table 6. Revised CWT sample expansion rate F_{samp} and hatchery proportion of 2010 Upper Sacramento River fall and late-fall carcass surveys.

2010 Upper Sacramento River fall Chinook carcass survey

Original CWT sample expansion rate F_{samp} and hatchery proportion

Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	p_{adc}	$p_{adc\text{-}cwt}$	F_{samp}	Total CWT Production	$\sum_{i=1}^{m} CWT_{total,i}$	Hatchery proportion
Combined	16,372	1415	130	129	117	**117**	8.6%	**9.2%**	**91%**	**11.66**	276.71	3,226	**20%**

Revised CWT sample expansion rate F_{samp} and hatchery proportion to reduce bias from false negatives and false positives (Mohr and Satterthwaite, in press)

Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	p_{adc}	$p_{adc\text{-}cwt}$	F_{samp}	Total CWT Production	$\sum_{i=1}^{m} CWT_{total,i}$	Hatchery proportion
Fresh		291	60	59	56	56	2%	**21%**	**95%**	57.21			
Decayed		1,124	70	70	61	61	7%	6%	87%				
Combined	16,372	1,415	130	129	117	**117**	9%			**27.38**	276.71	7,578	**46%**

2010 Upper Sacramento River late-fall Chinook carcass survey

Original CWT sample expansion rate F_{samp} and hatchery proportion

Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	p_{adc}	$p_{adc\text{-}cwt}$	F_{samp}	Total CWT Production	$\sum_{i=1}^{m} CWT_{total,i}$	Hatchery proportion
Combined	4,282	811	47	46	44	**43**	19%	**6%**	**96%**	**5.52**	45.2	250	**6%**

Revised CWT sample expansion rate F_{samp} and hatchery proportion to reduce bias from false negatives and false positives (Mohr and Satterthwaite, in press)

Fish Condition	Escapement N	Chinook sampled	Observed ad-clips	Heads processed	CWTs recovered	Valid CWTs n	Sample rate	p_{adc}	$p_{adc\text{-}cwt}$	F_{samp}	Total CWT Production	$\sum_{i=1}^{m} CWT_{total,i}$	Hatchery proportion
Fresh		187	28	27	27	27	4%	**15%**	**100%**	23.75			
Decayed		624	19	19	17	16	15%	3%	89%				
Combined	4,282	811	47	46	44	**43**	19%			**14.91**	45.2	674	**16%**

Original $F_{samp} = (N \text{ x } p_{\_adc} \text{ x } p_{\_cwt|adc}) / n_{valid\ cwt}$,
where N = estimated total escapement, $p_{\_adc}$ = proportion of fish sampled that were ad-clipped, $p_{\_cwt|adc}$ = proportion of ad-clipped fish that contained a CWT, and $n_{valid\ cwt}$ = total number of valid CWTs collected from both fresh and decayed fish.
(Kormos et al. 2012)

New $F_{samp} = (N \text{ x } p_{\_adc|fresh}, \text{ x } p_{\_cwt|fresh,adc}) / n_{valid\ cwt}$,
where N = estimated total escapement, $p_{\_adc|fresh}$ = proportion of fresh fish sampled that were ad-clipped, $p_{\_cwt|fresh,adc}$ = proportion of ad-clipped fresh fish that contained a CWT, and $n_{valid\ cwt}$ = total number of valid CWTs collected from both fresh and decayed fish.
(Mohr and Satterthwaite, in press)

Table 7. Raw and expanded CV Chinook CWT recoveries by stock and age, brood years 2006-2011.

Fall	2010	2009	2008	2007	2006		Total CV CWTs	Total CV %
Age	1	2	3	4	5			
Raw CWT Recoveries	3	27,506	9,053	1,381	1		37,944	81%
	(< 1%)	(72%)	(24%)	(4%)	(< 1%)			
Expanded CWTtotal	**47**	**121,939**	**76,753**	**13,412**	**4**		212,155	93%
	(< 1%)	(57%)	(36%)	(6%)	(< 1%)			

Spring	2010	2009	2008	2007	2006		Total CV CWTs	Total CV %
Age	1	2	3	4	5			
Raw CWT Recoveries		1,317	2,125	540			3,982	9%
		(33%)	(54%)	(14%)				
Expanded CWTtotal		**1,880**	**4,421**	**1,541**			7,843	3%
		(24%)	(56%)	(20%)				

Late-Fall	2011	2010	2009	2008	2007	2006	Total CV CWTs	Total CV %
Age	1	2	3	4	5	6		
Raw CWT Recoveries		102	1,077	2,974	511	4	4,668	10%
		(2%)	(23%)	(64%)	(11%)	(< 1%)		
Expanded CWTtotal		**375**	**2,273**	**3,941**	**1,104**	**4**	7,698	3%
		(5%)	(30%)	(51%)	(14%)	(< 1%)		

Winter	2011	2010	2009	2008	2007	2006	Total CV CWTs	Total CV %
Age	1	2	3	4	5	6		
Raw CWT Recoveries		1	1				2	0%
		(50%)	(50%)					
Expanded CWTtotal		**2**	**2**				4	0%
		(50%)	(50%)					

All Runs							Total CV	Total CV
Age	1	2	3	4	5	6	CWTs	%
Raw CWT Recoveries	3	28,926	12,256	4,895	512	4	46,596	100%
	(< 1%)	(62%)	(26%)	(11%)	(1%)	(< 1%)		
Expanded CWTtotal	**47**	**124,196**	**83,450**	**18,895**	**1,108**	**4**	227,700	100%
	(< 1%)	(54%)	(37%)	(8%)	(< 1%)	(< 1%)		

Table 8. Raw and expanded Ocean CWT recoveries by stock and age, brood years 2006-2010

Fall	2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	3,171	3,815	304	1	7,291	84%
	(43%)	(52%)	(4%)	(< 1%)		
Expanded CWT total	**20,055**	**33,975**	**2,825**	**5**	56,860	86%
	(35%)	(60%)	(5%)	(< 1%)		
Spring	2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	69	194	8	0	271	3%
	(25%)	(72%)	(3%)			
Expanded CWT total	**200**	**573**	**19**	**0**	793	1%
	(25%)	(72%)	(3%)			
Late-Fall	2010	2009	2008	2007	Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	0	383	66	3	452	5%
		(85%)	(15%)	(< 1%)		
Expanded CWT total	**0**	**1,015**	**168**	7	1,191	2%
		(85%)	(14%)	(< 1%)		
Winter	2010	2009	2008	2007	Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	0	71	1	0	72	1%
		(99%)	(< 1%)			
Expanded CWT total	**0**	**243**	**3**	**0**	246	0%
		(99%)	(< 1%)			
Non CV Rivers	2009	2008	2007	2006	Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	2	358	244	27	631	7%
	(< 1%)	(57%)	(39%)	(4%)		
Expanded CWT total	**28**	**4,329**	**2,299**	**103**	6,758	10%
	(< 1%)	(64%)	(34%)	(2%)		
All Runs					Total Ocean CWTs	Total Ocean%
Age	2	3	4	5		
Raw CWT Recoveries	3,242	4,821	623	31	8,717	100%
	(37%)	(55%)	(7%)	(< 1%)		
Expanded CWT total	**20,283**	**40,136**	**5,314**	**114**	65,848	100%
	(31%)	(61%)	(8%)	(< 1%)		

Table 9. Percentage of inland $\text{CWT}_{\text{total}}$ recoveries by location, run, and release type[a] in hatchery returns, natural escapement and sport harvest during 2011.

		Coleman National Fish Hatchery					Feather River Hatchery[b]								Nimbus Hatchery			Mokelumne/Merced hatcheries[b]						Total %		Total
Location	**Run**	**CFHLh**	**CFHLe**	**CFHFh**	**CFHFn**	**CFHFe**	**FRHS**	**FRHSn**	**FRHFe**	**FRHFn**	**FRHFnc**	**FRHFt**	**FRHFtib**	**FEAFw**	**NIMF**	**NIMFn**	**NIMFtib**	**MOKF**	**MOKFn**	**MOKFt**	**MokFw**	**MERF**	**nonCV**	**Hatchery**	**Natural**	**Run**
Hatchery Spawners																										
Coleman Hatchery	Late	98.4%	-	2.0%	0.1%												-			-				100%	0%	4,534
Feather River Hatchery	Spring						24.2%	29.5%	6.4%	33.1%			0.2%						0.2%					94%	6%	1,969
Coleman Hatchery	Fall	0.6%		86.8%	0.5%	-			-	0.6%			-						-			-		89%	11%	42,380
Feather River Hatchery	Fall			-	2.6%	-	3.3%	4.0%	1.6%	83.6%	0.1%	-	0.4%	-	0.1%	0.1%			0.1%	-		-		96%	4%	32,616
Nimbus Hatchery	Fall				2.0%				-	2.1%	-	-	-		25.9%	37.4%	0.1%		6.3%	0.6%		2.5%		77%	23%	12,680
Nimbus Weir	Fall				3.3%			0.2%	0.1%	3.4%			0.3%		11.3%	5.0%			1.4%	0.1%		0.7%		26%	74%	3,917
Mokelumne Hatchery	Fall	-		-	2.5%		-	0.1%	-	2.0%	-		0.1%		0.1%	3.5%	0.2%	1.2%	77.3%	7.1%	-	3.6%		98%	2%	15,922
Merced Hatchery	Fall	0.2%			3.7%					6.4%			0.2%			0.9%			39.6%	3.9%		33.0%		88%	12%	437
Total Hatchery Fall Run		**0.3%**		**34.1%**	**1.7%**	**-**	**1.0%**	**1.2%**	**0.5%**	**26.2%**	**-**	**-**	**0.1%**	**-**	**3.5%**	**5.1%**	**-**	**0.2%**	**12.4%**	**1.1%**	**-**	**1.0%**		**89%**	**11%**	**107,952**
Natural Spawners																										
Upper Sacramento River	Late	37.2%	4.0%													2.2%	1.1%							44%	56%	3,725
Butte Creek	Spring																							0%	100%	4,497
Clear Creek	Fall			2.3%		0.1%		0.5%	0.1%	5.0%			0.2%											8%	92%	4,841
Cottonwood Creek[c]	Fall			42.2%	6.7%					8.1%	0.3%		0.3%											58%	42%	2,144
Mill Creek[c]	Fall			6.2%	0.8%					0.3%			0.1%											7%	93%	1,485
Battle Creek[d]	Fall	0.6%		86.8%	0.5%	-			-	0.6%			-						-			-		89%	11%	12,867
Butte Creek	Fall				4.1%					2.1%									0.5%					7%	93%	419
Upper Sac River	Fall			12.4%	1.2%	0.2%		0.3%	0.4%	11.7%							0.1%		0.5%			0.1%		27%	73%	10,583
Feather River	Fall				3.1%		4.2%	4.3%	1.8%	75.8%	-	-	0.3%			0.1%	-		-			-		90%	10%	47,289
Yuba River - Above DPD	Fall				8.9%		0.4%	1.7%	1.3%	48.3%			1.5%		0.8%				1.3%			0.2%		65%	35%	7,723
Yuba River - Below DPD	Fall				5.8%		0.5%	1.0%	0.5%	17.4%			0.5%		3.9%	1.9%			1.9%	0.5%				34%	66%	1,398
American River	Fall				11.5%				-	4.6%		0.1%			17.0%	30.6%	0.1%		1.6%	0.4%		0.5%	0.1%	66%	34%	21,320
Mokelumne River	Fall				2.5%			0.1%	-	2.0%			0.1%		0.1%	3.1%	0.1%	1.1%	69.0%	6.4%		3.2%		88%	12%	2,667
Calaveras River[c]	Fall				0.9%											1.7%	0.2%		6.2%	1.9%		2.6%		14%	86%	465
Stanislaus River	Fall				21.4%					3.4%						3.3%	0.2%	0.2%	25.7%	15.6%		12.9%		83%	17%	1,063
Tuolumne River	Fall				8.7%			0.2%	0.5%	13.9%						0.9%	0.2%		21.1%	5.2%		21.9%		73%	27%	878
Merced River	Fall				15.7%					2.0%	0.5%					5.1%	0.2%		25.4%	15.5%		24.6%		89%	11%	1,615
Total Natural Area Fall Run[e]		**0.1%**		**11.2%**	**4.9%**	**-**	**1.8%**	**2.0%**	**0.9%**	**37.8%**	**-**	**-**	**0.2%**		**3.3%**	**6.0%**	**-**	**-**	**2.9%**	**0.6%**		**0.9%**	**-**	**73%**	**27%**	**112,663**
Sport Harvest																										
Inland Creel - Late Fall	Late	65.1%		2.2%				0.6%											0.6%					68%	32%	1,730
Inland Creel - Upper Sac	Fall	0.3%		69.6%	1.5%			0.2%	0.2%	2.8%													0.1%	75%	25%	19,971
Inland Creel - Lower Sac	Fall	1.6%		4.1%	9.0%			0.3%	0.5%	36.4%			0.2%		15.9%	6.1%	0.2%		4.4%	0.8%		1.4%	0.2%	81%	19%	14,900
Inland Creel - Feather	Fall				7.1%		0.5%		0.9%	73.9%			0.9%											83%	17%	4,218
Inland Creel - American	Fall				10.5%			0.2%		7.8%			0.4%		42.4%	29.5%			3.5%	0.2%		0.4%		95%	5%	21,411
Total Sport Fall Harvest		**0.5%**		**24.0%**	**6.9%**		**-**	**0.2%**	**0.2%**	**17.8%**			**0.2%**		**18.9%**	**12.0%**	**-**		**2.3%**	**0.3%**		**0.5%**	**0.1%**	**84%**	**16%**	**60,500**

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent a small number of recoveries and are not actual zeros.

b/ Natural-origin Feather River (FeaW) and Mokelumne River (Mokw) CWT releases are not included in this table due to minimal recoveries occurring only at the Feather River and Mokelumne hatcheries (contributed 0.02% and 0.01%, respectively).

c/ Surveys without representative sampling of CWTs; proportions shown are based only on CWTs collected opportunistically.

d/ No CWT recovery survey or ad-clip count available for Battle Creek natural escapement. CWT release group and total hatchery proportions assumed to be equivalent to Coleman National Fish Hatchery (FWS staff, per. comm).

e/ Total natural area fall run total only includes surveys with representative sampling of CWTs.

Table 10. 2011 CWT recovery rate (recoveries per 100,000 CWTs released) by release group, brood year, and recovery location (page 1 of 2).

Age 2 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[a/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
FRHS	2009	Spr	1,026,954				578	16					594		594	87	58		58	8	0.00
FRHSn	2009	Spr	1,058,635			18	1,033	104	6	4			1,136	28	1,164	113	107	3	110	11	0.02
CFHFh	2009	Fall	2,543,157	5,390	36	212	1			1			5,426	214	5,640	4,321	213	8	222	170	0.04
CFHFn	2009	Fall	339,179	35		35	243	85	215	92	25	28	35	722	757	1,741	10	213	223	513	0.95
FRHFn	2009	Fall	2,367,209	43	97	67	7,492	403	76	73	14	20	7,896	391	8,286	5,421	334	17	350	229	0.05
FRHFnc	2009	Fall	118,879			6	**58**		1	2	8		58	18	76	694	49	15	64	584	0.23
FRHFtib	2009	Fall	60,104				130		1	5	1		130	7	136	45	216	11	227	75	0.05
FeaFw	2009	Fall	177,657				4						4		4	2	2		2	1	0.00
NIMF	2009	Fall	1,000,559				6	30	1,916	6			1,916	42	1,958	3,881	191	4	196	388	0.02
NIMFn	2009	Fall	347,527			1	1		401	38	8		401	49	450	644	115	14	129	185	0.11
MokF	2009	Fall	99,048							220		2	220	2	222		222	2	224		0.01
MokFn	2009	Fall	2,015,730	10		27	33	124	1,145	14,034	534	449	14,034	2,321	16,354	2,730	696	115	811	135	0.14
MokFw	2009	Fall	1,113																		-
MerF	2009	Fall	154,685	2	12	11	28	16	386	605	487	293	487	1,353	1,840	576	315	875	1190	372	0.74
CFHLh	2010	Late	992,047	157						1	1		157	2	159		16	0.2	16		0.01
			Total	5,637	145	376	9,607	778	4,146	15,081	1,078	793	32,494	5,147	37,641	20,255	2,545	1,277	3,822	2,672	

Age 3 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[a/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
FRHS	2008	Spr	1,015,717				2,237	23		1			2,260	1	2,261	265	223	0.1	223	26	0.00
FRHSn	2008	Spr	1,005,727		24	4	2,006	39	1	10		2	2,045	41	2,086	308	203	4	207	31	0.02
CFHFh	2008	Fall	3,128,111	3,461	267	60							3,727	60	3,788	8,716	119	2	121	279	0.02
CFHFn	2008	Fall	371,685	21	36	8	351	97	472	23	45	51	57	1,048	1,105	4,056	15	282	297	1,091	0.95
FRHFe	2008	Fall	481,853	2	36	4	1,429	104	12	8		4	1,533	66	1,598	334	318	14	332	69	0.04
FRHFn	2008	Fall	2,061,211	20	109	34	6,626	435	135	17	1	24	7,061	340	7,401	8,161	343	17	359	396	0.05
FRHFtib	2008	Fall	89,859	4		17	111	120	11	11			231	43	274	120	257	48	305	133	0.16
FeaFw	2008	Fall	289,830				3						3		3	11	1		1	4	0.00
NIMF	2008	Fall	264,006						92				92		92	104	35		35	39	0.00
NIMFn	2008	Fall	976,955				15	7	2,330	55	9	2	2,330	87	2,417	10,983	238	9	247	1,124	0.04
MokFt	2008	Fall	250,300	2		9	1	7	159	1,305	267	211	1,305	657	1,962	1,433	521	262	784	573	0.33
MokFw	2008	Fall	20,680							2			2		2	4	11		11	21	0.00
MerF	2008	Fall	32,978				1		35	19	27	16	27	70	97	52	81	214	294	157	0.73
CFHLh	2009	Late	1,115,378	1,023	81								1,104		1,104	1,015	99		99	91	0.00
			Total	4,532	554	136	12,779	831	3,249	1,451	349	311	21,777	2,414	24,191	35,563	2,465	851	3,316	4,035	

Table 10. 2011 CWT recovery rate (recoveries per 100,000 CWTs released) by release group, brood year, and recovery location (page 2 of 2).

Age 4 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[a/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
ButSw	2007	Spr	323,916																		-
FRHS	2007	Spr	1,378,941				672						672		672	12	49		49	1	0.00
FRHSn	2007	Spr	1,242,480		12		811			1			811	13	824	7	65	1	66	1	0.02
CFHFe	2007	Fall	196,993	12	24	4	1						36	5	41	2	18	2	21	1	0.11
CFHFh	2007	Fall	2,801,459	343	24	6							367	6	373	359	13	0.2	13	13	0.02
CFHFn	2007	Fall	314,681	2		1	9	16	53	3			2	83	85	219	1	26	27	70	0.98
FRHFe	2007	Fall	619,085				43		1				43	1	44	6	7	0.2	7	1	0.02
FRHFn	2007	Fall	2,347,396	2	109	9	1,858	162	138	4		2	2,020	264	2,284	1,595	86	11	97	68	0.12
FRHFt	2007	Fall	101,712				13		24				13	24	37	10	12	24	36	10	0.66
FeaFw	2007	Fall	206,683				1						1		1		0.5		0.5		0.00
NIMFn	2007	Fall	1,714,858		20	1			127	66	4	9	193	34	227	430	11	2	13	25	0.15 [b/]
NIMFtib	2007	Fall	51,600	1	53	1	9		34	30	4	4	64	72	136	74	123	140	264	144	0.53 [b/]
MokF	2007	Fall	101,458							1			1		1		1		1		0.00
MokFn	2007	Fall	550,668		12	1	2		11	22	12	2	22	41	63	129	4	7	11	23	0.65
MokFw	2007	Fall	315																		-
CFHLh	2008	Late	1,072,854	2,932	808								3,740		3,740	168	349		349	16	0.00
			Total	3,292	1,063	23	3,419	178	388	128	21	17	7,984	543	8,527	3,013	740	215	955	372	

Age 5 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[a/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
CFHLe	2007	Late	299,292	1	141								142		142		48		48		0.00
CFHLh	2007	Late	732,952	481	445								926		926	5	126		126	0.6	0.00

a/ Natural creeks include Clear Creek, Cottonwood Creek, Butte Creek and Mill Creek.

b/ Nimbus Hatchery fall Chinook net pen releases (NIMFn and NIMFtib) brood year 2007 contained salmon from the American River raised at Mokelumne River Fish Hatchery.

Sacramento River fall Chinook releases (SFC)

CFHFe	Coleman Hatchery fall experimental releases
CFHFh	Coleman Hatchery fall hatchery releases
CFHFn	Coleman Hatchery fall net pen releases
FRHFe	Feather River Hatchery fall experimental (2008 brdyr includes spring x fall hybrids)
FRHFn	Feather River Hatchery fall bay net pen releases
FRHFnc	Feather River Hatchery fall coastal net pen releases
FRHFt	Feather River Hatchery fall trucked releases (no net pens)
FRHFtib	Feather River Hatchery fall Tiburon net pen releases (released as yearlings following fall)
FeaFw	Feather River fall wild
NIMF	Nimbus Hatchery fall basin releases
NIMFn	Nimbus Hatchery fall net pens
NIMFtib	Nimbus Hatchery fall Tiburon net pens (released as yearlings following fall)

Other CV releases (OCV)

CFHLe	Coleman Hatchery late fall experimental releases
CFHLh	Coleman Hatchery late fall hatchery releases
FRHS	Feather River Hatchery spring basin releases
FRHSn	Feather River Hatchery spring net pen releases
FRHSt	Feather River Hatchery spring trucked releases
MerF	Merced River fall releases
MokF	Mokelumne Hatchery fall basin releases
MokFn	Mokelumne Hatchery fall net pen releases
MokFt	Mokelumne Hatchery fall trucked releases
MokFw	Mokelumne River fall wild

Wild releases

ButSw	Butte Creek spring wild

Table 11. Percentage of ocean CWT$_{total}$ recoveries by majorport, month and release type[a] in 2011 California sport and commercial fisheries (page 1 of 2).

	Livingston/Coleman Hatcheries						Feather River Hatchery								Nimbus Hatchery			Mokelumne/Merced Hatcheries[b]						Total	Total %		Total
	SacW	CFHLh	CFHLe	CFHFh	CFHFn	CFHFe	FRHS	FRHSn	FRHFe	FRHFn	FRHFnc	FRHFt	FRHFtib	FeaW	NIMF	NIMFn	NIMFtib	MOKF	MOKFn	MOKFt	MokFw	MERF	nonCV	CV	Hatchery	Natural	Harvest
Sport Harvest																											
Eureka/Crescent City																											
May		0.5%		15.4%	5.8%			0.5%	1.0%	20.0%					0.5%	13.5%			1.9%	0.5%		0.5%	4.0%	60.1%	64%	36%	666
Jun				12.8%				0.5%	0.5%	8.0%						8.1%				2.0%			8.3%	31.9%	40%	60%	946
Jul		0.1%		12.7%	6.2%		0.1%	0.1%		11.2%					1.0%	9.8%			0.7%	2.2%		0.1%	9.8%	44.2%	54%	46%	4,384
Aug		0.7%		10.0%	2.2%		0.9%	0.6%		7.8%	0.4%				4.8%	12.4%	0.1%		4.5%	0.6%		0.8%	14.4%	45.8%	60%	40%	3,690
Sep				9.1%	9.2%		1.2%			18.4%	1.2%				4.6%	9.1%			18.3%			6.3%	4.6%	77.4%	82%	18%	301
Total		**0.3%**		**11.8%**	**4.2%**		**0.4%**	**0.3%**	**0.1%**	**10.4%**	**0.2%**				**2.4%**	**10.8%**	**-**		**2.7%**	**1.4%**		**0.6%**	**10.8%**	**45.7%**	**57%**	**43%**	**9,987**
Fort Bragg																											
Apr		0.4%		17.4%	13.2%		1.3%	0.5%	0.4%	23.4%			0.4%			24.4%				3.6%			0.9%	85.0%	86%	14%	880
May				13.2%	1.6%		1.0%	1.9%		17.1%						29.7%				0.9%			2.1%	65.4%	67%	33%	705
Jun		0.9%		6.4%	5.6%		0.3%	0.3%	0.3%	29.2%			0.3%		3.4%	8.1%	0.3%			1.8%			23.1%	57.0%	80%	20%	938
Jul		1.6%		14.1%	3.1%			0.1%	0.1%	12.3%	0.1%		0.1%		0.4%	10.7%	0.1%		1.0%	1.7%		0.3%	1.7%	45.7%	47%	53%	4,043
Aug		1.0%		17.2%	13.5%		0.5%	0.5%		17.2%	1.0%				9.7%	7.6%			4.8%	0.9%				73.8%	74%	26%	510
Sep		1.8%		11.0%						7.2%			0.9%		19.2%	14.6%			7.3%			1.9%		64.0%	64%	36%	204
Oct		4.1%		16.1%				8.2%			4.1%				16.0%				4.0%					52.6%	53%	47%	118
Total		**1.2%**		**13.6%**	**5.1%**		**0.3%**	**0.5%**	**0.2%**	**16.2%**	**0.2%**		**0.2%**		**2.1%**	**13.5%**	**0.1%**		**1.1%**	**1.7%**		**0.2%**	**4.2%**	**56.3%**	**60%**	**40%**	**7,398**
San Francisco																											
Apr		0.9%		13.9%	8.3%		0.9%	1.3%	0.9%	18.2%			1.4%			22.6%				2.6%				70.7%	71%	29%	432
May		2.7%		15.4%	4.2%		1.2%	0.4%	0.6%	11.5%			0.6%			14.6%				2.5%				53.6%	54%	46%	934
Jun	0.7%	2.2%		7.9%	13.1%		2.1%	2.8%	2.8%	33.5%			2.0%		0.8%	8.3%				2.8%			3.0%	79.0%	82%	18%	326
Jul	0.2%	1.1%		18.4%	10.6%		0.2%	0.2%	0.2%	22.8%	1.6%		0.3%	0.1%	6.6%	3.7%			5.8%	0.2%		0.7%	0.1%	72.7%	73%	27%	4,457
Aug	0.2%	0.3%		25.1%	10.5%		-	0.1%		25.1%	1.0%		0.1%		7.2%	2.4%			5.0%	0.2%		1.3%		78.6%	79%	21%	6,531
Sep	0.1%	0.2%		7.4%	2.7%		0.3%	0.2%		16.0%	0.2%		0.1%	-	23.1%	11.9%	0.1%		14.3%	0.7%	-	3.3%		80.6%	81%	19%	5,914
Oct	0.2%	3.7%		3.0%	2.3%			0.6%		3.8%	0.2%	0.2%			13.4%	12.2%	0.4%		15.9%	0.2%		3.6%		59.4%	59%	41%	1,140
Total	**0.2%**	**0.8%**		**16.0%**	**7.4%**		**0.2%**	**0.3%**	**0.1%**	**20.0%**	**0.8%**	**-**	**0.2%**	**-**	**11.6%**	**7.2%**	**-**		**8.2%**	**0.6%**	**-**	**1.8%**	**0.1%**	**75.4%**	**75%**	**25%**	**19,734**
Monterey																											
Apr	0.3%	0.9%		17.2%	12.7%		2.1%	1.7%	2.5%	24.2%			0.3%		0.1%	9.7%	0.1%			1.1%			4.8%	72.8%	78%	22%	4,210
May				8.5%	8.6%			4.3%	2.2%	17.2%						17.0%								57.8%	58%	42%	280
Jun	3.8%	3.4%		11.8%	7.0%				0.5%	21.8%	0.8%		0.4%		1.5%	5.5%	0.4%		0.7%	0.7%		0.4%		58.7%	59%	41%	1,170
Jul	1.1%	0.7%		14.4%	10.4%		0.3%	0.4%		25.5%	3.6%		0.1%		11.0%	3.7%			8.3%	0.1%		2.0%		81.6%	82%	18%	3,998
Aug	3.3%	0.7%		14.2%	2.5%		0.5%	0.9%		19.5%	5.0%		0.3%		14.6%	2.6%			10.5%			2.0%		76.5%	77%	23%	2,369
Sep				6.5%						8.7%	31.7%		1.1%		17.4%				11.3%	1.1%		1.7%		79.5%	79%	21%	676
Total	**1.4%**	**1.0%**		**14.5%**	**8.8%**		**0.9%**	**1.0%**	**0.9%**	**22.5%**	**3.8%**		**0.3%**		**7.3%**	**5.7%**	**0.1%**		**5.2%**	**0.5%**		**1.1%**	**1.6%**	**75.0%**	**77%**	**23%**	**12,703**
Total CA Harvest																											
	0.4%	**0.8%**		**14.4%**	**6.8%**		**0.5%**	**0.5%**	**0.3%**	**18.2%**	**1.3%**	**-**	**0.2%**	**-**	**7.2%**	**8.5%**	**0.1%**		**5.3%**	**0.9%**	**-**	**1.2%**	**3.2%**	**66.5%**	**70%**	**30%**	**49,822**

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent some small number of recoveries and are not actual zeros.

b/ Mokelumne River natural-origin tagged Chinook recoveries are not included in this table due to very small recovery totals in SF commercial (month 7) and SF sport (month 9), contributing only 0.03% and 0.04% respectively

Table 11. Percentage of ocean CWT_{total} recoveries by majorport, month and release type[a] in 2011 California sport and commercial fisheries (page 2 of 2).

	Livingston/Coleman Hatcheries						Feather River Hatchery								Nimbus Hatchery			Mokelumne/Merced Hatcheries[b]						Total	Total %		Total
	SacW	CFHLh	CFHLe	CFHFh	CFHFn	CFHFe	FRHS	FRHSn	FRHFe	FRHFn	FRHFnc	FRHFt	FRHFtib	FeaW	NIMF	NIMFn	NIMFtib	MOKF	MOKFn	MOKFt	MokFw	MERF	nonCV	CV	Hatchery	Natural	Harvest
Commercial Harvest																											
Eureka/Crescent City																											
Jul		0.1%		4.0%	1.9%					6.1%						4.0%				1.0%		0.1%	10.3%	17%	28%	72%	1,584
Aug		0.2%		4.6%						1.9%						3.5%	0.5%			0.5%			10.2%	11%	21%	79%	807
Total		**0.1%**		**4.2%**	**1.2%**					**4.7%**						**3.9%**	**0.2%**			**0.8%**		**0.1%**	**10.3%**	**15%**	**26%**	**74%**	**2,391**
Fort Bragg																											
Jul		0.7%		5.8%	1.7%		0.1%	0.1%	-	5.1%	-	-	-	-	0.1%	7.1%	0.1%		0.1%	0.9%		0.1%	12.7%	22%	34%	66%	21,085
Aug	-	1.5%	-	8.1%	1.8%		0.1%	0.1%	-	5.0%	0.1%	-	-	-	0.5%	12.4%	-		0.4%	1.6%		0.1%	9.4%	32%	41%	59%	17,766
Sep		4.5%		7.4%	2.5%			0.6%	0.7%	7.5%						32.4%			2.5%	3.7%			3.1%	62%	65%	35%	460
Total	**-**	**1.1%**	**-**	**6.9%**	**1.7%**		**0.1%**	**0.1%**	**-**	**5.1%**	**-**	**-**	**-**	**-**	**0.3%**	**9.8%**	**0.1%**		**0.2%**	**1.3%**		**0.1%**	**11.1%**	**27%**	**38%**	**62%**	**39,311**
San Francisco																											
May		0.3%		10.1%	6.0%	-	0.5%	0.7%	0.8%	14.8%			0.4%		0.2%	7.9%	-			1.0%		-	2.2%	43%	45%	55%	7,753
Jun		1.2%		15.5%	6.6%					11.9%			0.2%			17.5%				2.9%			0.2%	56%	56%	44%	2,830
Jul		2.1%		10.6%	5.9%		0.1%	0.1%	0.2%	11.3%		-	0.2%		0.2%	19.3%	0.1%		0.1%	2.8%	-	0.1%	3.3%	53%	56%	44%	8,305
Aug	0.2%	0.9%		26.4%	13.8%					15.1%			0.2%		2.8%	17.3%			0.2%	1.2%				78%	78%	22%	1,395
Sep		0.5%		10.0%	2.0%		0.2%			7.4%					9.4%	34.7%	0.3%		6.0%	2.1%		1.4%		74%	74%	26%	1,312
Oct		3.7%						0.8%							2.9%	23.2%	0.7%		4.3%	0.7%				36%	36%	64%	317
Total	**-**	**1.2%**		**11.9%**	**6.2%**	**-**	**0.2%**	**0.3%**	**0.4%**	**12.5%**		**-**	**0.3%**		**0.9%**	**15.9%**	**0.1%**		**0.5%**	**2.0%**	**-**	**0.1%**	**2.0%**	**52%**	**54%**	**46%**	**21,912**
Monterey																											
May	0.2%	0.3%		10.8%	9.3%		1.4%	2.2%	1.7%	25.1%			0.1%		0.1%	2.2%			0.5%	0.4%			2.4%	54%	57%	43%	3,979
Jun	0.6%	2.5%		17.4%	11.2%				0.6%	14.3%		0.1%		0.1%	0.3%	12.4%				0.7%		0.1%	0.2%	60%	61%	39%	1,359
Jul		1.6%		12.4%	3.6%			0.5%		6.3%					2.1%	10.4%			2.0%	1.6%				41%	41%	59%	695
Aug	2.2%	5.5%		17.3%	8.6%					17.4%	1.1%				14.1%	21.7%			1.1%	1.1%				90%	90%	10%	333
Sep											7.7%													8%	8%	92%	48
Total	**0.4%**	**1.2%**		**12.6%**	**9.0%**		**0.9%**	**1.4%**	**1.2%**	**20.2%**	**0.1%**	**-**	**-**	**-**	**1.1%**	**6.2%**			**0.6%**	**0.6%**		**-**	**1.6%**	**56%**	**57%**	**43%**	**6,414**
Total CA Harvest																											
	-	**1.1%**	**-**	**8.9%**	**3.8%**	**-**	**0.2%**	**0.3%**	**0.2%**	**8.8%**	**-**	**-**	**0.1%**	**-**	**0.5%**	**11.2%**	**0.1%**		**0.3%**	**1.4%**	**-**	**0.1%**	**7.4%**	**37%**	**44%**	**56%**	**70,028**

a/ Any values resulting in less than 0.05% are displayed here as "-". Note: These values represent some small number of recoveries and are not actual zeros.

b/ Mokelumne River natural-origin tagged Chinook recoveries are not included in this table due to very small recovery totals in SF commercial (month 7) and SF sport (month 9), contributing only 0.03% and 0.04% respectively

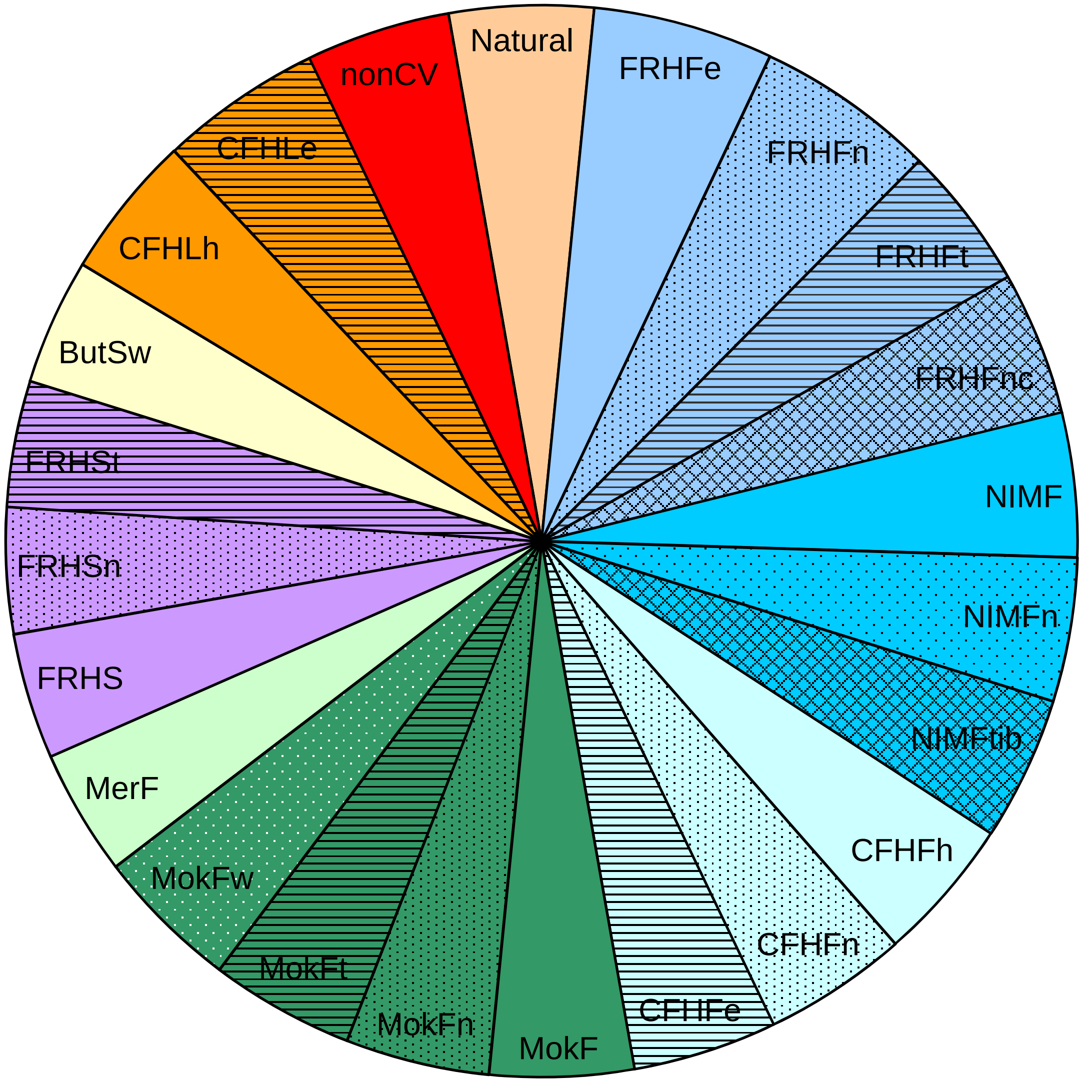


Figure 1. Central Valley hatchery release types color scheme (note: FRHFnc includes FRH fall Tiburon net pen releases).

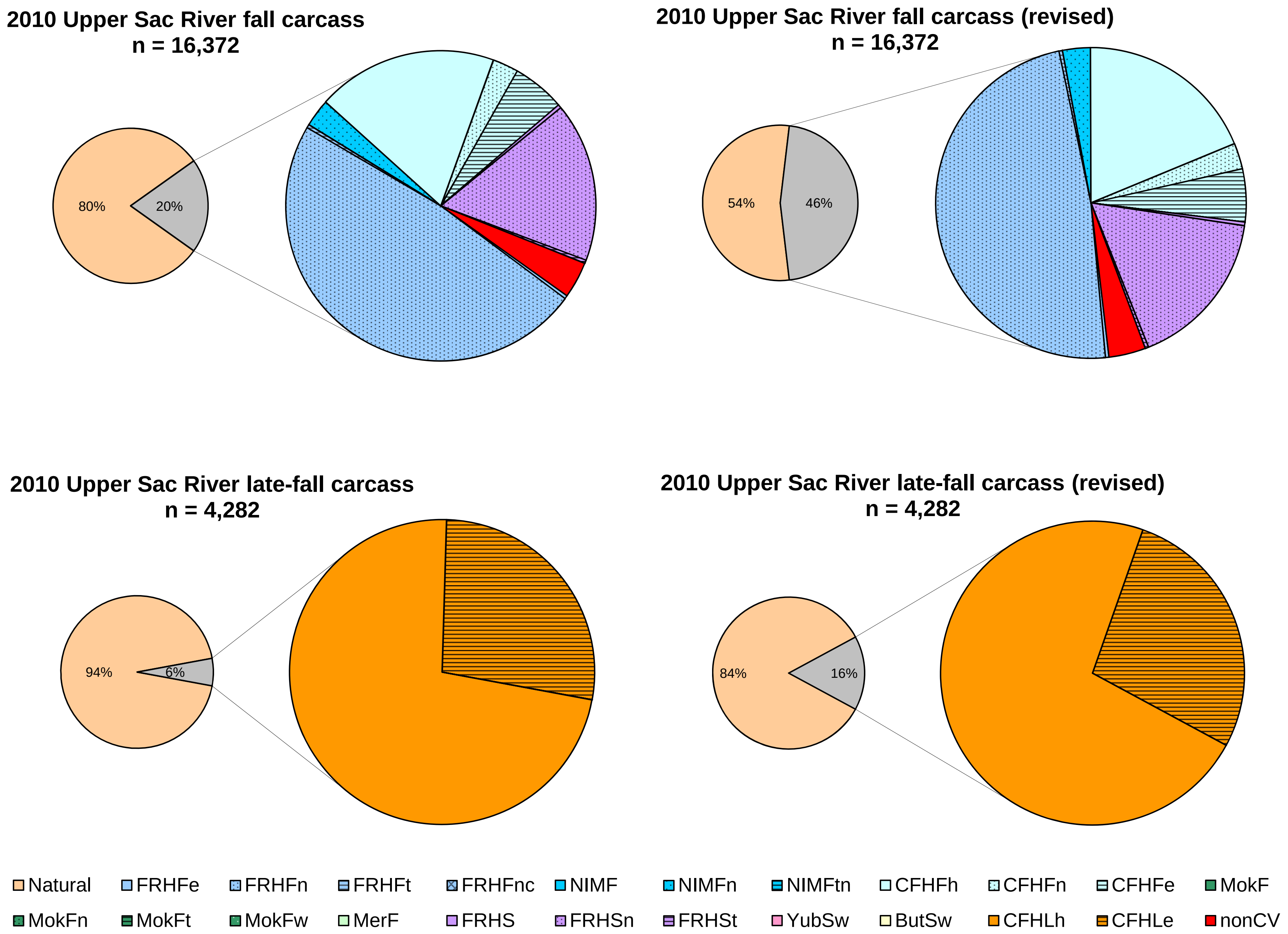


Figure 2. Revised proportion of hatchery and natural-origin fish in 2010 carcass surveys in the Upper Sacramento River Basin.

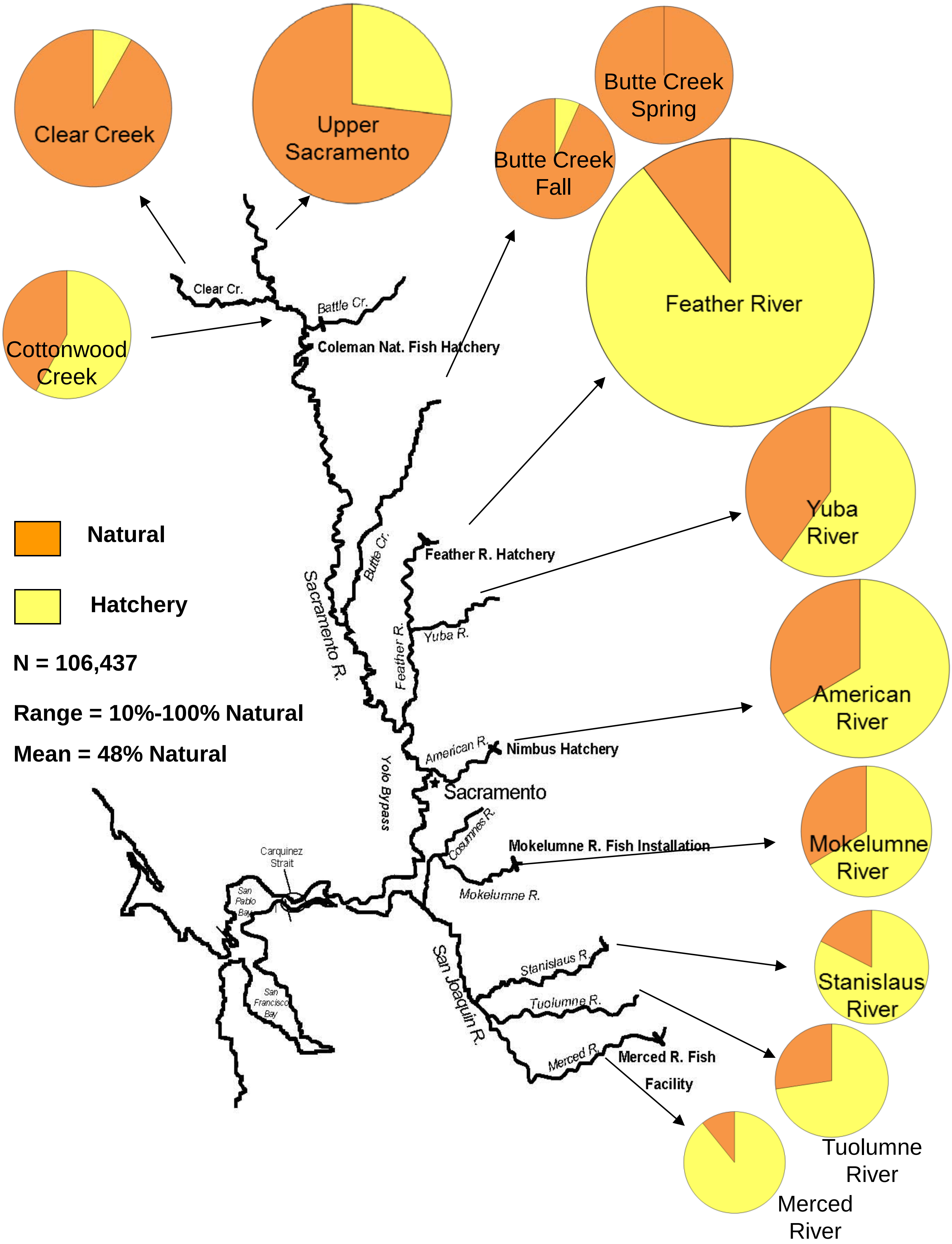
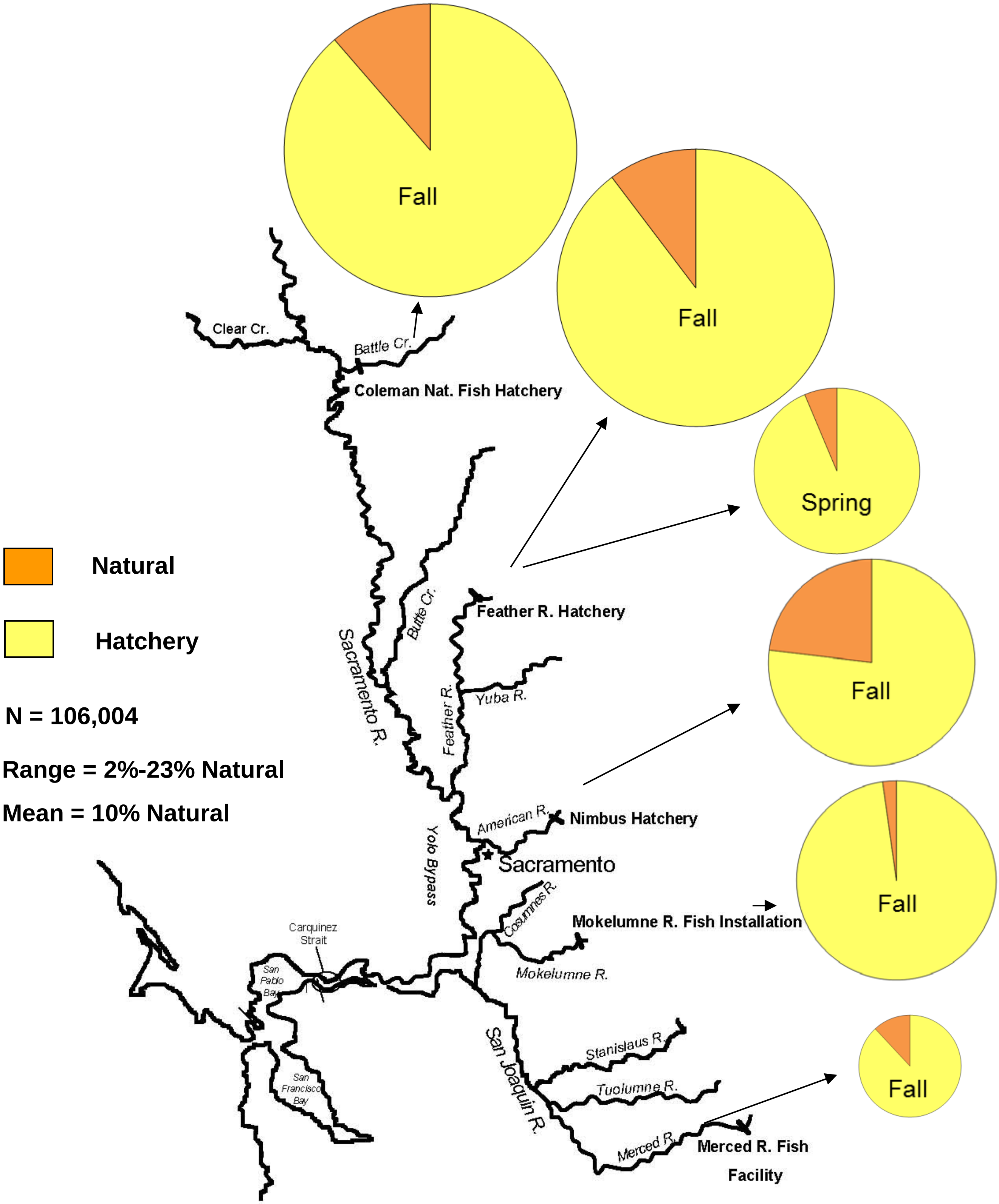


Figure 3. 2011 Chinook Salmon Natural Area Escapement, Hatchery and Natural Proportions.

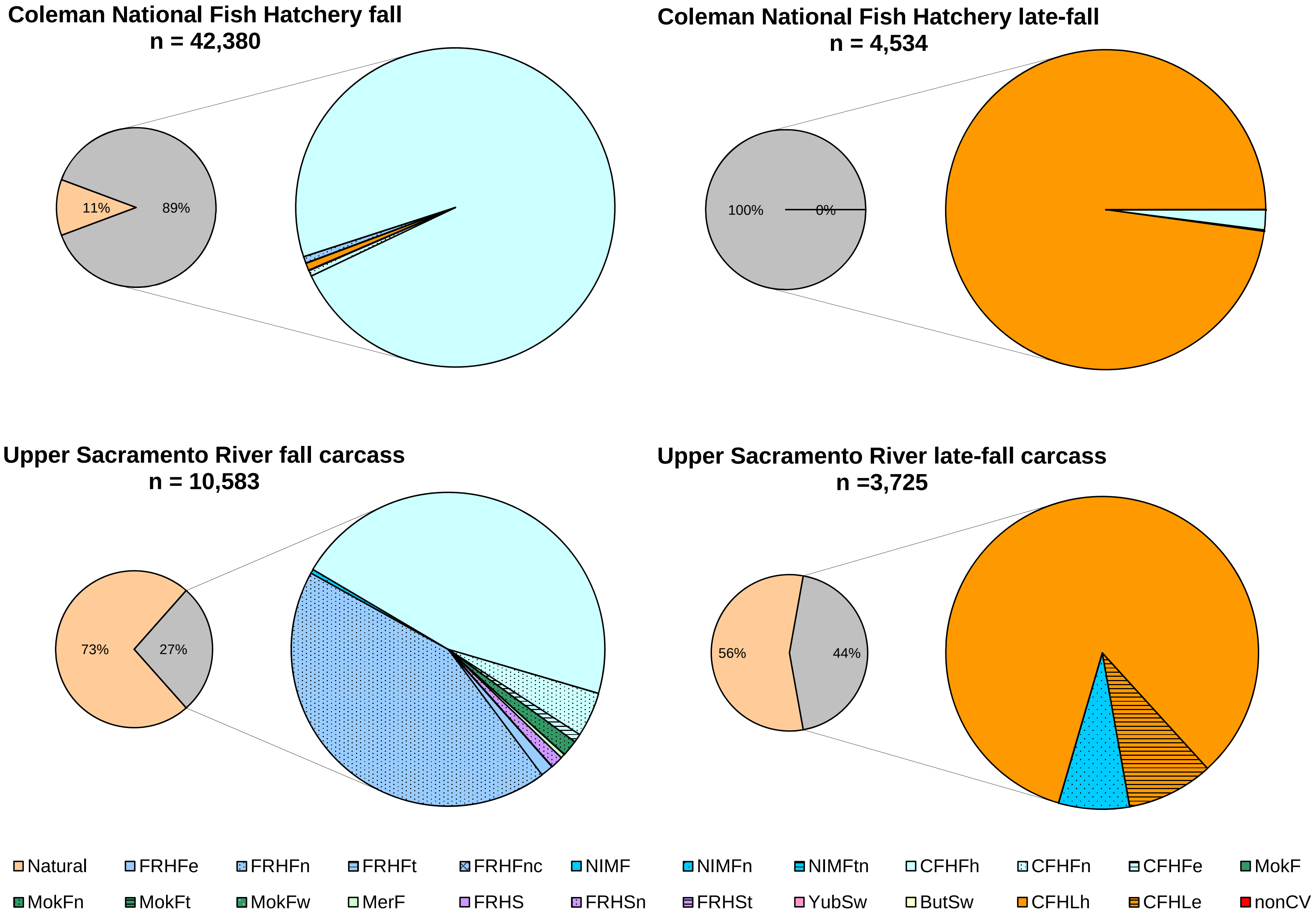


N = 106,004

Range = 2%-23% Natural

Mean = 10% Natural

Figure 4. 2011 Chinook Salmon Hatchery Escapement, Hatchery and Natural Proportions.



Coleman National Fish Hatchery fall
n = 42,380

Coleman National Fish Hatchery late-fall
n = 4,534

Upper Sacramento River fall carcass
n = 10,583

Upper Sacramento River late-fall carcass
n =3,725

Figure 5. Proportion of hatchery- and natural-origin fish in the Upper Sacramento River Basin.

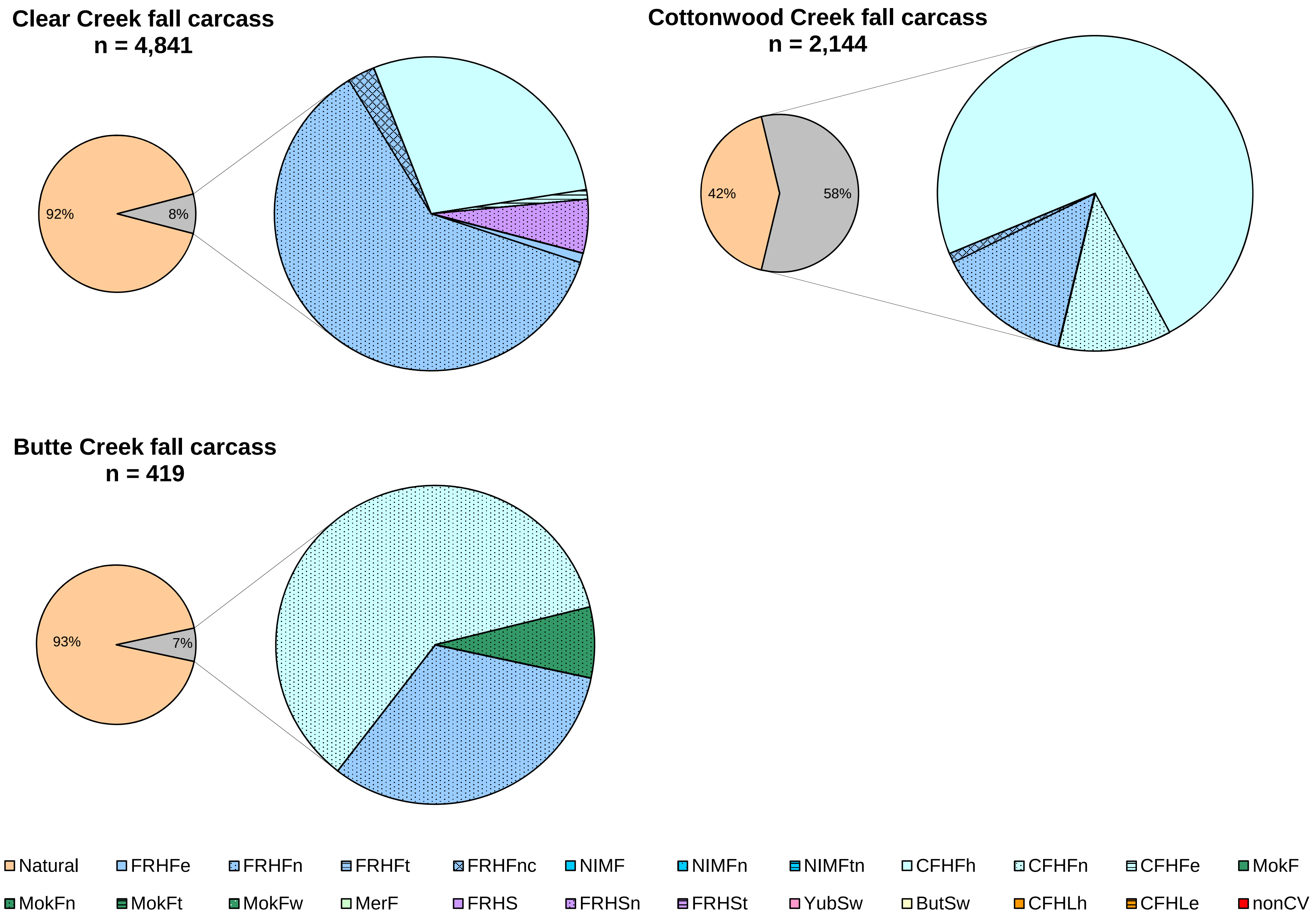


Figure 6. Proportion of hatchery- and natural-origin fish in Clear, Cottonwood, and Butte creeks.

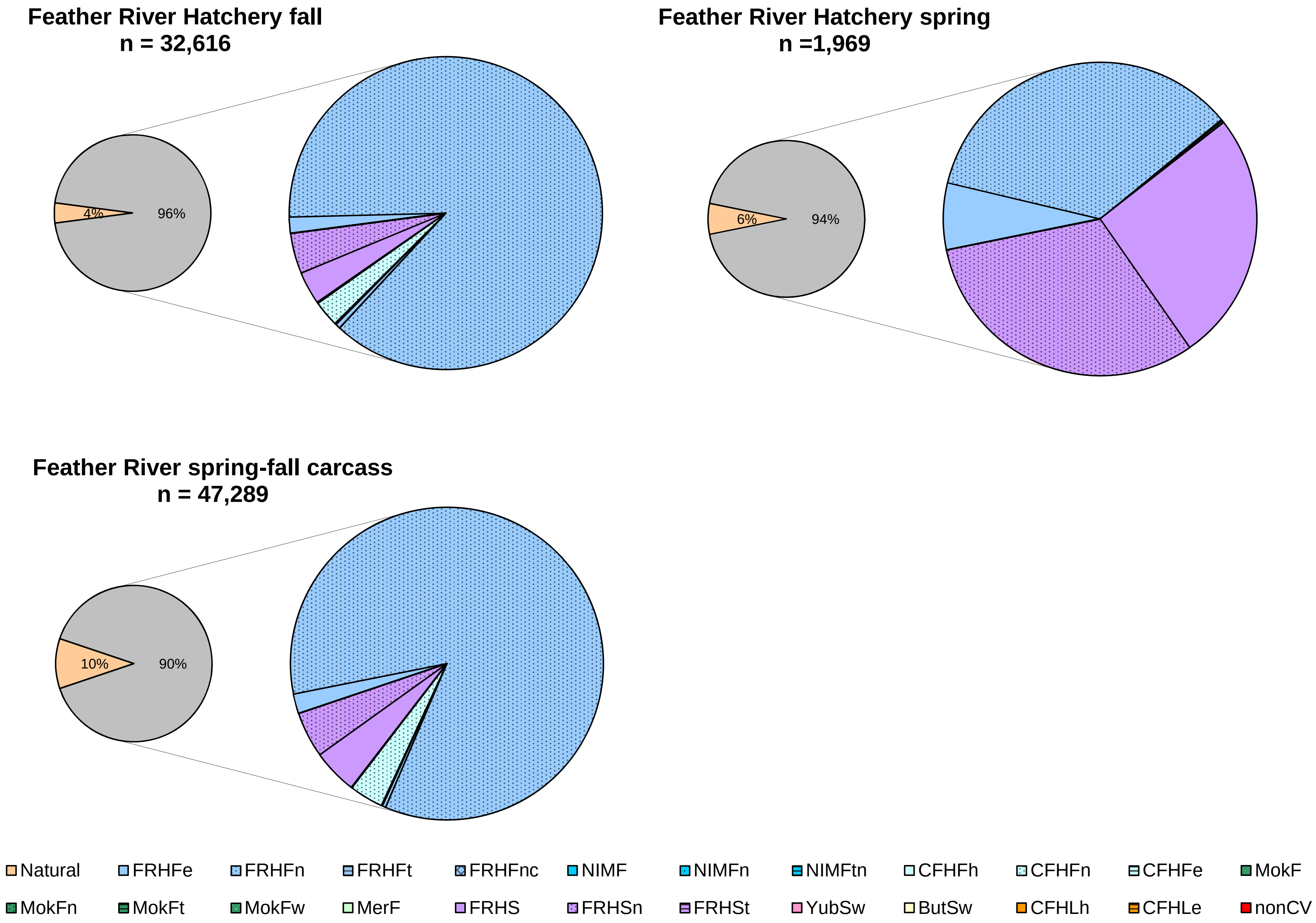


Figure 7. Proportion of hatchery- and natural-origin fish in the Feather River Basin.

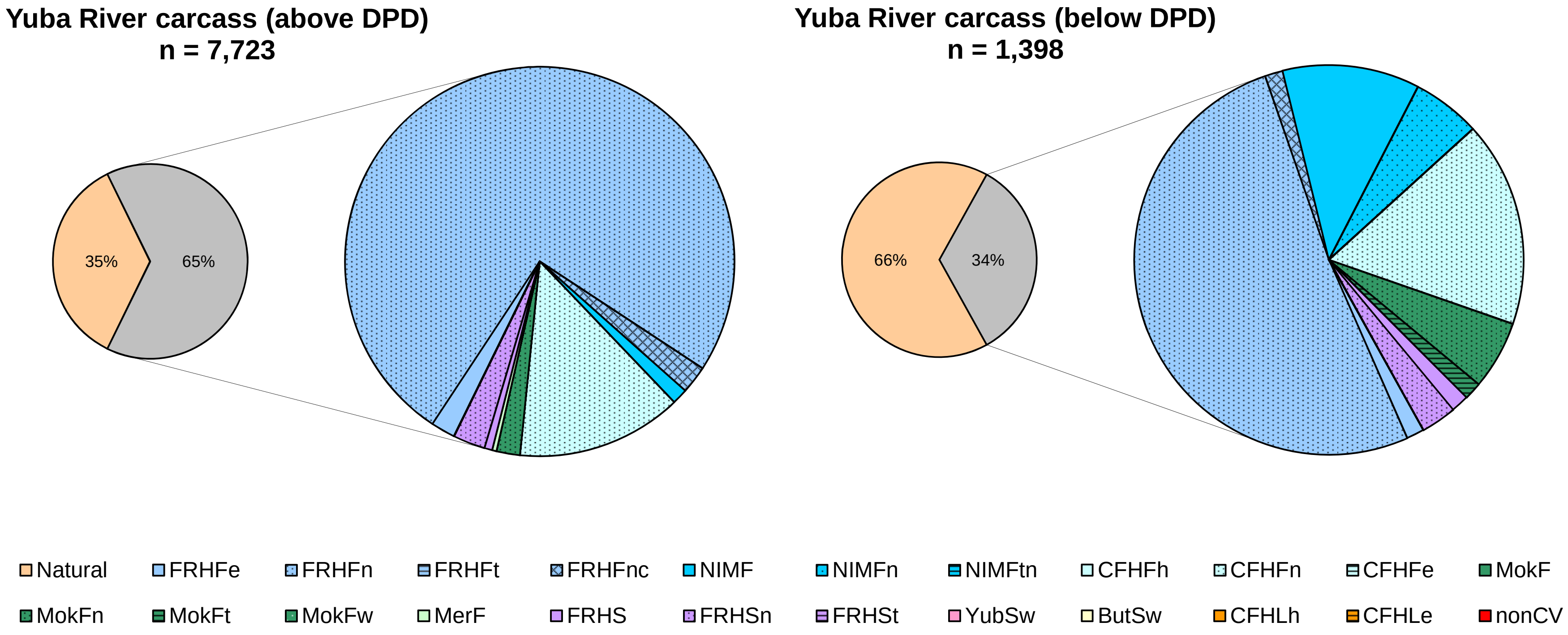


Figure 8. Proportion of hatchery- and natural-origin fish in the Yuba River.

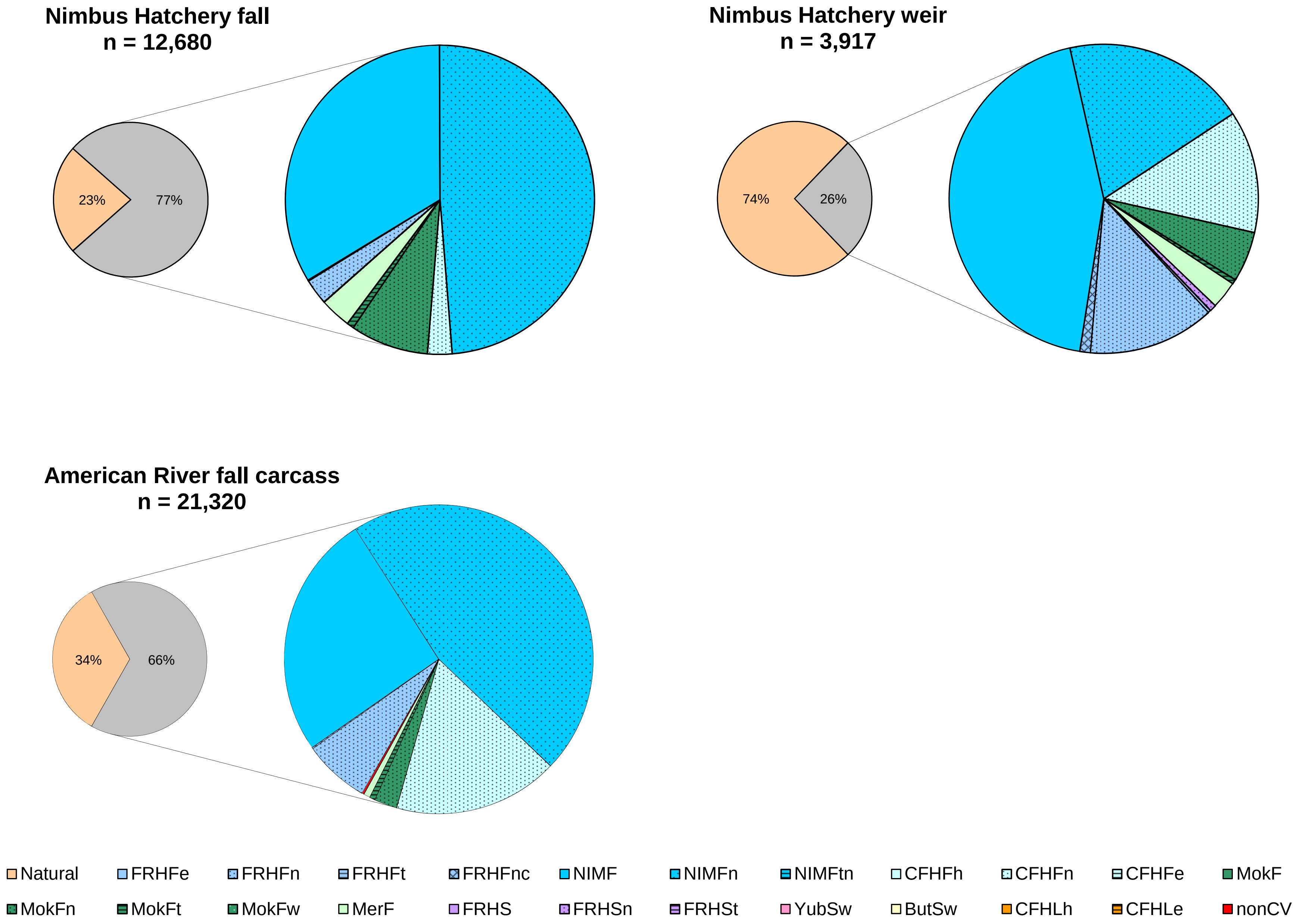
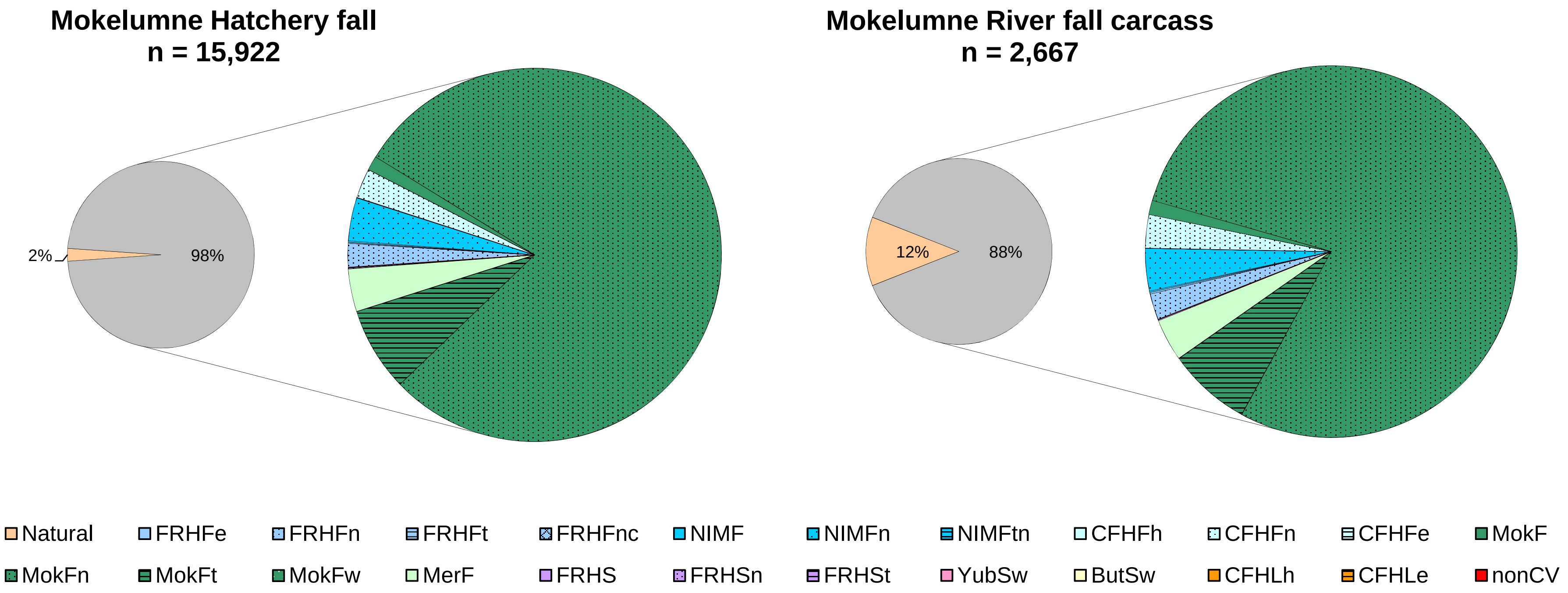


Figure 9. Proportion of hatchery- and natural-origin fish in the American River Basin.


Mokelumne Hatchery fall
n = 15,922

Mokelumne River fall carcass
n = 2,667

Figure 10. Proportion of hatchery- and natural-origin fish in the Mokelumne River Basin.

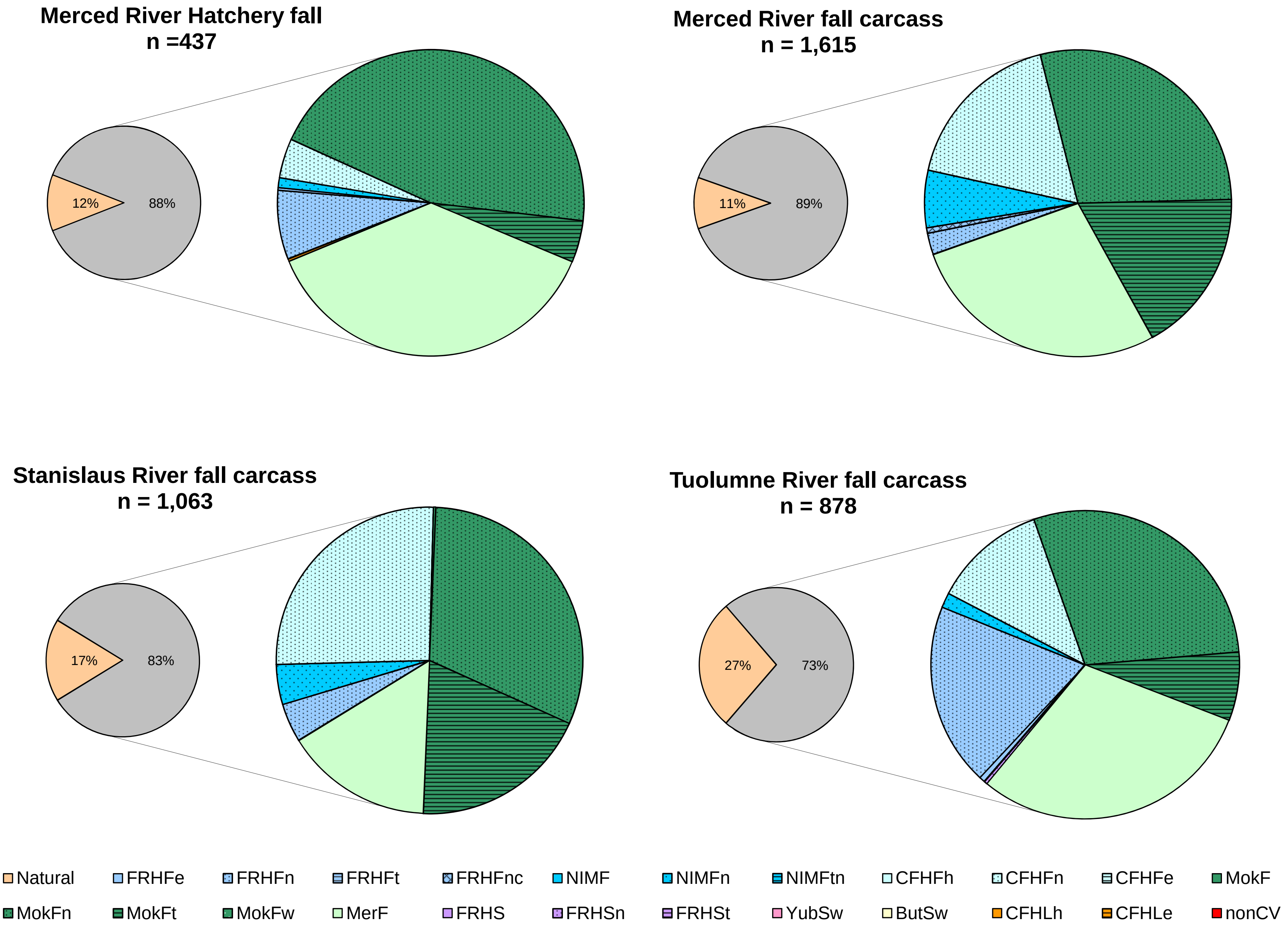
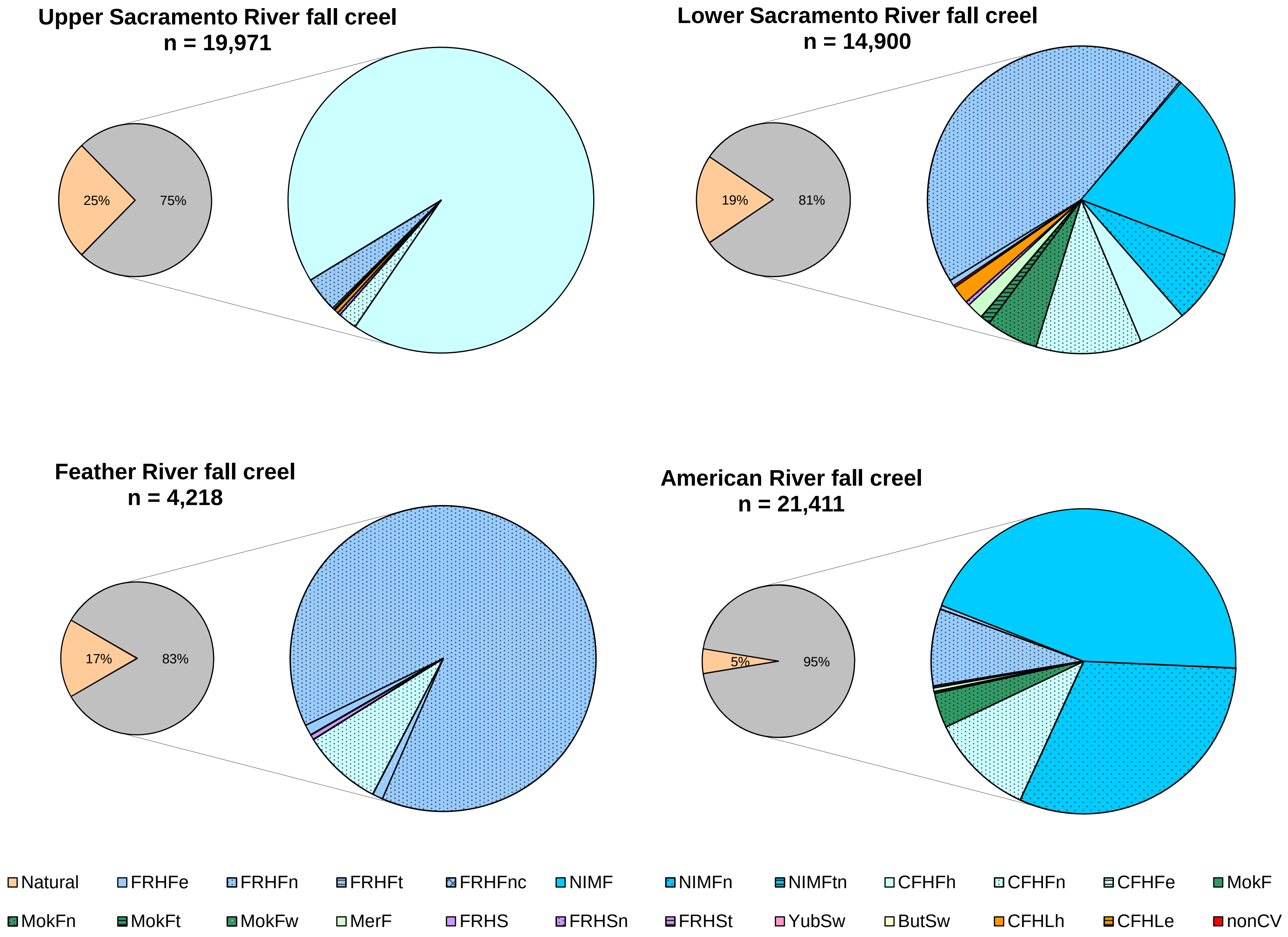


Figure 11. Proportion of hatchery- and natural-origin fish in other San Joaquin River tributaries.



Upper Sacramento River fall creel
n = 19,971

Lower Sacramento River fall creel
n = 14,900

Feather River fall creel
n = 4,218

American River fall creel
n = 21,411

Figure 12. Proportion of hatchery- and natural-origin fish in fall creel surveys on Sacramento, American & Feather rivers.

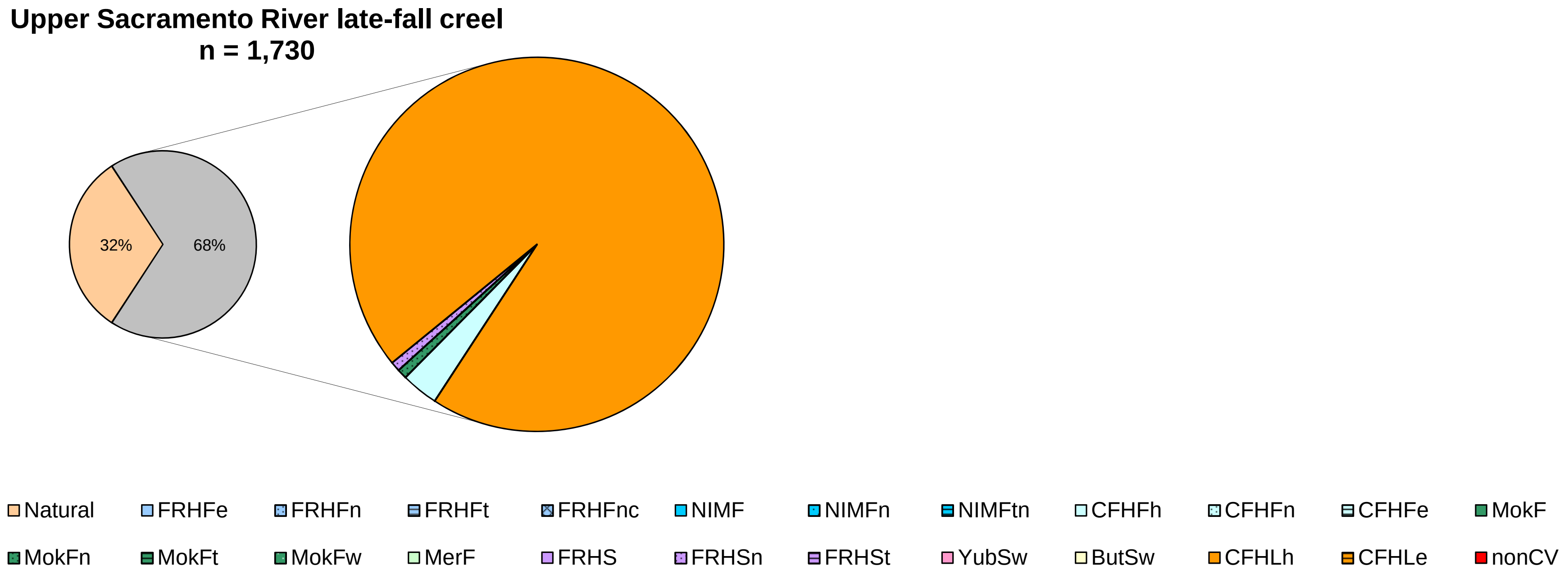
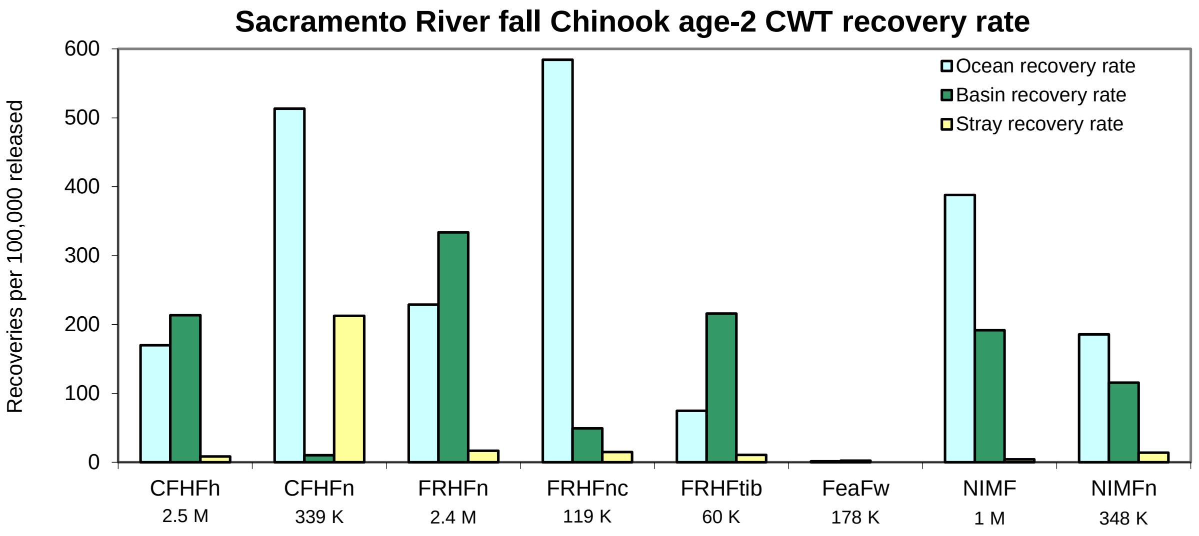
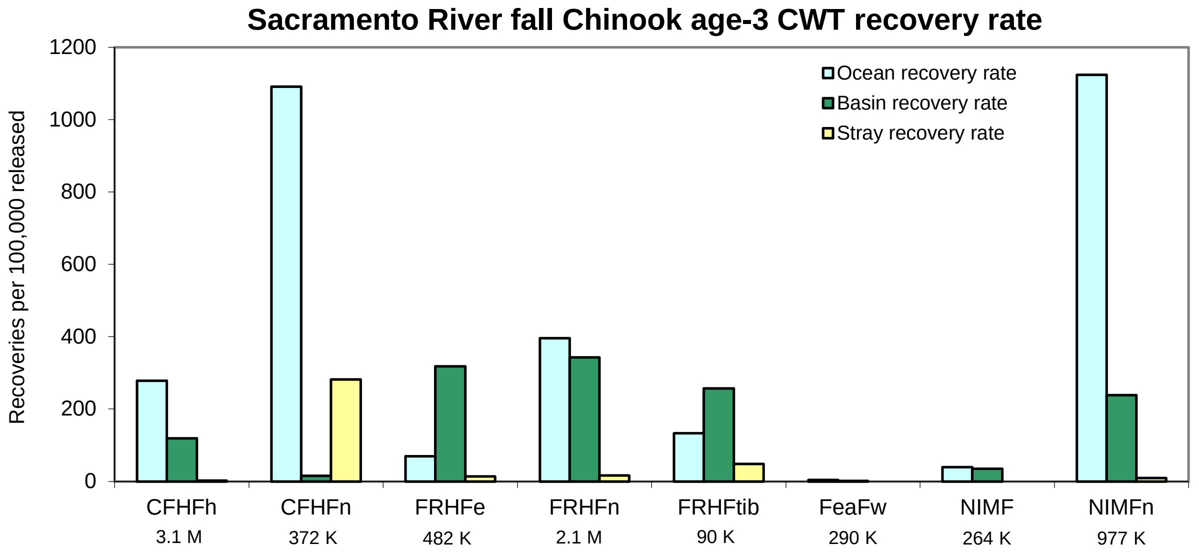


Figure 13. Proportion of hatchery- and natural-origin fish in late-fall creel survey on Upper Sacramento River.


Sacramento River fall Chinook age-2 CWT recovery rate


Sacramento River fall Chinook age-3 CWT recovery rate

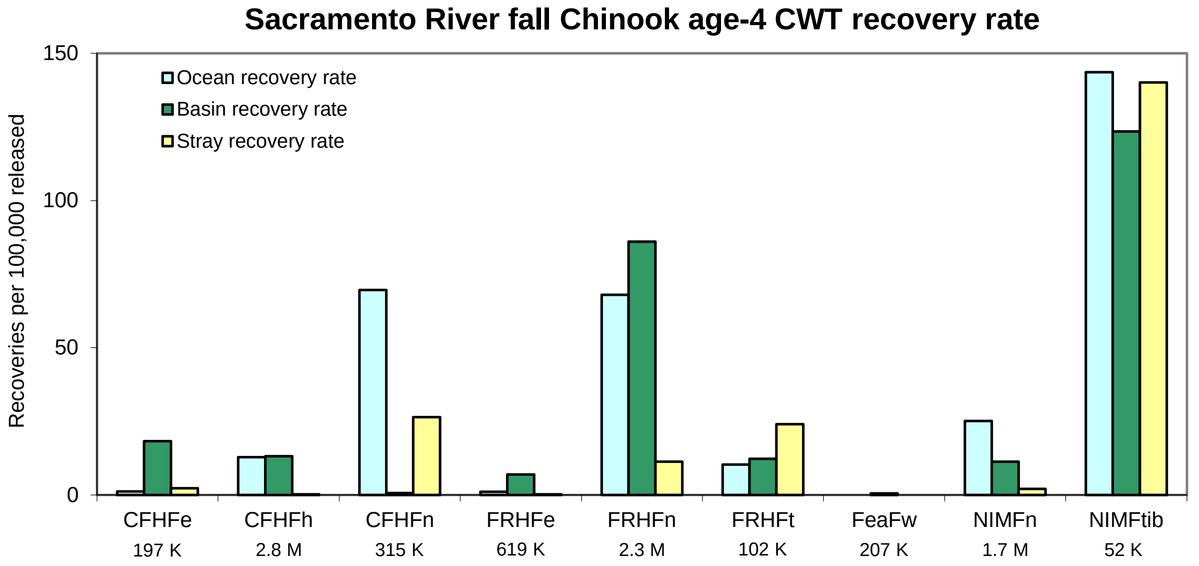
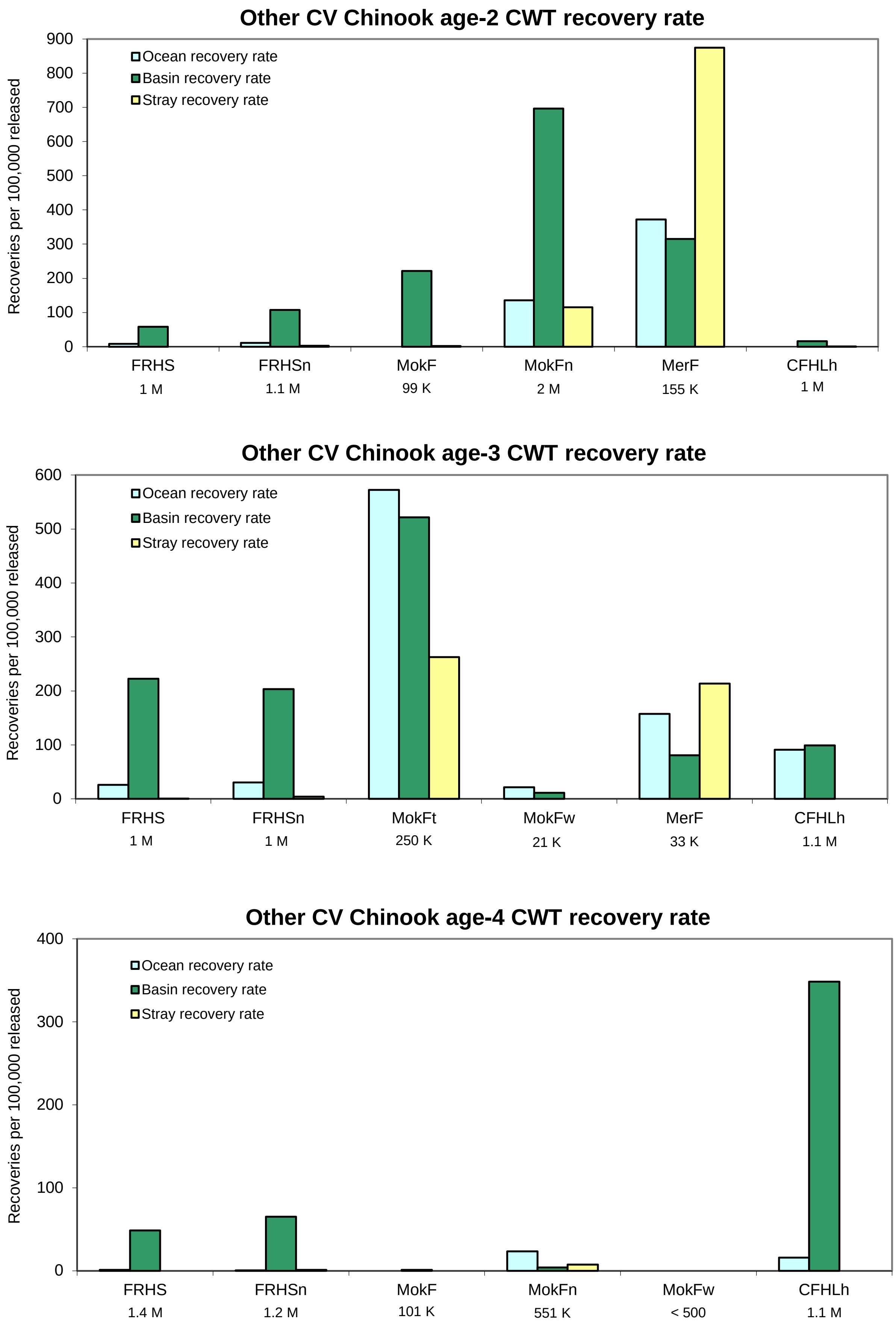

Sacramento River fall Chinook age-4 CWT recovery rate

Figure 14. 2011 recovery rates for Sacramento fall Chinook CWT releases by age.

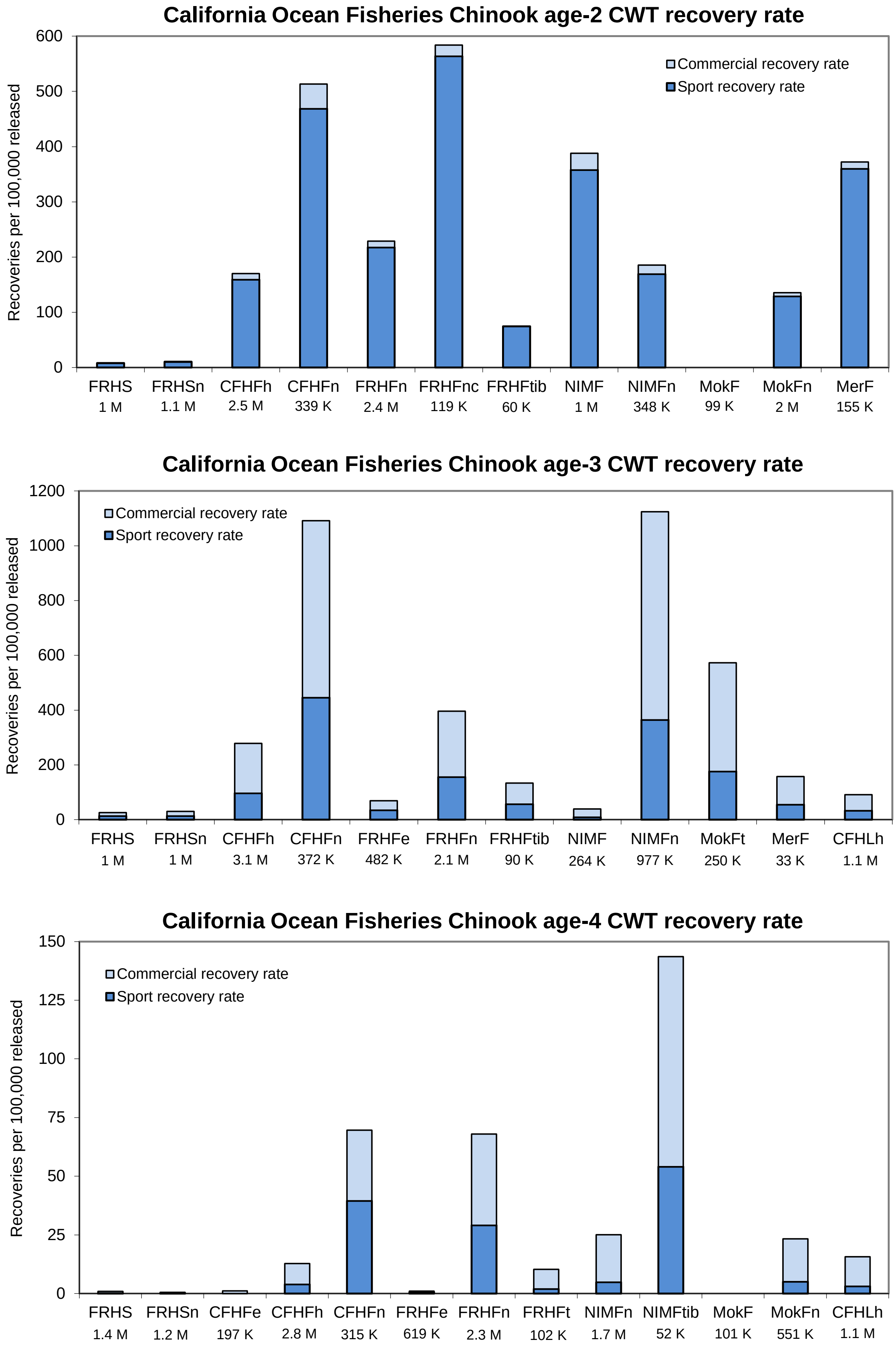


Other CV Chinook age-2 CWT recovery rate

Other CV Chinook age-3 CWT recovery rate

Other CV Chinook age-4 CWT recovery rate

Figure 15. 2011 recovery rates for other CV Chinook CWT releases by age.


California Ocean Fisheries Chinook age-2 CWT recovery rate

California Ocean Fisheries Chinook age-3 CWT recovery rate

California Ocean Fisheries Chinook age-4 CWT recovery rate

Figure 16. 2011 CV Chinook recovery rates in ocean sport and commercial fisheries.

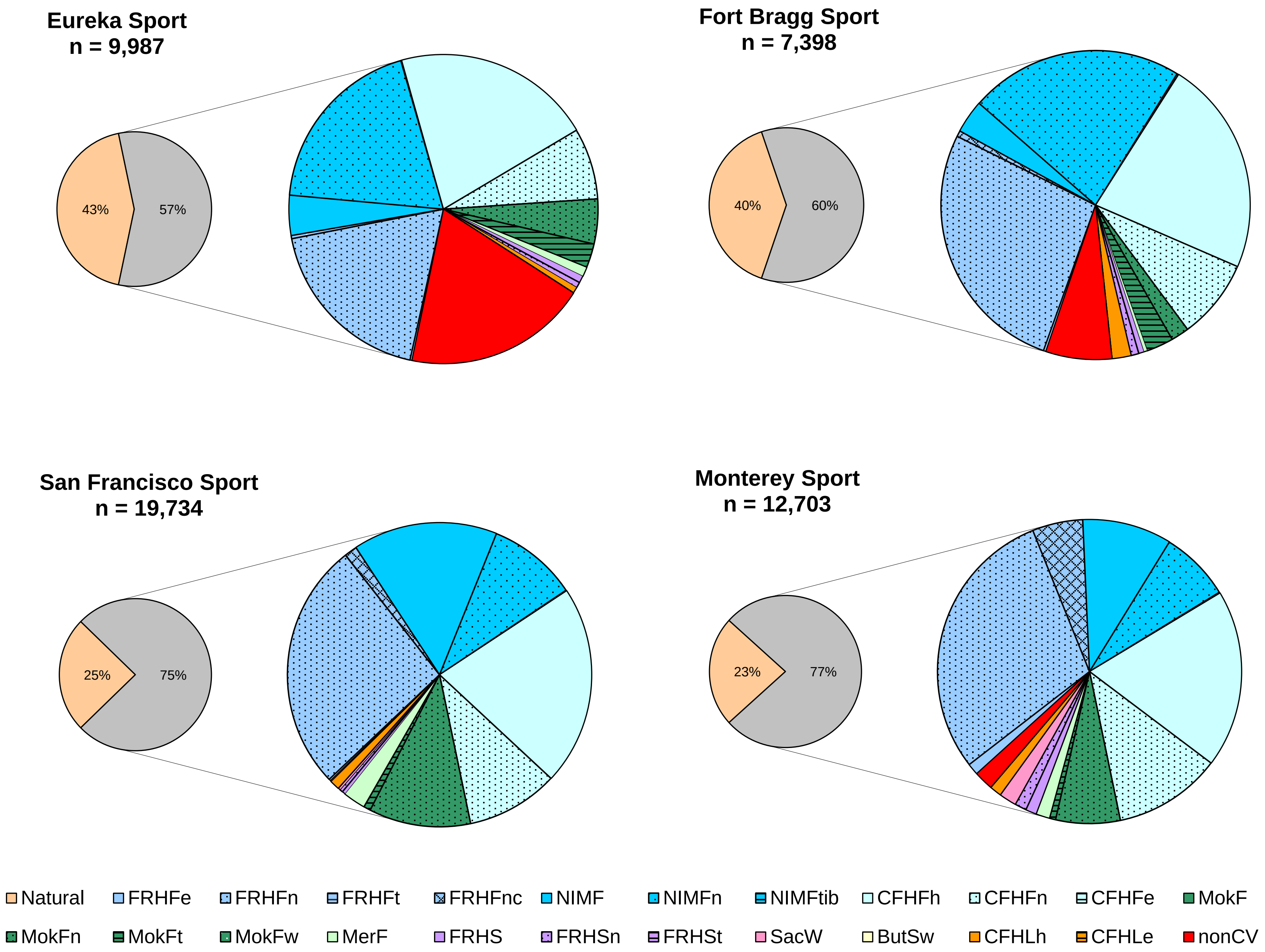


Figure 17. Proportion of hatchery- and natural-origin salmon in the 2011 California ocean sport fishery.

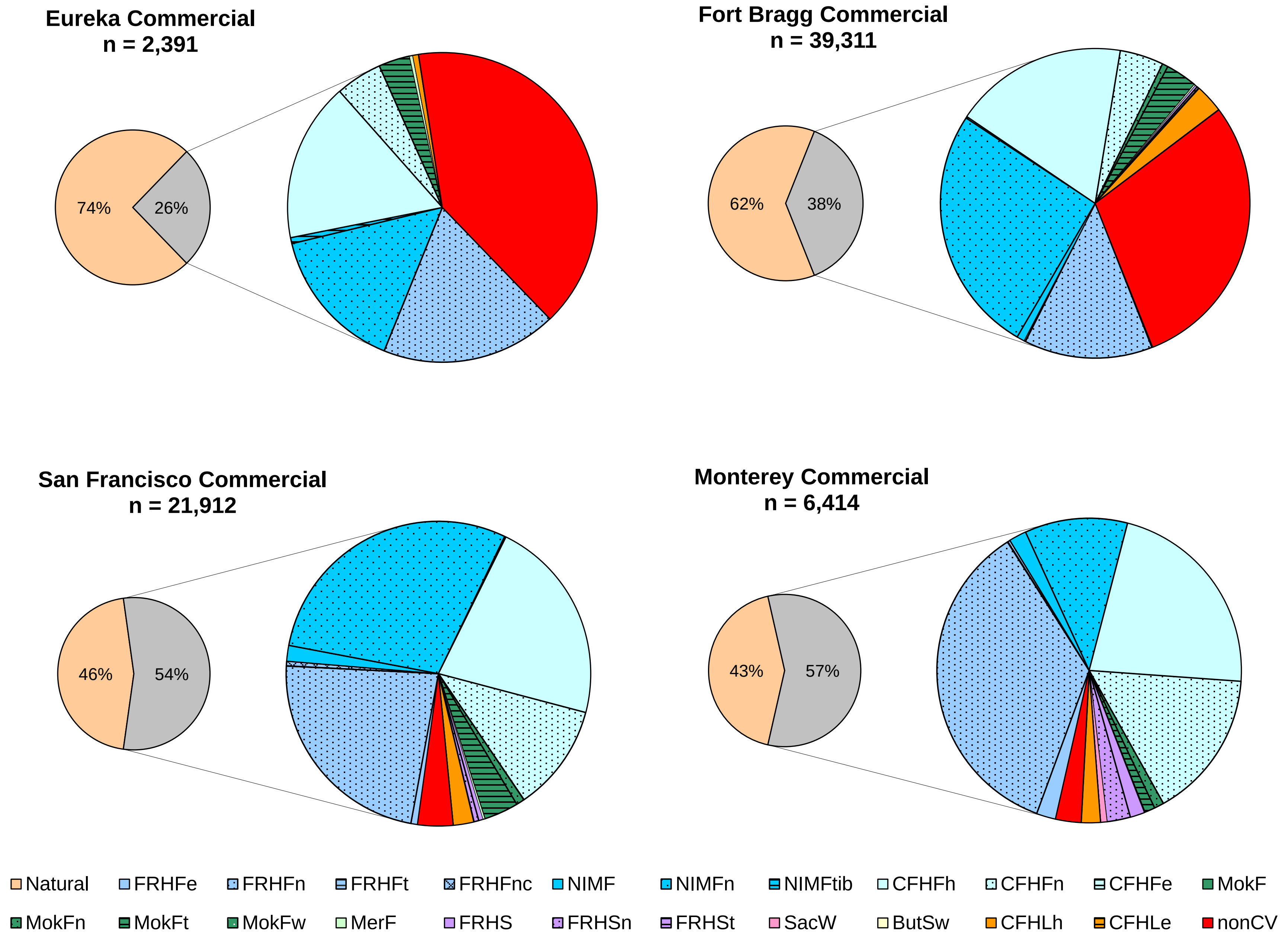


Figure 18. Proportion of hatchery- and natural-origin salmon in the 2011 California ocean commercial fishery.

Appendix 1a. Alternative 2011 CWT recovery and stray rates (recoveries per 100,000 CWTs released) of CNFH and FRH releases.[a/]

Age 2 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[b/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
CFHFh	2009	Fall	2,543,157	5,390	36	212	1			1			5,390	250	5,640	4,321	212	10	222	170	0.04
CFHFn	2009	Fall	339,179	35		35	243	85	215	92	25	28	35	722	757	1,741	10	213	223	513	0.95
CFHLh	2010	Late	992,047	157						1	1		157	2	159		16	0.2	16		0.01
FRHFn	2009	Fall	2,367,209	43	97	67	7,492	403	76	73	14	20	7,492	794	8,286	5,421	317	34	350	229	0.10
FRHFnc	2009	Fall	118,879			6	58		1	2	8		58	18	76	694	49	15	64	584	0.23
FRHFtib	2009	Fall	60,104				130		1	5	1		130	7	136	45	216	11	227	75	0.05
FRHS	2009	Spr	1,026,954				578	16					578	16	594	87	56	2	58	8	0.03
FRHSn	2009	Spr	1,058,635			18	1,033	104	6	4			1,033	132	1,164	113	98	12	110	11	0.11

Age 3 CV recoveries

Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[b/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
CFHFh	2008	Fall	3,128,111	3,461	267	60							3,461	327	3,788	8,716	111	10	121	279	0.09
CFHFn	2008	Fall	371,685	21	36	8	351	97	472	23	45	51	21	1,084	1,105	4,056	6	292	297	1,091	0.98
CFHLh	2009	Late	1,115,378	1,023	81								1,023	81	1,104	1,015	92	7	99	91	0.07
FRHFe	2008	Fall	481,853	2	36	4	1,429	104	12	8		4	1,429	170	1,598	334	296	35	332	69	0.11
FRHFn	2008	Fall	2,061,211	20	109	34	6,626	435	135	17	1	24	6,626	775	7,401	8,161	321	38	359	396	0.10
FRHFtib	2008	Fall	89,859	4		17	111	120	11	11			111	163	274	120	123	182	305	133	0.60
FRHS	2008	Spr	1,015,717				2,237	23		1			2,237	24	2,261	265	220	2.4	223	26	0.01
FRHSn	2008	Spr	1,005,727		24	4	2,006	39	1	10		2	2,006	80	2,086	308	199	8	207	31	0.04

Age 4 CV recoveries

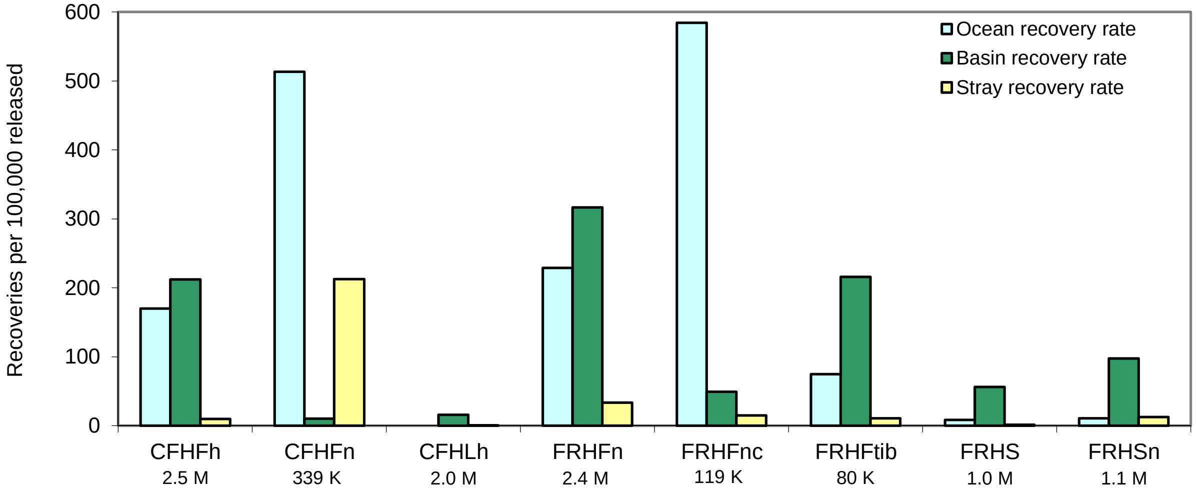
Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[b/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
CFHFe	2007	Fall	196,993	12	24	4	1						12	29	41	2	6	15	21	1	0.71
CFHFh	2007	Fall	2,801,459	343	24	6							343	30	373	359	12	1.1	13	13	0.08
CFHFn	2007	Fall	314,681	2		1	9	16	53	3			2	83	85	219	1	26	27	70	0.98
CFHLh	2008	Late	1,072,854	2,932	808								2,932	808	3,740	168	273	75	349	16	0.22
FRHFe	2007	Fall	619,085				43		1				43	1	44	6	7	0.2	7	1	0.02
FRHFn	2007	Fall	2,347,396	2	109	9	1,858	162	138	4		2	1,858	426	2,284	1,595	79	18	97	68	0.19
FRHFt	2007	Fall	101,712				13		24				13	24	37	10	12	24	36	10	0.66
FRHS	2007	Spr	1,378,941				672						672		672	12	49		49	1	0.00
FRHSn	2007	Spr	1,242,480		12		811			1			811	13	824	7	65	1	66	1	0.02

Age 5 CV recoveries

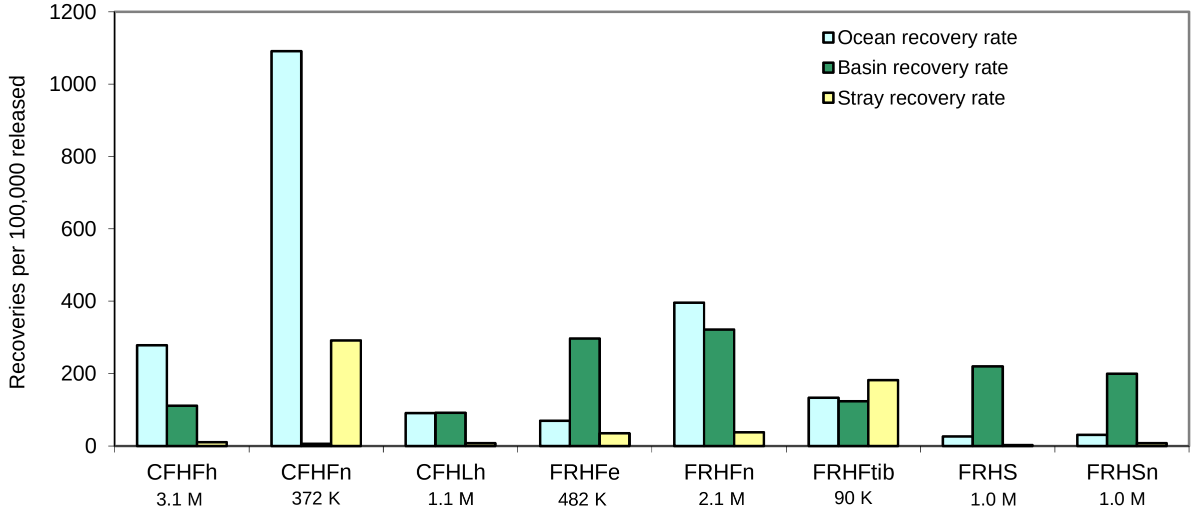
Release	Brood	Run	# CWT	Central Valley CWT_{samp} recoveries by location									CV CWT_{samp} totals			Ocean	Recovery rate per 100,000 released				CV Stray
group	year	type	tagged	Bat Cr	Up Sac	Nat crks[b/]	Fea	Yub	Ame	Mok	Mer	SJ	Basin	Stray	CV total	CWT_{samp}	Basin	Stray	CV total	Ocean	Proportion
CFHLe	2007	Late	299,292	1	141								1	141	142		0	47	48		0.99
CFHLh	2007	Late	732,952	481	445								481	445	926	5	66	61	126	0.6	0.48

a/ CNFH and FRH releases recovered in upper Sacramento River and Yuba River, respectively, considered as stray recoveries.

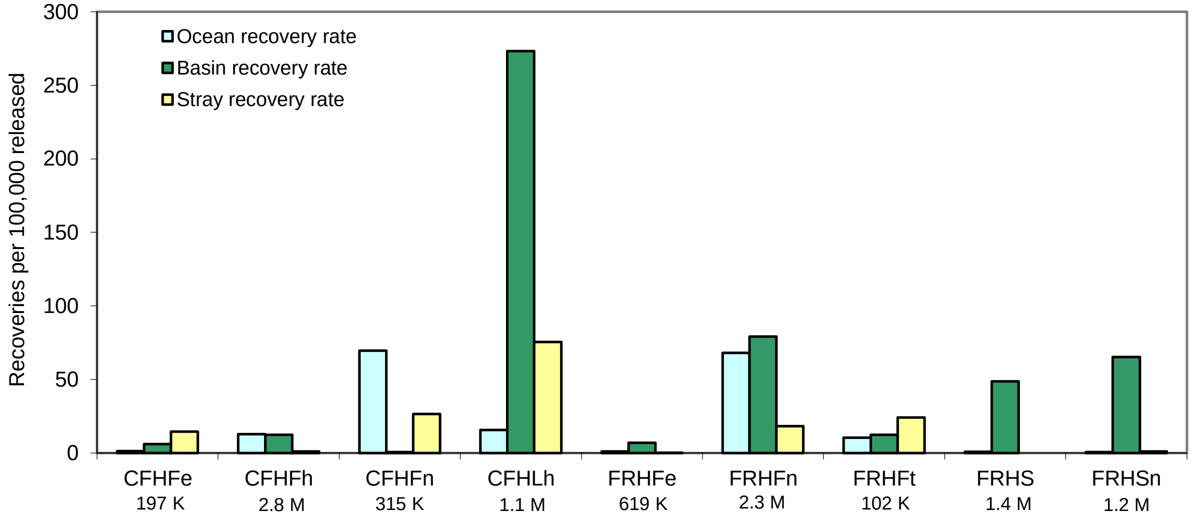
b/ Natural creeks include Clear Creek, Cottonwood Creek, Butte Creek and Mill Creek.



Alternative age-2 CWT recovery rate for CNFH and FRH releases



Alternative age-3 CWT recovery rate for CNFH and FRH releases



Alternative age-4 CWT recovery rate for CNFH and FRH releases

Appendix 1b. Graphs of alternative 2011 recovery rates for CNFH and FRH releases.

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
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Keywords:
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APRIL 2011

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

Modeling Delta Smelt Losses at the South Delta Export Facilities

Wim J. Kimmerer[1]

ABSTRACT

I previously estimated proportional losses of delta smelt to the water export facilities in the south Delta (Kimmerer 2008). This note is in response to Miller (2010), who disputes these estimated losses on several grounds. A re-analysis using a better analytical approach suggests a slight downward revision of the previous estimates for adult smelt. The distribution of smelt seems to have shifted northward in the last few years; if so, the smelt may now be less vulnerable to export losses than they previously were, although the reasons for such a shift are a concern. I argue, however, that it is legitimate to attempt such estimates in the absence of perfect information, and that mechanistic analyses are a valid way of estimating population-level impacts even in the absence of statistically significant correlations of estimated impact with subsequent population size.

KEYWORDS

delta smelt, *Hypomesus transpacificus*, management, water diversions, population ecology

INTRODUCTION

I previously calculated proportional losses of delta smelt (*Hypomesus transpacificus*) to the water export facilities in the south Delta (Kimmerer 2008). Here I respond to Miller (2010), who presents analyses to show that my estimates of proportional losses were overstated. Miller raises some valid points but misinterprets some of my original analyses, and offers comments that cannot be addressed with available information. His critique also raises, albeit indirectly, two important general issues for quantitatively estimating the impacts of human activities: (1) how such estimates can and should be made in the absence of complete information; and (2) the nature of evidence useful in quantifying these impacts. I first discuss Miller's more specific comments, and then return to these broader issues.

Kimmerer (2008) calculated proportional losses during times when delta smelt are captured in substantial numbers at the fish salvage facilities, i.e., roughly January to March for adults and March to June for larvae and juveniles. The proportional losses for each life stage were estimated using a rather complex procedure to determine inputs to a survival model (modified from Equation 12 in Kimmerer 2008):

$$P_L = 1 - \prod_{d=1}^{D}\left(1-\frac{\Phi_d}{N_d}\right) \tag{1}$$

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where P_L is the proportional loss during the season of vulnerability, that is, the decrement in the population by the end of the season attributable to export pumping. D is the number of days in that season, N_d is the population size on each day, and Φ_d is the daily loss to the fish facilities, including pre-screen mortality and assuming no successful salvage. Note that this formulation ignores mortality not attributable to export pumping, which was taken into account in the original analysis (see below).

To clarify Miller's arguments and my responses, I consider the following components of these calculations: (1) efficacy of the sampling programs used to estimate model inputs; (2) estimating the number of fish lost to entrainment per day Φ_d; (3) estimating the population size N_d; and (4) accumulating daily loss over the season of vulnerability.

EFFICACY OF SAMPLING

Sampling for fish involves numerous assumptions about their distribution and about the efficiency of the sampling gear used in relation to the particular species and size of fish collected (Rozas and Minello 1997). Generally, in any sampling process, the confidence limits around the estimate being made decrease as the number collected increases. Thus, very small catches do not invalidate a sampling effort, but the results are more uncertain than with large samples.

Three sets of sampling data were used in the original analysis. The Kodiak trawl survey of adults is considered to be an effective method that is roughly 100% efficient for fish in the channels. The 20–mm survey of larval and juvenile fish is most efficient for fish larger than 20mm, but less so for smaller fish. Kimmerer (2008, Equation 20) used a logistic model to correct catches for low gear efficiency for smaller fish. This model is based on the fact that surviving fish must grow through all size classes, and that therefore the abundance of the poorly sampled smaller sizes is constrained by the abundance of larger sizes. The principal assumption of the logistic model was that parameters of the model were constant *within* years but could vary *among* years. Statistical error in fitting the model contributed to rather large uncertainties in proportional losses, as much as a three-fold uncertainty in the relative abundance of the smallest (5 mm) size class. This error was propagated through subsequent analyses of proportional losses.

Miller argues that low catches of smaller fish in the 20–mm survey should not be scaled up using catch-efficiency curves. This is equivalent to saying that gear efficiency cannot be determined for small fish, and implies that the numbers in each size class must be determined independently of those in other size classes. However, he offers no argument why the logistic function cannot be used to estimate abundance of all size classes, how the larger fish might have arisen except by growth of the smaller ones, or what is wrong with providing estimates based on small catches if confidence limits are included. Furthermore, he labels as "unreliable" data from some 20–mm stations with zero catch, without an adequate explanation of why such data should be considered unreliable; 73% of the 20–mm tows from 1995 through 2005 had no delta smelt, but these contribute to the calculations of means and other population parameters.

The south Delta fish facilities sample far more volume and capture larger numbers of fish than the field surveys, but capture efficiency—the ratio of salvage to entrainment—is low and variable. Delta smelt are unlikely to be guided by the louvers, which were designed for and are most efficient for salmon (Bowen and others 2004). Mark–recapture studies with adult delta smelt gave an average 24% recovery of fish at the federal fish facility that had been released in front of the primary louvers. Castillo and others (2009) conducted a mark–recapture study of delta smelt in Clifton Court Forebay and concluded that pre-screen mortality presumably from predation was the largest source of mortality for fish entrained in the forebay, and likely much larger than for other studied fish such as salmon. These studies provide limited support, though not quantitative information, for the low capture efficiency of the salvage facilities.

Kimmerer (2008) found that catch per volume of water sampled differed between the two salvage facilities on a daily basis, but that the overall mean differences were very small. This was the basis for using the same salvage efficiencies for both facilities. The salvage values are useful for indicating the timing and relative magnitude of entrainment events, but underestimate entrainment and mortality of delta smelt many-fold as discussed above. Without calibration to field data, salvage is not a useful proxy for mortality.

Miller reports a lack of correlation between salvage of young delta smelt and estimated flux to the pumps, concluding from this lack of relationship that the calculated flux is biased upward. The reason for this putative bias is not really explained. Three factors interfere with such a correlation: (1) the low and variable efficiency of the salvage facilities, (2) the high variability and small number of samples per survey (six) used in calculating the flux (see below), and (3) the distance from the sampling stations to the export facilities. None of these should introduce bias. I previously showed that the south Delta catches and salvage during springs of 4 years matched reasonably well in timing and magnitude but with a lot of error, and a low but non-zero correlation (Figure 7 in Kimmerer 2008). Thus, there is evidence for substantial statistical error but not for bias.

ESTIMATES OF FISH FLUX

The flux or entrainment of fish toward the salvage facilities Φ_d comprises three factors: pre-screen mortality, losses through the louvers, and salvage. Because salvage is likely a small fraction of entrainment (see above), it gives a poor estimate of Φ_d, which must therefore be determined using other information, such as the density and rate of movement of fish in the waterways leading to the fish facilities.

The basis for such calculations (not spelled out by Kimmerer 2008) is a simple hydrodynamic flux calculation for a channel:

$$\Phi_C = A\left[(U + U_s)C - (K_h + K_s)\frac{dC}{dx}\right] \tag{2}$$

where Φ_C is the flux of a substance or particles with concentration C, A is cross-sectional area of a channel, U is water velocity, U_s is additional velocity of C (e.g., due to swimming in the positive x direction), K_h is a horizontal dispersion coefficient, K_s is an additional dispersion coefficient due to randomly directed swimming, and the last term is the longitudinal gradient in C. If the gradient is small and the particles are passive, the flux is simply $AU_C = Q_C$, where Q is the volume flow rate. Kimmerer (2008) used this to calculate the flux of young smelt with Q represented by the southward net flow in Old and Middle rivers and C by the catch per unit volume at six 20–mm stations in the south Delta. This calculation was not possible for adults because of low (often zero) catches, so the catches were used to calibrate salvage density (fish per unit volume of water) to catch per volume in the Kodiak trawl, and this calibration factor was applied to all salvage data to estimate flux.

Miller argues that since fish are not passive particles this calculation is invalid, but offers no alternative way to compute the fish flux. Larval fish have very limited swimming abilities and are essentially passive particles before they obtain a swim bladder, after which they can affect their position only through vertical migration. Tidal vertical migrations were found in pelagic fish larvae in the low-salinity zone but the sample size for delta smelt was small, and migration was not detected (Bennett and others 2002). Even the fish and copepods that demonstrably migrate tidally can overcome net seaward flow only in water that is stratified in salinity (Kimmerer and others 1998), which is not the case in the south Delta. The smelt that leave freshwater in early summer are post-larvae over 20mm long with developed swim bladders and initial distribution near the surface (also in the low-salinity zone, Bennett and others 2002). If this behavior applied in freshwater it would move most of the population westward to their brackish rearing habitat except those in the south Delta, which would move toward the pumps. Thus, during spring they can be treated as passive particles at the scale of the south Delta, and Equation 2 applies to these fish. Miller's argument implies that the fish are somehow escaping the southward flow of Old and Middle rivers, but there is no evidence that they are capable of doing that, nor do environmental cues exist that would persuade them to orient away from the export facilities.

Adult smelt move up-estuary during their spawning migration and are, therefore, demonstrably capable of moving against the net downstream flow in the Delta. However, high salvage numbers indicate the existence of a large southward flux of adults. I calculated an efficiency Θ (Equations 16 and 17 in Kimmerer 2008) relating salvage to the estimated fish flux based on the Kodiak trawl samples in the south Delta, and applied that to salvage to get the fish flux for all days of the season.

Miller argues on several grounds that Θ was overestimated. The most cogent argument is that there were too many zeros in the data to use a Poisson model to fit the data. I therefore re-fit the model in Equation 17 (Kimmerer 2008) with a zero-inflated Poisson model (Lambert 1992) which has two parameters; the Poisson mean and the proportion of excess zeros. This model was fit using a Bayesian approach in WinBUGS (Lunn and others 2004) using fitting and model checking procedures in Kimmerer and Gould (2010). The resulting estimate of Θ was 22 with a 95% credible interval of 13 to 33. This estimate is about 76% of the previous estimate but with better resolution. Estimates of mean adult loss in Kimmerer (2008) should, therefore, be reduced by 24%. Miller also argues that the data are contaminated by a single high catch of 17 fish. This might be true if the model were improperly cast as a linear regression, but for a properly formulated model it poses no problem. In any case, the analysis should be based on the data at hand.

Miller also argues that the adults are not passive particles, implying that they can overcome the effects of net flow in the south Delta. That is, the term U_S in Equation 2 may be negative, reducing the actual fish flux Φ_C. In that case salvage would be lower than expected if U_S were zero, and the effect of a negative U_S would be accounted for in the calculation of Θ.

According to Miller, Old and Middle river flows are unrelated to salvage of either adult or young delta smelt and therefore are insufficient for calculation of fish flux. The relationship between these flows and salvage is actually quite obvious, if nonlinear and noisy (Figure 4 in Kimmerer 2008): when these rivers flow southward, salvage is often high, and when they flow northward, salvage is either mostly zero (juveniles, adults in the state facility) or sometimes non-zero (adults for the federal facility only). The latter case is likely due to U_S in Equation 2 being positive for some fish, i.e., toward the export facilities. Thus, while the fish are not entirely behaving as passive particles, their behavior is not necessarily oriented to take them away from the facilities.

The calculations of proportional losses of young smelt were remarkably consonant with predictions made using the DSM2 particle tracking model (Figure 16 in Kimmerer 2008). This supports the use of Old and Middle River flows for the calculations, and the assumption of passive transport for this life stage. Furthermore, the estimate of Θ above is, if anything, low—considering the estimates to date of pre-screen losses and losses through the louvers.

Delta smelt are more abundant where the water is turbid (Feyrer and others 2007) and, therefore, salvage and salvage-related losses should be more predictable using information about turbidity than without this information. This issue arose after I had finished the final draft of the 2008 paper, but, in any case, turbidity data for the south Delta were not available for the time–period of this study. Ignoring it introduces error in the calculations but there is no reason to expect bias, since all the calculations were based either on salvage (adults) or fish collected in the south Delta (juveniles).

SIZE OF THE POPULATION

The denominator in Equation 1 is essentially the mean catch in all samples times the volume over which those samples were taken. An alternative is to calculate mean catch per trawl by region of the estuary, multiply by area or volume of each region, and sum the result to get an index of abundance. The assumptions underlying these two approaches are somewhat different, but there are no data to suggest one is superior to the other. The annual abundance indices in several monitoring programs are calculated by region, but simple mean catch per trawl over all stations is closely correlated to these indices (Kimmerer and Nobriga 2005). Thus Miller's calculations of population size using a region–by–region approach are unlikely to be much different from the simpler calculation in Kimmerer (2008).

The fish fluxes Φ were calculated so that efficiency of the sampling gears was factored out of Equation 1. Therefore, the remaining issue for this part of the calculation is whether the samples in the south Delta represented the population there to the same degree that sampling throughout the Delta represented the overall population. Catchability is unlikely to differ between the south Delta and elsewhere (and we have no data either way on this), so the degree of representation boils down to whether the spatial coverage of sampling is adequate to represent the population.

Miller argues the contrary on the basis that high catches of adults in the Sacramento River Deep Water Ship Channel (sampled beginning in February 2005) indicate that most of the fish are in that region and are, therefore, under-sampled. Most of my analyses were for earlier years; furthermore, most of the salvage occurred between mid-December and the end of February (Figure 11 in Kimmerer 2008), when relatively few fish are yet in the north Delta (Figure 1). It does appear that more adults are in the north Delta during more recent years, mainly in the later surveys.

Miller makes a similar argument for young fish, although the argument is muddied by a claim that the 20–mm survey collects too few fish to provide a reliable index of total population size, based on projections of abundance of young fish from calculated abundance and assumed reproductive success of adults. If this were true it would call into question the results of all sampling programs. The stronger part of Miller's argument is the same as for adults: i.e., that a greater proportion of the population is in the north Delta and that it has been under-sampled. The data show an increasing proportion of the total catch in the north Delta stations (Figure 2) as the total catch has decreased. However, that proportion was never more than 8% during the period of this study.

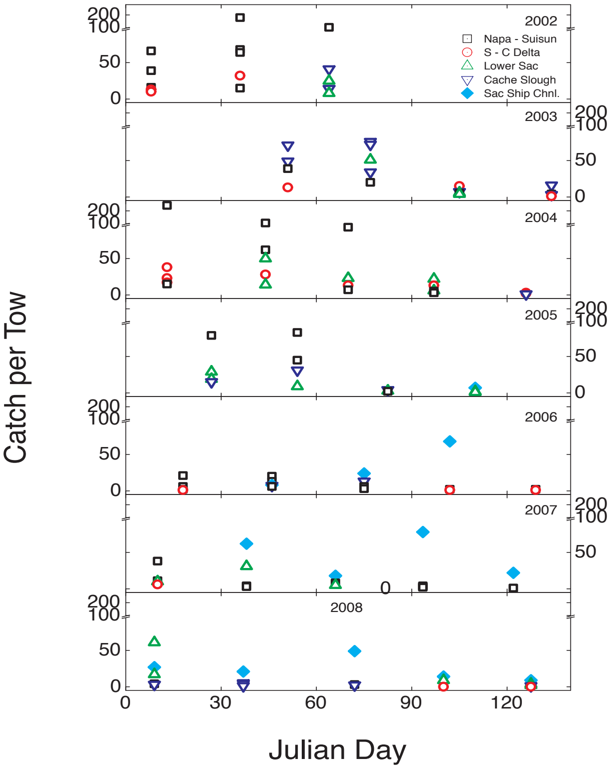

Figure 1 Delta smelt catch per tow in the Spring Kodiak trawl survey for the five stations with the highest catches during each month's sampling, by year. These stations made up at least 62% of the total catch of the respective surveys. Symbols indicate sampling regions, with stations included as follows: Napa–Suisun: stations <699 plus 801; South–Central Delta: 802 to 999; Lower Sacramento River: 704 to 707; Cache Slough area: 711 to 716; and Sacramento Ship Channel: 719, sampled beginning February 2005.

The apparent northward shift in distribution of adult and young smelt means that the exposure of the delta smelt population to export pumping is less in recent years than it was during the time period of my study. Although this might be considered a benefit, conceivable mechanisms for this shift are not promising for the long–term maintenance of the species. One possible such mechanism is that the south Delta is occupied less by delta smelt because of a degradation of the habitat (e.g., by increasing water clarity). The implications of that for proportional losses to exports would depend on the mechanism keeping abundance low in the south Delta, which are not yet known.

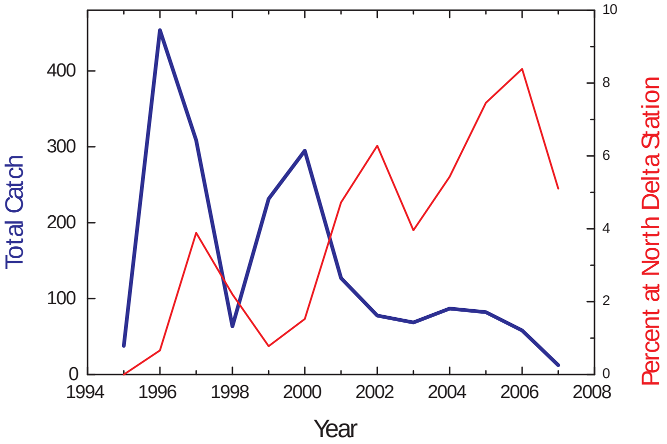

Figure 2 Delta smelt catch in the 20–mm survey. Heavy blue line, left axis: total catch in all samples; thin red line, right axis: percent of catch from Station 716 in Cache Slough in the north Delta. Note that catches at Station 719 in the Sacramento River Deep Water Ship Channel have been high since sampling at this station began in 2008, but there is no information on whether this is a sampling artifact or a result of smelt movement.

ACCUMULATING LOSSES OVER THE SEASON

Accumulating losses means calculating the proportional difference between the population that would have existed at the end of the exposure season with and without export losses. This requires that the relative size of the vulnerable population and other mortality be taken into account. For example, a high daily fractional loss early in spring when few young fish had hatched will have a smaller effect on ultimate population size than a high loss after all the fish had hatched.

Equation 1 could be parsed in a number of different ways, but the end result would not be very different using the same values of the fractional loss terms. The calculations are made a bit more difficult by the need to account for natural mortality of juveniles, as explained by Kimmerer (2008). Leaving mortality out of the calculations results in a modest increase in the calculated seasonal losses (Figure 15 in Kimmerer 2008). Although Miller argues that mortality is unlikely to be constant in space or time, the effects of such undeniable but unmeasured variability cannot, therefore, be very large. Since losses of larvae and juveniles were based on catches in the south Delta rather than salvage, an excess of mortality in the south Delta relative to the entire habitat would bias the loss estimates low, not high as Miller claims.

ALTERNATIVE APPROACHES TO ESTIMATING EXPORT EFFECTS

To date, nobody has reported a relationship between any measure of flow toward the export pumps or losses of delta smelt, and either subsequent population abundance indices or ratios of successive indices. Miller argues that this lack of statistical link to population estimates is evidence that losses calculated mechanistically are unimportant compared to other effects such as food limitation.

This is part of a broader issue: the nature of evidence to be used in estimating the magnitude of human impacts on a biological population. Fundamentally, such impacts can be estimated through correlative measures, or they can be determined mechanistically. I do not believe that Miller is arguing against the use of mechanistic approaches (as some have done), since far more of our current scientific understanding in most fields of science rests on mechanistic than on correlative analyses.

Mechanistic approaches are based on known or inferred processes that influence the population in some way. In the specific case of estimated mortality to a fish population, the key issue is whether subsequent density dependence compensates for that mortality. If not, it is tautological that mortality will proportionally reduce subsequent population size.

Density dependence is a controversial topic mainly because of statistical difficulties, although conceptual problems also contribute. Compensatory density dependence can arise through a wide variety of causes, most involving food supply or predation (Rose and others 2001). Density dependence in striped bass in the San Francisco Estuary apparently compensated for very high losses to the export facilities, at least during a period of relatively high abundance (Kimmerer and others 2000).

Density dependence in stock–recruit relationships for delta smelt were driven largely by high values in the 1970s, although some evidence for density dependence remained in the data after 1981 (Bennett 2005); however, these relationships and the influence of environmental factors on them have likely changed over the intervening decades. The key question for interpretation of export losses of delta smelt is whether density dependence is strong in the post-decline population. This seems unlikely: since 2002 abundance of delta smelt has been too low for most potential mechanisms for compensatory density dependence to exert much influence. If so, the delta smelt population does not compensate for reductions in abundance by, e.g., increased fecundity or reduced mortality. Therefore, losses at any life stage permanently and proportionally reduce the population from the trajectory it would have otherwise have followed.

Correlative measures can be useful to the extent that they offer statistical support for a relationship. However, they cannot establish cause. More importantly, there is a clear difference between a finding that a result does not meet statistical standards of significance, and concluding it is not important. Thus, in making such an argument it seems important to determine what level of impact could be detected by correlative methods.

I determined this level through simulations, assuming density-independent population processes by the arguments above. I used the observed ratio of the fall midwater trawl index to the previous year's index as a stock–recruit index that should be sensitive to losses in the spring. The percentage loss in a given year was set as:

$$P_L = P_{max} \left(\begin{array}{c} 0 \text{ if OMR} \geq 0 \\ \dfrac{\text{OMR}}{\text{OMR}_{min}} \text{ if OMR} < 0 \end{array} \right) \qquad (3)$$

where P_{max} is the maximum percentage loss in any year (a free parameter in this simulation), OMR is the mean flow in Old and Middle rivers in spring (negative is southward), and OMR_{min} is the minimum OMR flow (i.e., the maximum southward flow). OMR flows were determined for each spring as described in Kimmerer (2008). In this equation, P_L is zero for positive OMR, and scales linearly with negative OMR to a maximum at P_{max} when OMR = OMR_{min}. Alternative scaling would affect the quantitative results but not the qualitative conclusion.

For each year, the simulation ran using flow data from 1981 through 2006, with each year's fall population reduced by the simulated proportional loss during the previous spring. The choice of years to simulate was made to get a representative range of OMR flows, not to simulate an actual population trajectory, and the simulation was intended only to investigate the effects of export losses at low population size where density dependence would have a minimal effect. The flows were randomized among years to eliminate potential confounding factors from actual annual flow patterns. Then, for each integer value of P_{max} from 0 to 100% a regression was calculated between southward Old and Middle river flow (the quantity in parentheses in Equation 3) and the log of the stock–recruit index. The intent was to determine how large P_{max} had to be before losses become detectable in regression analyses.

The results (Figure 3) show that the losses were not generally detectable in the regression until P_{max} reached about 60% to 80%. The levels of loss reported by Kimmerer (2008) were obscured by interannual variability in nearly all simulations, and maximum losses less than 20% were undetectable. Yet a P_{max} of 20% (mean annual loss of ~10%) results in a 10-fold reduction in population size by the end of the 26-year simulation (Figure 3). Repeating the above simulation 10,000 times with P_{max} = 20%, the upper 95% and 90% confidence limits of the regression slope excluded zero (i.e., was statistically detectable) in 5% and 9% of the cases, respectively. Thus, a loss to export pumping on the order reported by Kimmerer (2008) can be simultaneously nearly undetectable in regression analysis, and devastating to the population. This also illustrates how inappropriate statistical significance is in deciding whether an effect is biologically relevant (Stephens and others 2007).

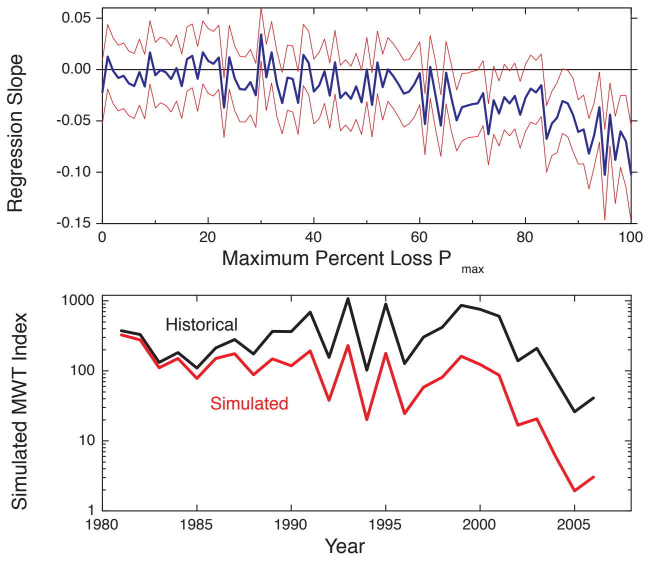

Figure 3 Results of simulation of ability to detect export loss through regression analysis. Upper panel: individual simulation results giving the slope (thick blue line) and 95% confidence limits (thin red lines) for regressions of the stock-recruit index on southward OMR flow. Lower panel: trajectory of the fall midwater trawl index (upper line) and the same index with a 20% P_{max} value imposed for the entire time series (mean P_L ~10%). This is for illustration only (see text), and does not imply anything about the cause of the decline in delta smelt.

CONCLUSIONS

Miller raises some valuable points about the data and methods used in calculating proportional losses. He also introduces new developments in understanding (e.g., turbidity effects) and in the delta smelt population (e.g, spatial distribution) that occurred recently. I do not believe these points cast doubt on the overall conclusion of my paper, which is that export–related losses to the delta smelt population during some of the years analyzed were substantial.

I previously reported that export effects had little effect on the striped bass population because of density dependence at levels of population abundance that existed up to 1995 (Kimmerer and others 2001). I also previously determined that export losses of mysids (*Neomysis mercedis*) were unlikely to be important to that population (reported by Orsi and Mecum 1996). During my work on the Environmental Water Account, I continually but unsuccessfully challenged my colleagues in the resource agencies to determine the effect of export pumping on fish populations, and therefore the magnitude of the benefit that the Account was having on fish (see Brown and others 2008). Therefore, my labors on export losses of delta smelt began with a strong skepticism about the importance of these losses, and ended with considerable surprise at their magnitude.

All of that said, neither my paper nor this exchange is the final word on this subject. More sophisticated statistical tools and models could and should be brought to bear on what controls delta smelt abundance, and these should be updated as new data become available. Information from new studies (e.g., Castillo and others 2009; Grimaldo and others 2009) and based on more recent distributional data should also be considered, both in refining understanding of influences on the smelt population and in assessing changes in the population itself.

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REFERENCES

Bennett WA. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary Watershed Science [Internet]. Available from: *http://escholarship.org/uc/item/0725n5vk*

Bennett WA, Kimmerer WJ, Burau JR. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone. Limnology and Oceanography 47: 1496–1507.

Bowen MD, Baskerville-Bridges B, Frizell KW, Hess L, Karp CA, Siegfried SM, Wynn SL. 2004. Empirical and experimental analyses of secondary louver efficiency at the Tracy Fish Collection Facility: March 1996 to November 1997. Tracy Fish Facility Studies, California, Volume 11. Sacramento (CA): U.S. Bureau of Reclamation, Mid-Pacific Region.

Castillo G, and others. 2009. An experimental approach to evaluate entrainment losses of delta smelt in the South Delta. Poster. Oakland, CA; State of the Estuary Conference.

Feyrer F, Nobriga ML, Sommer TR. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 64: 723–734.

Grimaldo LF, Sommer T, Ark NV, Jones G, Holland E, Moyle PB, Herbold B, Smith P. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? North American Journal of Fisheries Management 29:1253–1270.

Kimmerer WJ. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary Watershed Science [Internet] Available from: *http://escholarship.org/uc/item/7v92h6fs*

Kimmerer WJ, Burau JR, Bennett WA. 1998. Tidally-oriented vertical migration and position maintenance of zooplankton in a temperate estuary. Limnology and Oceanography 43:1697–1709.

Kimmerer WJ, Cowan JH Jr., Miller LW, Rose KA. 2000. Analysis of an estuarine striped bass population: influence of density-dependent mortality between metamorphosis and recruitment. Canadian Journal of Fisheries and Aquatic Sciences 57:478–486.

Kimmerer WJ, Cowan JH Jr., Miller LW, Rose KA. 2001. Analysis of an estuarine striped bass population: effects of environmental conditions during early life. Estuaries 24:556–574.

Kimmerer W, Nobriga M. 2005. Development and evaluation of bootstrapped confidence intervals of IEP fish abundance indices. Interagency Ecological Program Newsletter [Internet] 18(2):68–75. Available from: *http://www.water.ca.gov/iep/newsletters/2005/IEPNews_spring2005final.pdf*

Lambert D. 1992. Zero-inflated Poisson regression, with an application to defects in manufacturing Technometrics 34:1–14.

Miller WJ. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of delta smelt by state and federal water diversions from the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science [Internet]. Available from: *http://www.escholarship.org/uc/jmie_sfews*

Orsi JJ, Mecum WL. 1996. Food limitation as the probable cause of a long-term decline in the abundance of *Neomysis mercedis* the opossum shrimp in the Sacramento-San Joaquin Estuary. In: Hollibaugh JT, editor. San Francisco Bay: the ecosystem. San Francisco (CA): AAAS, Pacific Division. p. 375–401.

Rose KA, Cowan JH, Jr., Winemiller KO, Myers RA, Hilborn R. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2:293-327.

Rozas LP, Minello TJ. 1997. Estimating densities of small fishes and decapod crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. Estuaries 20:199–213.

Stephens PA, Buskirk SW, Del Rio CM. 2007. Inference in ecology and evolution. Trends in Ecology and Evolution 22:192–197.

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Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR)

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Abstract. Four species of pelagic fish of particular management concern in the upper San Francisco Estuary, California, USA, have declined precipitously since ca. 2002: delta smelt (*Hypomesus transpacificus*), longfin smelt (*Spirinchus thaleichthys*), striped bass (*Morone saxatilis*), and threadfin shad (*Dorosoma petenense*). The estuary has been monitored since the late 1960s with extensive collection of data on the fishes, their pelagic prey, phytoplankton biomass, invasive species, and physical factors. We used multivariate autoregressive (MAR) modeling to discern the main factors responsible for the declines. An expert-elicited model was built to describe the system. Fifty-four relationships were built into the model, only one of which was of uncertain direction a priori. Twenty-eight of the proposed relationships were strongly supported by or consistent with the data, while 26 were close to zero (not supported by the data but not contrary to expectations). The position of the 2‰ isohaline (a measure of the physical response of the estuary to freshwater flow) and increased water clarity over the period of analyses were two factors affecting multiple declining taxa (including fishes and the fishes' main zooplankton prey). Our results were relatively robust with respect to the form of stock–recruitment model used and to inclusion of subsidiary covariates but may be enhanced by using detailed state–space models that describe more fully the life-history dynamics of the declining species.

Key words: Bayesian analysis; delta smelt; expert models; longfin smelt; Sacramento River, California, USA; San Joaquin River, California, USA; striped bass; threadfin shad; threatened species; water management.

Introduction

Estuaries, especially those associated with large rivers near major cities, are among the ecosystems most adversely affected by land use change (Nichols et al. 1986). Impacts of human actions in all upstream watersheds (catchments) are concentrated in the estuaries (Kennish 2002, Townend 2004). Diversion of water affects the location of boundaries between fresh, brackish, and saline water (Drinkwater and Frank 1994, Gillanders and Kingsford 2002, Gleick 2003). Large settlements often are located along shorelines, which convey contaminants and effects of boating and fishing to estuarine systems (Dauer et al. 2000). Shipping has led to introductions of many aquatic invasive species (Bollens et al. 2002, Williams and Grosholz 2008). Climate change will affect interactions between oceans and estuaries and will reduce catchment inflows in many regions (Scavia et al. 2002, Vicuna and Dracup 2007, Cai and Cowan 2008, Schindler et al. 2008).

The San Francisco Estuary is an archetype of a stressed estuarine system (Kimmerer et al. 2005*a*). The social, economic, and ecological effects of freshwater flows and diversions throughout the San Francisco Estuary have received much attention. Some 25 million Californians and 12 000 km^2 of agricultural land rely on water diversions from the delta created by the Sacramento and San Joaquin rivers. Annual agricultural

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revenue from California's Central Valley, which accounts for about half of the production of fruits and vegetables in the United States, frequently approaches US$15 billion.

Populations of many aquatic species in the estuary have declined since extensive human activities began in the mid-1800s (Bennett and Moyle 1996, Brown and Moyle 2005). However, conflicts over water management recently have intensified because of the apparently precipitous decline in four species of pelagic fish (delta smelt [*Hypomesus transpacificus*], longfin smelt [*Spirinchus thaleichthys*], striped bass [*Morone saxatilis*], and threadfin shad [*Dorosoma petenense*]) since ca. 2002 (Thomson et al. 2010). Delta smelt was listed as threatened under the U.S. and California Endangered Species Acts in 1993. Recent litigation to protect the species resulted in court orders to halt water diversions temporarily (Wanger 2007*a*, *b*). Longfin smelt was listed as threatened under the California Endangered Species Act in 2009, although a petition for federal listing was declined. Striped bass was deliberately introduced to the Sacramento–San Joaquin Delta from the east coast of the United States in 1879 and supports a sport fishery (Moyle 2002). Threadfin shad was introduced into California reservoirs as a forage fish in 1954 and spread to the Delta (Moyle 2002, Feyrer et al. 2009).

To date, models and statistical analyses to identify mechanisms causing fish declines in the San Francisco Estuary generally have been on a species-by-species basis (Jassby et al. 1995, Kimmerer et al. 2001, Bennett 2005). These efforts suggest that several abiotic factors (e.g., water flows, salinity, turbidity), bottom-up biotic effects (e.g., zooplankton abundances, invasion of a filter-feeding, non-native clam [*Corbula amurensis*]), and top-down factors (e.g., incidental mortality associated with water diversions to pumping facilities) may play important roles. However, the relative importance of these factors remains unclear (Sommer et al. 2007). Identification of processes causing declines is critical because possible solutions include major investments in infrastructure, changes in water management, and rehabilitation of species' habitats, which would cost billions of dollars.

Although detailed analyses of the population dynamics of any one declining species are valid, it is plausible that more insight might be gained through multivariate analyses that consider community dynamics, including direct and indirect effects of interacting species and abiotic factors. These analyses might yield inferences on the biotic and abiotic factors that best explain patterns of abundance for multiple species in the community and on the relative influences of density dependence, among-species interactions, and abiotic factors on species abundances.

We used a multivariate statistical technique called multivariate autoregressive modeling (MAR) (Ives et al. 2003) with 40 years of data for pelagic fishes and their principal prey within the upper San Francisco Estuary. In a manner similar to path analysis (Shipley 1997), MAR uses time series data for multiple taxa to estimate the degree of association between the different taxa as well as between covariates and each taxon. Multivariate autoregressive modeling includes autoregressive terms for each species' abundance. Ives et al. (2003) provided a detailed introduction to the underlying theory and assumptions of MAR along with methods for estimating model parameters. Multivariate autoregressive modeling has been used in analyses of community dynamics in lakes in Wisconsin (Ives et al. 2003), Lake Washington (Hampton and Schindler 2006), and Lake Baikal (Hampton et al. 2008).

We developed a Bayesian implementation of MAR. Bayesian methods allow propagation of and account for multiple sources of uncertainty in complex models (Punt and Hilborn 1997) and allow great flexibility in model structure (Cressie et al. 2009). The Bayesian MAR modeling is a complementary approach to methods we used in a companion paper, which presented a Bayesian change point analysis (Thomson et al. 2010). The two methods were developed in tandem to evaluate whether the different strengths of the MAR and change point analyses provided similar inferences about factors potentially underlying causes of declines in the fish species. Multivariate autoregressive modeling is based on a food web structure, which allows both direct and indirect influences on the focal species (fish) to be represented. Moreover, MAR models the dynamics of all species (including prey) simultaneously. It is based on linear relationships (on a log-abundance scale), both within the food web and with covariates, over the entire time period.

Our implementation of MAR is underlain by an expert-elicited model, which draws on expert knowledge to specify whether particular trophic or covariate effects may be influential. The change point analysis is not embedded in a food web context, although availabilities of prey taxa can be used as covariates, but it does explicitly employ time dependence and nonlinearity in covariate relationships between log-abundances of the focal species and covariates. The change point method uses Bayesian variable selection (Green 1995) so that relationships do not need to be specified a priori. Both individual-species (species-specific model parameters) and multiple-species (common hyper-parameter distributions) versions of the change point analyses were implemented (Thomson et al. 2010), with the latter having some overlap, therefore, with the MAR analyses.

Here, we describe the upper San Francisco Estuary, the four species of fish on which we focused and their principal prey, and the set of covariates included in the MAR model. Multivariate autoregressive models are heavily parameterized because they describe many among-taxa interactions and relationships to covariates. Therefore, we developed an expert-elicited, circumscribed model that reduced the number of parameters to be estimated. We review the relative importance of

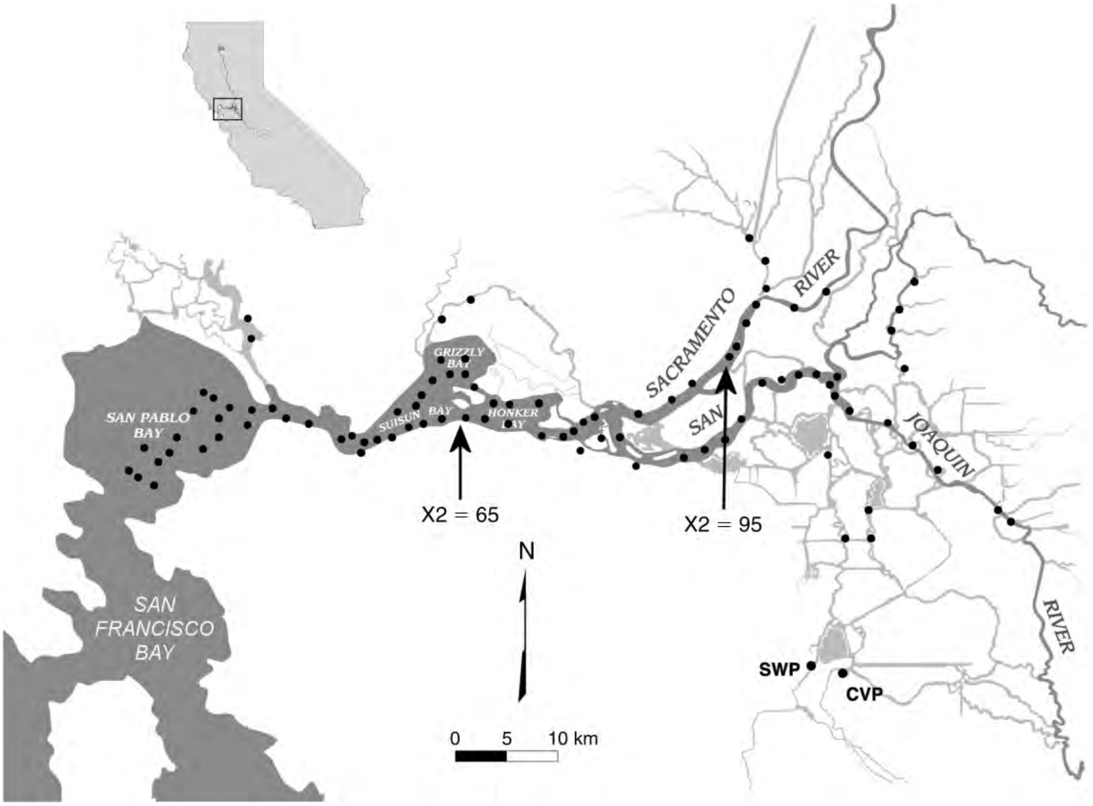

FIG. 1. Location and physiography of the upper San Francisco Estuary, California, USA. The solid circles denote sampling locations of the autumn midwater trawl surveys; arrows indicate two representative positions of the 2‰ isohaline (X2); SWP (State Water Project) and CVP (Central Valley Project) are locations of water exports from the estuary.

different factors in driving the temporal dynamics of our four declining fish species and comment on the usefulness and limitations of MAR models. Last, we comment on the agreement or otherwise between the MAR and change point approaches.

METHODS

The San Francisco Estuary

The San Francisco Estuary consists of three major regions: San Francisco Bay, the most seaward region; Suisun Bay, an intermediate brackish region; and the generally freshwater Sacramento–San Joaquin Delta (Fig. 1). The watershed has wet winters and dry summers. The Delta is the core of a massive system of dams and canals that store and divert water from the estuary for agricultural, industrial, and domestic use throughout California (Nichols et al. 1986). The water diversion facilities export ~30% of the annual freshwater flow into the Delta, although that percentage has exceeded 60% during many recent summers. Regulations, including standards for the position of the 2‰ isohaline (a measure of the physical response of the estuary to freshwater flow; Jassby et al. 1995), locally termed "X2," have become increasingly stringent.

Response variables: declining fish and their principal prey

Delta smelt is endemic to the San Francisco Estuary and reaches 60–70 mm standard length (SL) (Bennett 2005), feeding on zooplankton, mainly calanoid copepods, throughout life. The delta smelt is weakly anadromous, migrating between the brackish waters of Suisun Bay and the freshwaters of the Delta. Upstream migration begins in the late autumn or early winter and spawning occurs from March through May in freshwater. Most delta smelt spawn ~12 months after hatching, with a small percentage surviving for another year to spawn. Young delta smelt move downstream in early summer and remain in the low-salinity zone (0.5–10‰) until they migrate for spawning.

Longfin smelt is native to the San Francisco Estuary. The species usually reaches 90–110 mm SL (Moyle 2002, Rosenfield and Baxter 2007) and is anadromous. It spawns at age 2 yr in freshwater in the Delta from December to April. Young longfin smelt occur from the low-salinity zone seaward throughout the estuary and into the coastal ocean. Longfin smelt feed on copepods as larvae and mysids and amphipods as young and adults.

Striped bass is a potentially large (>1 m), potentially long-lived (>10 yr) anadromous species. Females begin

TABLE 1. Definitions of variables used in the multivariate autoregressive modeling, years for which data were available, and ranges of values for variables.

Variable	Years (missing)	Range	Definition
Response variables			
Delta smelt (*Hypomesus transpacificus*)	1967–2007 (3)	0.06–4.02	autumn (Sep–Dec) midwater trawl, mean total catch per trawl
Longfin smelt (*Spirinchus thaleichthys*)	1967–2007 (3)	0.03–113.16	autumn (Sep–Dec) midwater trawl, mean total catch per trawl
Striped bass (*Morone saxatilis*)	1967–2007 (3)	0.12–59.38	autumn (Sep–Dec) midwater trawl, mean age-0 catch per trawl
Threadfin shad (*Dorosoma petenense*)	1967–2007 (3)	1.36–31.21	autumn (Sep–Dec) midwater trawl, mean total catch per trawl
Calanoid copepods, spring	1972–2007 (1)	0.98–43.87	mean biomass of calanoid copepodites and adults during spring (Mar–May) in low-salinity zone
Calanoid copepods, summer	1972–2007 (1)	2.93–27.62	mean biomass of calanoid copepodites and adults during summer (Jun–Sep) in low-salinity zone
Mysids	1972–2007 (0)	0.42–35.05	mean biomass of mysid shrimp during Jun–Sep in low-salinity zone
Covariates			
Northern anchovy (*Engraulis mordax*)	1980–2006 (1)	0.22–490.42	mean catch per trawl of northern anchovy in the Bay Study midwater trawl (Jun–Sep) in the low-salinity zone
"Other zooplankton" in spring	1972–2006 (0)	3.79–56.86	mean biomass of other zooplankton (not including crab and barnacle larvae, cumaceans) during spring (Mar–May) in the freshwater zone
Spring chlorophyll *a* (freshwater zone)	1972–2006 (0)	2.35–43.54	mean chl *a* (mg/m^3) during spring (Mar–May) in freshwater zone
Spring chlorophyll *a* (low-salinity zone)	1975–2006 (0)	1.12–21.32	mean chl *a* (mg/m^3) during spring (Mar–May) in low-salinity zone
Summer chlorophyll *a*	1975–2006 (0)	1.23–20.15	mean chl *a* (mg/m^3) during summer (Jun–Sep) in low-salinity zone
Cyclopoid copepod *Limnoithona tetraspina*	1972–2006 (0)	0–7.78	mean biomass of *Limnoithona* copepodites and adults during summer (Jun–Sep) in low-salinity zone
Inland silverside (*Menidia beryllina*)	1994–2006 (0)	19.88–116.54	mean catch per seine haul of inland silverside in the USFWS survey during Jul–Sep (for stations within the delta)
Largemouth bass (*Micropterus salmoides*)	1994–2006 (0)	0.02–8.00	mean catch per seine haul of largemouth bass in the USFWS survey during Jul–Sep (for stations within the delta)
Spring X2 (isohaline)	1967–2006 (0)	48.53–91.74	mean Mar–May position of the 2‰ isohaline (X2)
Autumn X2 (isohaline)	1967–2006 (0)	60.24–93.18	mean Sep–Dec position of the 2‰ isohaline (X2)
Water clarity	1967–2006 (0)	0.44–11.00	mean Secchi depth (m) for the autumn midwater trawl survey
Winter exports	1967–2006 (0)	0.13–12.00	total volume of water (km^3) exported by the California State Water Project and Central Valley Project during Dec–Feb
Spring exports	1967–2006 (0)	0.37–13.00	total volume of water (km^3) exported by the California State Water Project and Central Valley Project during Mar–May
Invasive clam *Corbula amurensis*	1967–2006 (0)	0–1	binary variable for presence (1987–2006, 1) or absence (1967–1986, 0)
Duration of spawning window for delta smelt	1975–2007 (0)	24–85	no. days for which mean temperature was between 15° and 20°C,† mean of five continuous monitoring stations throughout Suisun Bay and the Sacramento–San Joaquin Delta
Mean summer water temperature	1967–2006 (0)	20.45–23.65	mean water temperature (°C), mean of five continuous monitoring stations throughout Suisun Bay and the Sacramento–San Joaquin Delta during Jun–Sep

Notes: Mean catch per trawl was measured in terms of individuals. Biomass was measured as mg C/m^3. The freshwater zone was determined to be <0.5‰. The low-salinity zone was determined to be at 0.5–10‰. The X2 position was measured in km upstream from the Golden Gate Bridge.

† Range of water temperatures that best induce spawning by delta smelt (15°C) and limit larval survivorship (20°C).

to spawn at age 4 yr in the Sacramento River and, to a lesser extent, in the San Joaquin River, from April through June. Eggs drift with the current as they develop and hatch. Larvae drift into the low-salinity zone where they grow, later dispersing throughout the estuary. Adults occur primarily in saline waters of the estuary and the coastal ocean, except during spawning migrations. Age-0 striped bass feed mainly on copepods, later switching to macroinvertebrates and then to fish.

Threadfin shad typically is <100 mm total length and primarily inhabits freshwater. It switches between filter- and particle-feeding, consuming phytoplankton, zooplankton, and detritus. Most threadfin shad spawn in their second summer, although some may spawn at the end of their first year. Spawning occurs mainly in June and July. Threadfin shad is the most abundant pelagic fish in the upper San Francisco Estuary.

While other fish and plankton groups might be included in our model as response variables, we chose to limit our analysis to species of zooplankton that are especially important for delta smelt, longfin smelt, age-0 striped bass, and threadfin shad. Adult and juvenile (copepodites) calanoid copepods have different relationships with the fish in spring and summer, so we considered the two life stages as different "taxa" in our models. Mysid shrimps were regarded as most important to the fishes in the mid to late summer (Table 1).

Covariates

The covariates used in the MAR (Table 1) relate to factors thought to be important for one or more of the response variables (Table 2). Covariates included fish species that are potential competitors or predators of the four declining fish species (possibly at only certain life-history stages), food for the latter fishes or their crustacean prey (including phytoplankton), competitors (*Limnoithona*) or predators (*Corbula*) of the crustaceans, the primary surrogate of the fishes' habitat (X2) in spring and autumn, amounts of water extracted from the Delta in winter and spring, water clarity (measured using Secchi discs), and two water temperature variables (duration of the delta smelt spawning window, mean summer water temperature).

The expert model (Table 2) was based on extensive, long-term knowledge and experience of several of the authors (W. J. Kimmerer, F. Feyrer, W. A. Bennett, L. Brown, S. D. Culberson, G. Castillo), and justifications for expected relationships were drawn from the literature. Although Bayesian model selection (Green 1995) might have been incorporated into the MAR model, as was done for the complementary change point analyses (Thomson et al. 2010), we believe that there is didactic value in concentrating on the evidential support for the expert-elicited model.

STATISTICAL ESTIMATION

MAR: Gompertz dynamics

We used a variant of a MAR model (Ives et al. 2003) to represent dynamics of the response variables. We represented population dynamics with the Gompertz model (Dennis et al. 2006). We began with a deterministic version of the Gompertz model (Reddingius 1971):

$$n_{i,t} = n_{i,t-1}\exp(\gamma_i + \delta_i \ln n_{i,t-1}) \qquad (1)$$

in which $n_{i,t}$ is abundance of species i at time t, $n_{i,t-1}$ is abundance of species i at time $t-1$, γ_i is the intrinsic rate of population growth for species i, and δ_i, which has been interpreted as the degree of density dependence.

We extended Eq. 1 first by allowing propagation for longer lags (up to L years prior to the current year), that is, an Lth-order Gompertz model (Zeng et al. 1998):

$$n_{i,t} = n_{i,t-1}\exp\left(\gamma_i + \sum_{l=1}^{L}\delta_{il}\ln n_{i,t-l}\right). \qquad (2)$$

It is possible that the γ_i may vary, so we allowed linear time dependence: $\gamma_i(t) = \gamma_{i,0} + \gamma_{i,1}t$. We expected the $\gamma_{i,1}$ parameters to be <0 given the declines in the abundances of the fishes. Taking logarithms, setting $x_{i,t} = \ln n_{i,t}$, and allowing species-specific lags (L_i), we have

$$x_{i,t} = x_{i,t-1} + \gamma_i(t) + \sum_{l=1}^{L_i}\delta_{il}x_{i,t-l}. \qquad (3)$$

Interspecific interactions among the seven taxa included as response variables were incorporated by appending terms relating to the previous year $\beta_{ij}x_{j,t-1}$, excluding self-terms:

$$x_{i,t} = x_{i,t-1} + \gamma_i(t) + \sum_{l=1}^{L_i}\delta_{il}x_{i,t-l} + \sum_{j=1, j\neq i}^{J}\beta_{ij}x_{j,t-1}. \qquad (4)$$

We included effects of covariates u_k through α coefficients for the current year t:

$$x_{i,t} = x_{i,t-1} + \gamma_i(t) + \sum_{l=1}^{L_i}\delta_{il}x_{i,t-l} + \sum_{j=1, j\neq i}^{J}\beta_{ij}x_{j,t-1} + \sum_{k=1}^{K}\alpha_{ik}u_{k,t}. \qquad (5)$$

MAR implementation

We used a Bayesian framework for implementing the model. There are many advantages to so doing. First, propagation of measurement uncertainties is straightforward using hierarchical models. Second, missing data are easily accommodated and estimated within the same process by which the parameters estimated are made, rather than a clumsier two-stage imputation–estimation approach. Third, we believe that the prior expectations, which also are easily implemented in a Bayesian framework, are critical encapsulations of the state of knowledge before the modeling was undertaken and need to be made explicit, as we have done.

We implemented Eq. 5 using the following model in WinBUGS, version 1.4 (Spiegelhalter et al. 2003):

$$z_{i,t} \sim \mathcal{N}(x_{i,t}, \omega_{i,t}^2) \qquad x_{i,t} \sim \mathcal{N}(\mu_{i,t}, \sigma_i^2) \qquad c'_{k,t} \sim \mathcal{N}(u_{k,t}, \zeta_k^2)$$

$$\mu_{i,t} = x_{i,t-1} + \gamma_i(t) + \sum_{l=1}^{L_i}\delta_{il}x_{i,t-l} + \sum_{j=1, j\neq i}^{J}\beta_{ij}x_{j,t-1} + \sum_{k=1}^{K}\alpha_{ik}u_{k,t} \qquad (6)$$

($\mathcal{N}$ denotes the normal distribution). The model states

TABLE 2. Matrix of effects included in the model with explanations.

Response variable or covariate	Response variable							
	DS	LFS	SB	TFS	CA-SP	CA-SU	MYS	Explanation
Delta smelt (DS)					–	–		Calanoid copepods are consumed by delta smelt (Hobbs et al. 2006).
Longfin smelt (LFS)					–	–	–	Calanoid copepods and mysids are consumed by longfin smelt (Feyrer et al. 2003).
Striped bass (SB)					–	–	–	Calanoid copepods and mysids are eaten by young striped bass (Feyrer et al. 2003, Bryant and Arnold 2007).
Threadfin shad (TFS)								Threadfin shad consume phytoplankton and copepods but are most abundant in freshwater (Turner and Kelley 1966, Feyrer et al. 2007).
Calanoids, spring (CA-SP)	+	+	+					Key food for young fish in spring.
Calanoids, summer (CA-SU)	+	+	+				+	Key food for young fish in summer; mysids consume calanoids (Siegfried et al. 1979, Siegfried and Kopache 1980).
Mysids (MYS)		+	+			–		Key food for young longfin smelt and striped bass in summer.
Anchovy					–	–	–	Biomass dominant, consumes all plankton (Kimmerer 2006).
Other zooplankton				+				Threadfin shad consume zooplankton in freshwater (Turner and Kelley 1966).
Chlorophyll *a*, spring, freshwater					+			
Chlorophyll *a*, spring, low-salinity zone					+		+	Calanoids eat microplankton, including phytoplankton (Gifford et al. 2007) and respond positively to phytoplankton blooms (Kimmerer et al. 2005*b*).
Chlorophyll *a*, summer, low-salinity zone						+	+	Mysids eat phytoplankton and small zooplankton (Siegfried and Kopache 1908).
Limnoithona tetraspina						–		Indirect effect through depression of food resource (ciliates; not measured) (Bouley and Kimmerer 2006, Gifford et al. 2007).
Inland silverside	–				–	–		Silversides consume copepods and potentially delta smelt eggs and larvae (Bennett and Moyle 1996).
Largemouth bass	–		–	–				Potentially important predator on small fish in freshwater (Nobriga and Feyrer 2008).
X2, spring		–	–		+/–		–	Effects of spring X2 on subsequent abundance in the following autumn (Jassby et al. 1995, Kimmerer et al. 2009).
X2, autumn	–	–	–					X2 affects surface area available for fish through salinity distribution (Feyrer et al. 2007).
Water clarity	–	–	–	–				Turbidity favors all fish at various life-history stages by offering increased protection from predators (Feyrer et al. 2007, Nobriga and Feyrer 2008, Kimmerer et al. 2009).
Export flow, winter	–	–						Adult smelt are entrained by pumping facilities during winter (Baxter et al. 2008, Kimmerer 2008).
Export flow, spring	–	–	–	–				Juvenile and adult smelt and shad and juvenile striped bass are entrained by pumping facilities during spring (Baxter et al. 2008).
Corbula amurensis					–	–		Nauplius larvae of copepods are consumed by *Corbula* (Kimmerer et al. 1994).
Spawning window	+							Spawning window for delta smelt is constrained by temperature (Bennett 2005).
Mean summer water temperature	–							Delta smelt are negatively influenced by high water temperatures, reducing time spent in the freshwater Delta (Swanson et al. 2000).

Notes: A "+" denotes that the covariate was expected to exert a positive influence on the response variable (e.g., food source). A "–" indicates that the covariate was expected to have a negative influence on the response variable (e.g., by consumption). All null entries were deemed likely to be unimportant by expert knowledge. The abbreviations "X2" refers to the position of the 2‰ isohaline (a measure of the physical response of the estuary to freshwater flow).

that the (ln-transformed) observed values ($z_{i,t}$) represent the true values ($x_{i,t}$). The former have observation errors, which are included by use of (ln-transformed) unobserved values ($x_{i,t}$) and observation errors, $\omega^2_{i,t}$. The observation errors were estimated from SEs of mean values for the response variables for each time period. Given that the $z_{i,t}$ were ln-transformed, we used a Taylor functional expansion to approximate the ln-transformed SEs [$\mathrm{SE}(\ln(\bar{n})) \approx \mathrm{SE}(\bar{n})/\bar{n}$] (Seber 1973, Stuart and Ord 1987). Process variances (σ^2_i) were allowed to be species-specific and were implemented with priors on σ_i of U(0.01, 10) (Gelman 2005) (U = Uniform). The true, unobserved values ($\mu_{i,t}$) are driven by the population dynamic parameters, trophic interactions, and covariates as described by the MAR model (Eq. 5).

Observed covariates $c_{k,t}$ were standardized for all available years of data (subtract mean $\bar{c}_k$, divide by standard deviations SD_k over all years, $c'_{k,t} = (c_{k,t} - \bar{c}_k)/\mathrm{SD}_k$). Standardizing is helpful for model convergence and for equalizing numerical ranges among different scales of measurement. Uncertainties in covariate measurements (within-year SEs) correspondingly were scaled by the interannual standard deviations (i.e., $\mathrm{SE}_{k,t}/\mathrm{SD}_k$). The model specifies that the true (standardized) covariate values ($u_{k,t}$) are related to the observed standardized values ($c'_{k,t}$) but include the covariate-specific uncertainties [$\zeta_k^2 = (\mathrm{SE}_{k,t}/\mathrm{SD}_k)^2$]. Uncertainties for most covariates were included in the models (a few variables, such as presence of *Corbula*, were regarded as fixed). There were sporadic missing data for some covariates, which we allowed to be interpolated within the Markov chain Monte Carlo (MCMC) modeling. These missing covariate values need to be segregated from the main estimation of effects by using the "cut()" function in WinBUGS. If the uncertainties are not so isolated, the model will "sacrifice" fitting precision for the parameters describing dynamics of the response variables to better "fit" missing covariate values, which is not intended (Carrigan et al. 2007).

Priors

Relatively uninformative priors were assigned for these model parameters:

$$\gamma_{i,0} \sim \mathcal{N}(0,1) \qquad \eta_\gamma \sim \mathcal{N}(0,10^3) \qquad \sigma_\gamma \sim \mathrm{U}(0.01,10)$$

$$\sigma_i \sim \mathrm{U}(0.01,10) \qquad \delta_{il} \sim \mathcal{N}(0,1). \tag{7}$$

Use of standard Normal priors for the γ_0 and δ parameters is consistent with the expected values being within approximately ±1 (i.e., constrained to reasonable values) given the ln-transforms for the response variables and the standardized covariates. From expert elicitation, species-specific lags were 2 (delta smelt), 3 (longfin smelt), 5 (striped bass), 2 (threadfin shad), and 1 (calanoids and mysids).

For the key α, β, and γ_1 parameters, we used a Weibull distribution to represent the prior beliefs of the expert-elicited model (Table 2). Use of the Weibull allows long tails in the expected direction if these are supported by the data. We used the construction $\psi_0\mathrm{Weibull}(2,\ 1) + \psi_1$, where $\psi_0 = 1$ for expected influences in a positive direction and is -1 for negative expected influences, while ψ_1 is -0.55 for expected influences in a positive direction and 0.55 for negative ones. These configurations invest ~3:1 prior probability mass in favor of the expected influence. Only one α parameter had a neutral expected influence (Table 2), so this was assigned a $\mathcal{N}(0,\ 10^3)$ prior (i.e., low precision). Many of the potential relationships were specifically excluded from the model (i.e., deemed unlikely to be important). For such relationships, coefficients were assigned $\mathcal{N}(0,\ 10^{-6})$ priors (i.e., 0 with high certainty).

Parameter inference

We inferred importance of model parameters from the probability distributions of the parameters. We computed the proportion of the posterior probability distribution for each parameter exceeding 0 (designated as PPM), which is computed in WinBUGS with the "step()" function. The posterior odds are PPM/(1 − PPM) for a positive parameter and (1 − PPM)/PPM for a negative parameter. The ratio of these posterior odds to the prior odds is termed the odds ratio (OR). Common decision criteria for ORs are 3.2–10 (substantial evidence) and 10–100 (strong evidence) (Jeffreys 1961). For an uninformative prior, in which the ratio of prior probabilities for the parameter is unity, the OR is PPM/(1 − PPM) (or (1 − PPM)/PPM for negative parameters). We used a decision criterion of $\geq$10 for such parameters.

For informative priors, the prior odds were 3 (positive or negative). If the OR $\geq$ 3.2, we concluded that there was substantial support in the data for the expected relationship. If $1 \leq \mathrm{OR} < 3.2$, the data did not invalidate the expectation but there was less support (Jeffreys 1961). If $1 \geq \mathrm{OR} > 1/3.2$, then the data weakly contradicted the expectation. If $\mathrm{OR} \leq 1/3.2$, then the prior ratio of 3:1 had been shifted to 1:1 (or more extreme), suggesting that the expected relationship was inconsistent with the data but likely to be null. We interpreted $\mathrm{OR} < 1/10$ (viz. from 3:1 prior expectation to 1:3.2 posterior odds) as clear refutation of the expected relationship.

Modeling details and model fit

Parameters were estimated from three MCMC chains of 20 000 iterations after 10 000 iterations of burn-in ("model settling"). We checked MCMC mixing and convergence using the "boa" package (Smith 2006) in *R* (R Development Core Team 2006).

We determined relative importance of the autoregressive (A), among-response variables (R), and covariate (C) factors of the best model. To do so, we calculated the r^2 for eight models: null (fitting constant-only averages for the seven response variables), A, R, C, A + R, A + C, R + C, A + R + C (full model). These models were effected by deleting terms from Eq. 6 as appropriate. The γ_i terms were retained for all models. The r^2 are the squared Pearson correlation coefficients between the z and μ values from the seven response variables and all years. To decompose variance we used hierarchical partitioning (Chevan and Sutherland 1991, Mac Nally 2000), which identifies independent contributions from individual terms (viz. A, R, and C) and joint variance explanation. We used the R package "hier.part" (Walsh and Mac Nally 2003) to perform the decomposition.

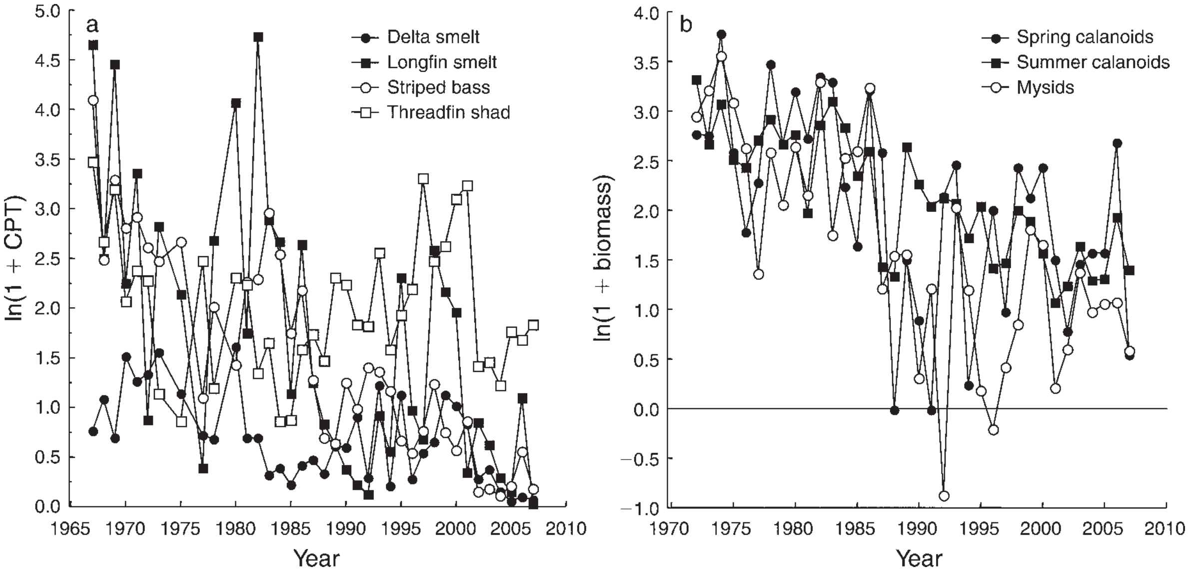

FIG. 2. Population trends (log-transformed) of (a) four fish species (mean catch per trawl [CPT]) and (b) zooplankton taxa (biomass, originally measured in mg C/m^3).

RESULTS

Abundance trajectories

Abundances of all four species of fish declined over the period of data collection, especially since about 2002 (Fig. 2a). Biomasses of the three crustacean groups have been declining consistently since the 1970s, with less evidence of a sudden decline in the 2000s (Fig. 2b).

Overall model characteristics

We used the r^2 (squared Pearson correlation coefficient) between the observed values and the posteriors of the fitted means as our measure of model fit. The full model (autoregressive components, among-response variables interactions, covariates) had an $r^2 = 0.69$. This explained variance was decomposed into independent explanatory amounts of (a) 0.13 for the autoregressive components (A), (b) 0.21 for among-response variable components (R), and (c) 0.35 for covariate relationships (C) (hence 1:1.62:2.69). Thus, the covariates were roughly 66% more important in explaining variation than the response variables, which in turn were ~62% more important than autoregressive elements.

Specific relationships

Parameter estimates and related details are provided in Appendix A. Some covariates appeared to affect more than one response variable (Fig. 3a, b). For expectations that seemed strongly supported by the data, the large values of spring X2 (upstream location) were negatively related to abundances of longfin smelt, biomass of calanoids in spring, and biomass of mysids (Fig. 3a). High water clarity was associated negatively with abundances of striped bass and threadfin shad, while high mean summer water temperatures had an inverse relationship with delta smelt abundance (Fig. 3a).

Several expectations were more weakly supported by the data, but were not refuted. Spring exports were negatively associated with abundances of delta smelt and threadfin shad (Fig. 3b). Many of the trophic interactions among response variables were supported to some extent, including negative relationships between the abundance of longfin smelt and delta smelt and biomass of calanoids in summer, negative correlations between abundance of striped bass and calanoid biomass in spring, and a positive relationship between concentration of chlorophyll *a* in spring and biomass of mysids and calanoids. Calanoid biomass in spring and summer was negatively associated with presence of the nonnative clam *Corbula amurensis*, while abundance of largemouth bass and volume of winter exports were negatively associated with abundance of delta smelt (Fig. 3b).

For all four declining fish species, the parameters indicating density dependence (δ) from the previous year were strongly negative, ranging from -0.79 ± 0.26 (mean ± SD) for threadfin shad to -1.03 ± 0.18 for longfin smelt (Appendix A). Current abundances were positively related to those for two years previous for longfin smelt (0.30 ± 0.16). Other lag effects were deemed unimportant, although a four-year lag (positive) for striped bass had OR = 9.2.

For the γ parameters, only one result seemed unexpected. The anticipated negative slope for threadfin shad was positive, with high certainty (OR < 1/57.8; Appendix A). This suggested, counterintuitively, that the intrinsic population growth parameter had increased over the duration of study.

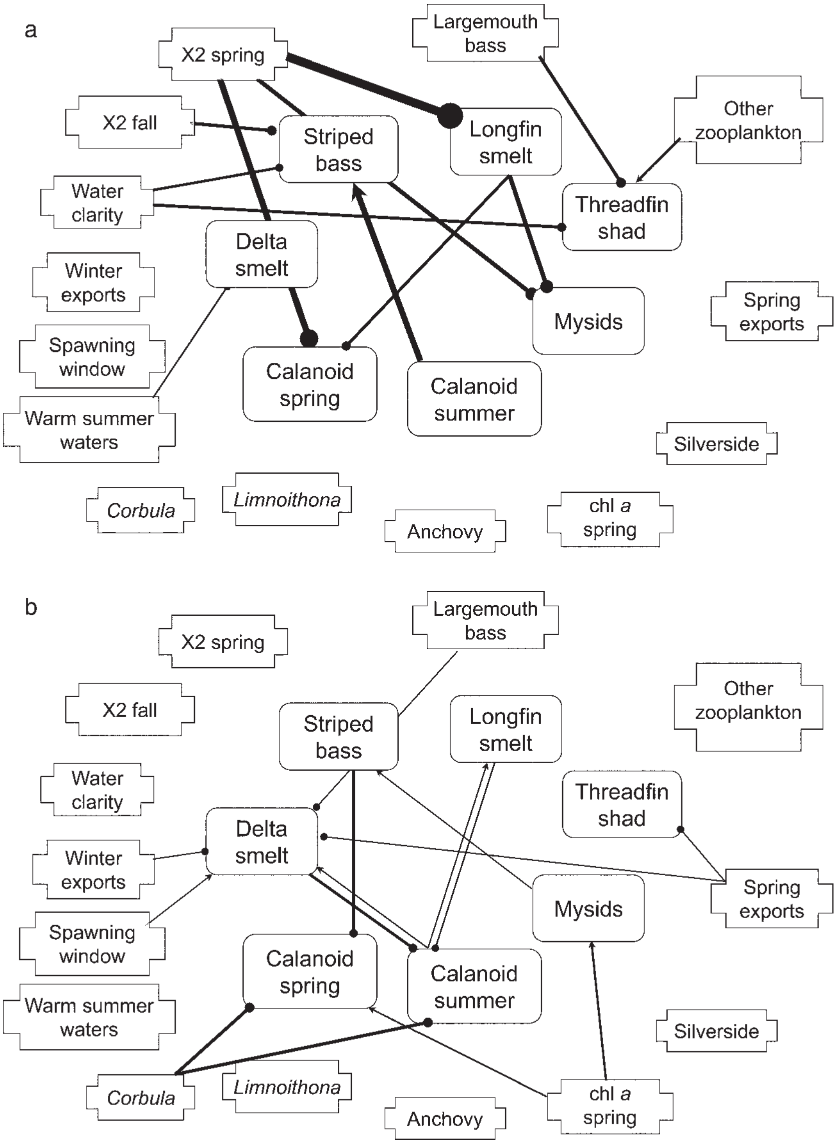

FIG. 3. Relationships supported by the Bayesian multivariate autoregressive analysis of the expert-elicited model, with width of lines proportional to the regression coefficient divided by its standard error. Response variables (focal taxa) are enclosed in rounded boxes while covariates are in boxes with side tabs. Arrows toward a focal taxon indicate a positive effect related to the focal taxon or covariate of line origin, while solid circles indicate negative relationships. (a) Relationships for which the odds ratio ≥ 3.2. (b) Relationships for which the odds ratio falls between 1 and 3.2. The abbreviation "X2" refers to the 2‰ isohaline.

DISCUSSION

Overview of the MAR results

The importance of covariates (51% of explained variation) suggests that some aspects of the environment that can be managed are associated with the declining fish species (e.g., X2 and exports). However, other potential remedial actions would be difficult or impossible to enact (e.g., total removal of *Corbula amurensis*). The relatively large proportion of variance explained by interactions among the declining fishes and their prey suggests that trophic interactions also are important, but it is less clear how management actions could modify such relationships.

The MAR analysis largely supported the expert model, suggesting that existing knowledge is sufficient to identify important interactions and processes, although not all relationships were supported. The expert model included 54 relationships, all but one of which was assigned an expected direction (Table 2). The latter was an "uninformed" expectation that calanoids in spring would be affected by spring X2. The direction was found to be strongly negative (Fig. 3a), suggesting that spring calanoid abundance is greater when X2 is more seaward. Of the 53 relationships with expected directions, 13 were strongly supported on the basis of odds ratios (OR) of ≥ 3.2 (Fig. 3a) and 15 were not inconsistent with the expected direction ($3.2 > \text{OR} \geq 1$) (Fig. 3b). The other 25 coefficients had posterior means close to zero, indicating that the data did not support the expected directions.

One advantage of using the MAR approach is that results can be represented easily in a form with which most ecologists are familiar, a (partial) food web (Fig. 3). The predator–prey relationships involving the calanoids and mysids support existing reports of direct and indirect effects on the four declining fish species. For example, abundance of striped bass was positively related to availability of calanoid copepods in summer (Fig. 3a). This was negatively associated with the occurrence of the introduced clam *Corbula amurensis* (Fig. 3b), which has induced an ongoing decrease of ~60% in chlorophyll *a* concentration in the low-salinity zone (Alpine and Cloern 1992). Other indirect food limitation relationships may be the chlorophyll *a* (spring) → mysids → striped bass and chlorophyll *a* (spring) → calanoids (spring) → striped bass pathways (Fig. 3b). Longfin smelt abundances had strong negative correlations with calanoids in spring and summer and mysids in spring (Fig. 3a, b). Abundance of delta smelt was related to calanoid biomass in summer (Fig. 3b). These results and relationships of copepods and mysids to chlorophyll *a* concentrations (Fig. 3b) suggest that food web dynamics are important for both smelt species. The isohaline position (X2) in spring had strong negative relationships with spring calanoids and mysids, which also would propagate back through those food pathways (Fig. 3a).

Few covariate relationships were expressed clearly for more than one of the four declining fish species (Fig. 3a, b). Increased water clarity appeared to be related negatively to both striped bass and to threadfin shad (Fig. 3a). Increased water clarity has been attributed to reduction of sediment supply in the rivers (Wright and Schoellhamer 2004) and to sediment capture by submerged aquatic vegetation. Water clarity affects fish feeding (Hecht and Vanderlingen 1992) and vulnerability to predation (Gregory and Levings 1998). Abundance of largemouth bass, a potential predator of the declining fish species (Nobriga and Feyrer 2008), was negatively related to abundance of threadfin shad and, more weakly, to abundance of delta smelt (Fig. 3). Abundance of largemouth bass has increased in the Delta concurrently with expansion of submerged aquatic vegetation (Brown and Michniuk 2007), which provides high-quality habitat for the species. Greater cover of submerged aquatic vegetation also reduces turbidity. Reduced water clarity has been identified as a key component of habitat for delta smelt, at least in autumn (Feyrer et al. 2007). The absence of a discernible relationship between water clarity and abundance of delta smelt may be due to an indirect expression through trophic relationships. Young delta smelt require suspended particles in the water column to feed properly (Baskerville-Bridges et al. 2002, Mager et al. 2002), so reduced prey availability (e.g., summer calanoids) may mask the direct water clarity effect. The multiple effects of temperature, feeding, exports, and introduced species are more consistent with understanding of delta smelt biology (Bennett 2005, Baxter et al. 2008) than are effects of individual covariates per se.

There were clear relationships between warmer summer waters (negative) and duration of water temperatures suitable for spawning (positive) (Fig. 3) and delta smelt, which were consistent with known effects of high temperatures on delta smelt survival (Swanson et al. 2000) and spawning requirements (Bennett 2005).

Increases in water exports in both winter and spring were negatively associated with abundance of delta smelt and increases in spring exports with abundance of threadfin shad. Losses of delta smelt previously have been related to exports through entrainment and mortality at pumping facilities and may be important to population dynamics under some circumstances, particularly during dry years (Kimmerer 2008). Effects of spring exports on threadfin shad have not been measured but possibly are important given that this is the only species of the four to occupy freshwater throughout its life cycle and whose main distribution is near the export facilities (Feyrer et al. 2009).

Modeling formulation: data and limitations

Using MAR, we identified plausible results, notwithstanding a number of important caveats within the model framework, which relate to the nature of the underlying data and to the structure of the analytical model.

Data limitations.—Three major forms of data limitation inherent in MAR are relevant to our study: (1) characterization of all variables and covariates by using a single value per year; (2) lack of spatially and temporally explicit data; and (3) selection of covariates and their measurement. For the declining fish species, we used an estimate of abundance based on average catch per sampling trawl over ~100 sampling stations over each of the four autumn months (September to December). Fish have been collected by other sampling methods (e.g., beach seine nets), but either not consistently over the duration of the data collection or only recently. We included observation error as the standard error from the ~400 trawls per year, but whether this is the most appropriate measure is arguable (Newman 2008).

Apart from allowing γ_i to be time-dependent (albeit linearly), the MAR model assumed process stationarity over the entire duration, which means that the structure of the model and distributions of model parameters are regarded as being the same over the 40+ years. It is possible that population dynamics of the declining taxa changed greatly as a function of population size. It is plausible that per capita reproductive rates, age structures, social (e.g., schooling) behaviors, Allee effects (Stephens and Sutherland 1999), and vulnerability to predation may differ when there are many individuals compared to when there are few. This is a common tenet in conservation biology (Caughley 1994).

Given the high certainty that all four species declined in concert in 2002 (Thomson et al. 2010), we modified Eq. 6 to allow all parameters to have a two-phase structure. The first phase was the 1967–2001 period and the second phase was 2002–2007. Each parameter was represented by a term of the form $\varpi + \delta\varpi$, where $\delta\varpi$ was the deviation in the second phase from values in the first phase. There were no parameters in which $\delta\varpi$ differed substantially from zero using our OR criteria. This suggests that the stationarity assumption of the MAR model is reasonable, although the small number of years in phase two may make changes difficult to detect.

Stakeholders have commissioned extensive correlative analyses (D. Fullerton, W. J. Miller, and B. F. J. Manly, *unpublished data*), which suggest a wide range of possibilities for potential covariates that might have sparked the precipitous declines. We included eight commonly mentioned covariates in additional runs of the MAR model (Appendix B). Our inferences were little changed, which suggests that our expert model was resilient to inclusion of additional variables and that the latter were largely uninformative.

Model form and structure.—The MAR model is underlain by the Gompertz population dynamic model (Eq. 1). Inference on stock recruitment is contingent on the form of the model (Maunder 2003). We explored whether our inferences were highly dependent on the use of the Gompertz by replacing it with another widely used formulation, the Ricker model (Appendix C; Zeng et al. 1998). The Ricker model emphasized more strongly several relationships: for example, the negative relationships between striped bass and X2 (autumn) and between spring calanoids and X2 (spring) (Appendix C). The Ricker and Gompertz versions of the MAR model generally provided similar inferences but the Gompertz appeared to resolve with greater precision a larger number of relationships given our criteria for their identification (i.e., using ORs).

The values for the δ_{i1} coefficients for the four declining fish species suggested strong negative density dependence (values between −0.79 and −1.03 for one-year lag; Appendix A). Such results seem difficult to reconcile biologically given that the fish sampled each year are young-of-the-year and it is difficult to conceive of a mechanism producing such density dependence. It is possible that this apparent contradiction may be a statistical artifact of the parameterization of the usual Gompertz model. Estimates of γ and δ can be highly correlated and identifiability depends upon length of time series (J. Ponciano, *personal communication*). Even if there were estimation problems for γ and δ, these probably do not affect our estimates of trophic interactions and covariate relationships. From simulations of a Gompertz model with one covariate, we found that the estimate for the covariate coefficient was unbiased even though the estimates of γ and δ were biased (results not shown).

The MAR formulation assumed linear relationships (on the log-abundance scale) and no interactions among covariates, although many interactions are plausible. Interactions would add substantially to the complexity and difficulty of interpretation of an already highly parameterized model. Inclusion of nonlinear functions and interactions among covariates may reduce capacity to resolve drivers of responses if used injudiciously.

A comparison of major outcomes of the MAR analysis with those of the change point analyses, which did allow nonlinear functions of covariates, showed some commonalities, but also several differences. Relationships with water clarity were important in the change point analyses for delta smelt, striped bass, and longfin smelt, although the relationship for the latter was rather stronger in a multispecies model (Thomson et al. 2010). A correlation of water clarity with abundances of threadfin shad, but not with delta smelt, was identified in MAR. A pervasive relationship of spring X2 with abundances of longfin smelt was clear in both analyses. A correlation of winter exports with delta smelt was evident in the change point, but was weaker in the MAR (Fig. 3b). The MAR analysis, but not the change point analysis, identified a correlation between autumn X2 and striped bass. Spring exports appeared to be related to abundances of threadfin shad in both analyses, although the magnitude of the correlation was less in the MAR. Unlike the change-point analysis, the MAR analysis did not identify a relationship between winter exports and threadfin shad. However, in the change-point analysis the magnitude of the average regression coefficient for winter exports and threadfin shad was substantially less than that for spring exports (Thomson et al. 2010). The trophic interactions evident in the MAR, of which many were pronounced (Fig. 3), were less evident in the model selection procedures used in the change point analysis.

A broader life-history model with a more general state–space approach to modeling the pelagic species decline should be more informative (M. N. Maunder and K. B. Newman, *personal communication*). Such a model would incorporate multiple sources of survey data, including data pertinent to egg, larval, juvenile, and adult phases and covariates appropriate for each stage (Maunder 2004).

Estuarine management

Our application of the MAR model provides evidence from a multivariate analysis of how abiotic habitat factors directly relate to declining fish abundance in the upper San Francisco Estuary and indirectly to these fish populations through the food web. Synthesis of previous univariate analyses have come to similar conclusions, albeit indirectly (Bennett 2005, Baxter et al. 2008). Before the fish species declined precipitously, the abiotic component of their habitat in the estuary was represented mainly as X2 because position of the salinity field was correlated with the abundances of many organisms (Jassby et al. 1995). Recent results have highlighted the importance of other abiotic variables, including water clarity and water temperatures, in the estuary (Feyrer et al. 2007, Nobriga and Feyrer 2008). Our results, which identify trophic relationships, suggest the need to better understand the processes underlying the influence of abiotic conditions on the food web of the estuary. The upper San Francisco Estuary is an exemplar, perhaps an extreme one, of severe, adverse ecological response to many of the stressors to which such systems increasingly are exposed (Fig. 3). Some of the key issues relate to how the isohaline position (X2), which seems to have a profound effect on the declining fish and on their prey, might be managed. While evidence that water exports directly affect striped bass or longfin smelt in a consistent linear manner is weak, there is evidence of potential effects of water exports on delta smelt and threadfin shad. Successfully managing the estuary, at least for the declining fish species, requires a more complete understanding of how the direct effects of water exports interact with the indirect effect of controlling abiotic conditions and the food web.

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Literature Cited

Alpine, A. E., and J. E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37: 946–955.

Baskerville-Bridges, B., J. Lindberg, and S. Doroshov. 2002. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. Pages 219–228 *in* F. Freyer, L. Brown, R. Brown, and J. Orsi, editors. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society, Bethesda, Maryland, USA.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. Technical Report 227. Interagency Ecological Program for the San Francisco Estuary, State of California Department of Water Resources, Sacramento, California, USA.

Bennett, W. A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science 3(2):1.

Bennett, W. A., and P. B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento–San Joaquin Estuary. Pages 519–542 *in* J. T. Hollibaugh, editor. San Francisco Bay: the ecosystem. American Association for the Advancement of Science, San Francisco, California, USA.

Bollens, S. M., J. R. Cordell, S. Avent, and R. Hooff. 2002. Zooplankton invasions: a brief review, plus two case studies from the northeast Pacific Ocean. Hydrobiologia 480:87–110.

Bouley, P., and W. J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324:219–228.

Brown, L. R., and D. Michniuk. 2007. Littoral fish assemblages of the alien-dominated Sacramento–San Joaquin Delta, California, 1980–1983 and 2001–2003. Estuaries and Coasts 30:186–200.

Brown, L. R., and P. B. Moyle. 2005. Native fish communities of the Sacramento–San Joaquin watershed, California: a history of decline. Pages 75–98 *in* F. Rinne, R. N. Hughes, and R. Calamusso, editors. Fish communities of large rivers of the United States. American Fisheries Society, Bethesda, Maryland, USA.

Bryant, M. E., and J. D. Arnold. 2007. Diets of age-0 striped bass in the San Francisco Estuary, 1973–2002. California Fish and Game 93:1–22.

Cai, W., and T. Cowan. 2008. Evidence of impacts from rising temperature on inflows to the Murray-Darling Basin. Geophysical Research Letters 35:L07701.

Carrigan, G., A. G. Barnett, A. J. Dobson, and G. Mishra. 2007. Compensating for missing data from longitudinal studies using WinBUGS. Journal of Statistical Software 19: 1–17.

Caughley, G. 1994. Directions in conservation biology. Journal of Animal Ecology 63:215–244.

Chevan, A., and M. Sutherland. 1991. Hierarchical partitioning. American Statistician 45:90–96.

Cressie, N., C. A. Calder, J. S. Clark, J. M. V. Hoef, and C. K. Wikle. 2009. Accounting for uncertainty in ecological analysis: the strengths and limitations of hierarchical statistical modeling. Ecological Applications 19:553–570.

Dauer, D. M., J. A. Ranasinghe, and S. B. Weisberg. 2000. Relationships between benthic community condition, water quality, sediment quality, nutrient loads, and land use patterns in Chesapeake Bay. Estuaries 23:80–96.

Dennis, B., J. M. Ponciano, S. R. Lele, M. L. Taper, and D. F. Staples. 2006. Estimating density dependence, process noise, and observation error. Ecological Monographs 76:323–341.

Drinkwater, K. F., and K. T. Frank. 1994. Effects of river regulation and diversion on marine fish and invertebrates. Aquatic Conservation: Marine and Freshwater Ecosystems 4: 135–151.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277–288.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, U.S.A. Canadian Journal of Fisheries and Aquatic Sciences 64:723–734.

Feyrer, F., T. Sommer, and S. Slater. 2009. Old school vs. new school: status of threadfin shad five decades after its introduction to the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science 7(1):3.

Gelman, A. 2005. Prior distributions for variance parameters in hierarchical models. Bayesian Analysis 1:1–19.

Gifford, S. M., G. C. Rollwagen Bollens, and S. M. Bollens. 2007. Mesozooplankton omnivory in the upper San Francisco Estuary. Marine Ecology Progress Series 348:33–46.

Gillanders, B. M., and M. J. Kingsford. 2002. Impact of changes in flow of freshwater on estuarine and open coastal habitats and the associated organisms. Oceanography and Marine Biology 40:233–309.

Gleick, P. H. 2003. Global freshwater resources: soft-path solutions for the 21st century. Science 302:1524–1528.

Green, P. J. 1995. Reversible jump Markov chain Monte Carlo computation and Bayesian model determination. Biometrika 82:711–732.

Gregory, R. S., and C. D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society 127:275–285.

Hampton, S. E., L. R. Izmest'eva, M. V. Moore, S. L. Katz, B. Dennis, and E. A. Silow. 2008. Sixty years of environmental change in the world's largest freshwater lake: Lake Baikal, Siberia. Global Change Biology 14:1947–1958.

Hampton, S. E., and D. E. Schindler. 2006. Empirical evaluation of observation scale effects in community time series. Oikos 113:424–439.

Hecht, T., and C. D. Vanderlingen. 1992. Turbidity-induced changes in feeding strategies of fish in estuaries. South African Journal of Zoology 27:95–107.

Hobbs, J. A., W. A. Bennett, and J. E. Burton. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco estuary. Journal of Fish Biology 69:907–922.

Ives, A. R., B. Dennis, K. L. Cottingham, and S. R. Carpenter. 2003. Estimating community stability and ecological interactions from time-series data. Ecological Monographs 73: 301–330.

Jassby, A. D., W. J. Kimmerer, S. G. Monismith, C. Armor, J. E. Cloern, T. M. Powell, J. R. Schubel, and T. J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272–289.

Jeffreys, H. 1961. Theory of probability. Oxford University Press, Oxford, UK.

Kennish, M. J. 2002. Environmental threats and environmental future of estuaries. Environmental Conservation 29:78–107.

Kimmerer, W. J. 2006. Response of anchovies dampens effects of the invasive bivalve *Corbula amurensis* on the San Francisco Estuary foodweb. Marine Ecology Progress Series 324:207–218.

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science 6(2):2.

Kimmerer, W. J., J. H. Cowan, L. W. Miller, and K. A. Rose. 2001. Analysis of an estuarine striped bass population: effects of environmental conditions during early life. Estuaries 24: 557–575.

Kimmerer, W. J., E. Gartside, and J. J. Orsi. 1994. Predation by an introduced clam as the probable cause of substantial declines in zooplankton in San Francisco Bay. Marine Ecology Progress Series 113:81–93.

Kimmerer, W. J., E. S. Gross, and M. MacWilliams. 2009. Variation of physical habitat for estuarine nekton with freshwater flow in the San Francisco Estuary. Estuaries and Coasts 32:375–389.

Kimmerer, W., D. D. Murphy, and P. L. Angermeier. 2005*a*. A landscape-level model for ecosystem restoration in the San Francisco Estuary and its watershed. San Francisco Estuary and Watershed Science 3:2.

Kimmerer, W. J., M. H. Nicolini, N. Ferm, and C. Peñalva. 2005*b*. Chronic food limitation of egg production in populations of copepods of the genus *Acartia* in the San Francisco Estuary. Estuaries 28:541–550.

Mac Nally, R. 2000. Regression and model-building in conservation biology, biogeography and ecology: the distinction between—and reconciliation of—'predictive' and 'explanatory' models. Biodiversity and Conservation 9:655–671.

Mager, R., S. I. Doroshov, J. P. Van Eenennaam, and R. L. Brown. 2002. Early life history of fishes in the San Francisco Estuary and watershed. Pages 169–180 *in* F. Freyer, L. Brown, R. Brown, and J. Orsi, editors. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society, Bethesda, Maryland, USA.

Maunder, M. N. 2003. Is it time to discard the Schaefer model from the stock assessment scientist's toolbox? Fisheries Research 61:145–149.

Maunder, M. N. 2004. Population viability analysis based on combining Bayesian, integrated, and hierarchical analyses. Acta Oecologica 26:85–94.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley, California, USA.

Newman, K. B. 2008. Sample design-based methodology for estimating delta smelt abundance. San Francisco Estuary and Watershed Science 6:3.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231:567–573.

Nobriga, M., and F. Feyrer. 2008. Diet composition in San Francisco Estuary striped bass: Does trophic adaptability have its limits? Environmental Biology of Fishes 85:495–503.

Punt, A. E., and R. Hilborn. 1997. Fisheries stock assessment and decision analysis: the Bayesian approach. Reviews in Fish Biology and Fisheries 7:35–63.

R Development Core Team. 2006. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Reddingius, J. 1971. Gambling for existence: a discussion of some theoretical problems in animal population ecology. Acta Biotheoretica 20(Supplement):1–208.

Rosenfield, J. A., and R. D. Baxter. 2007. Population dynamics and distribution patterns of longfin smelt in the San Francisco estuary. Transactions of the American Fisheries Society 136:1577–1592.

Scavia, D., et al. 2002. Climate change impacts on US coastal and marine ecosystems. Estuaries 25:149–164.

Schindler, D. E., X. Augerot, E. Fleishman, N. J. Mantua, B. Riddell, M. Ruckelshaus, J. Seeb, and M. Webster. 2008. Climate change, ecosystem impacts, and management for Pacific salmon. Fisheries 33:502–506.

Seber, G. A. F. 1973. The estimation of animal abundance and related parameters. Griffin, London, UK.

Shipley, B. 1997. Exploratory path analysis with applications in ecology and evolution. American Naturalist 149:1113–1138.

Siegfried, C., and M. Kopache. 1980. Feeding of *Neomysis mercedis* (Holmes). Biological Bulletin 159:193–205.

Siegfried, C. A., M. E. Kopache, and A. W. Knight. 1979. Distribution and abundance of *Neomysis mercedis* in relation to the entrapment zone in the Western Sacramento–San Joaquin Delta. Transactions of the American Fisheries Society 108:262–270.

Smith, B. 2006. Bayesian output analysis program (BOA) for MCMC. R Package version 1.1.5-3. R Foundation for Statistical Computing, Vienna, Austria. ⟨http://www.r-project.org/⟩

Sommer, T., et al. 2007. The collapse of pelagic fishes in the Upper San Francisco Estuary. Fisheries 32:270–277.

Spiegelhalter, D., A. Thomas, and N. Best. 2003. WinBUGS version 1.4. Bayesian inference using Gibbs sampling. Medical Research Council, Biostatistics Unit, Institute for Public Health, Cambridge, UK.

Stephens, P. A., and W. J. Sutherland. 1999. Consequences of the Allee effect for behaviour, ecology and conservation. Trends in Ecology and Evolution 14:401–405.

Stuart, A., and J. K. Ord. 1987. Kendall's advanced theory of statistics. Oxford University Press, New York, New York, USA.

Swanson, C., T. Reid, P. S. Young, and J. Cech, Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384–390.

Thomson, J. R., W. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431–1448.

Townend, I. H. 2004. Identifying change in estuaries. Journal of Coastal Conservation 10:5–12.

Turner, J. L., and D. W. Kelley, editors. 1966. Ecological studies of the Sacramento–San Joaquin Estuary. California Department of Fish and Game, Sacramento, California, USA.

Vicuna, S., and J. A. Dracup. 2007. The evolution of climate change impact studies on hydrology and water resources in California. Climatic Change 82:327–350.

Walsh, C., and R. Mac Nally. 2003. The hier.part package. Hierarchical Partitioning. R Foundation for Statistical Computing, Vienna, Austria. ⟨http://cran.r-project.org/⟩

Wanger, O. W. 2007*a*. Findings of fact and conclusions of law re interim remedies re: delta smelt ESA remand and reconsultation. Case 1:05-cv-01207-OWW-GSA, Document 01561. United States District Court, Eastern District of California, Fresno, California, USA.

Wanger, O. W. 2007*b*. Interim remedial order following summary judgment and evidentiary hearing. Case 1:05-cv-01207-OWW-GSA, Document 01560. United States District Court, Eastern District of California, Fresno, California, USA.

Williams, S. L., and E. D. Grosholz. 2008. The invasive species challenge in estuarine and coastal environments: marrying management and science. Estuaries and Coasts 31:3–20.

Wright, S., and D. Schoellhamer. 2004. Trends in the sediment yield of the Sacramento River, California, 1957–2001. San Francisco Estuary and Watershed Science 2:2.

Zeng, Z., R. M. Nowierski, M. L. Taper, B. Dennis, and W. P. Kemp. 1998. Complex population dynamics in the real world: modeling the influence of time-varying parameters and time lags. Ecology 79:2193–2209.

APPENDIX A

Details of parameter estimates for the multivariate autoregressive (MAR) model including credible intervals of odds ratios (all model parameters are listed) (*Ecological Archives* A020-050-A1).

APPENDIX B

Details of parameter estimates for multivariate autoregressive (MAR) model with and without distinct variables suggested by other analyses (only parameters with large odds ratios are listed) (*Ecological Archives* A020-050-A2).

APPENDIX C

Details of parameter estimates for multivariate autoregressive (MAR) models underlain by Ricker and Gompertz population-dynamic formulations (only parameters with large odds ratios are listed) (*Ecological Archives* A020-050-A3).

SAN FRANCISCO ESTUARY & WATERSHED SCIENCE
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Delta Flow Factors Influencing Stray Rate of Escaping Adult San Joaquin River Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*)

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Keywords:
Fall-run, Chinook, Salmon, Stray, Delta, San Joaquin, Sacramento, Exports, Age, Hatchery, Aquaculture and Fisheries, Biostatistics, Hydrology, Population Biology, Probability

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Abstract:

Adult salmon that stray when they escape into non-natal streams to spawn is a natural phenomenon that promotes population growth and genetic diversity, but excessive stray rates impede adult abundance restoration efforts. Adult San Joaquin River (SJR) Basin fall-run Chinook salmon (*Oncorhynchus tshawytscha*) that return to freshwater to spawn migrate through the San Francisco Bay and Sacramento–San Joaquin River Delta (Delta). The Delta has been heavily affected by land development and water diversion. During the fall time-period for the years 1979 to 2007 Delta pumping facilities diverted on average 340% of the total inflow volume that entered the Delta from the SJR. The hypothesis tested in this paper is that river flow and Delta exports are not significantly correlated with SJR salmon stray rates. Adult coded-wire-tagged salmon recoveries from Central Valley rivers were used to estimate the percentage of SJR Basin salmon that strayed to the Sacramento River Basin. SJR salmon stray rates were negatively correlated ($P = 0.05$) with the average magnitude of pulse flows (e.g., 10 d) in mid- to late-October and positively correlated ($P = 0.10$) with mean Delta export rates. It was not possible to differentiate between the effects of pulse flows in October and mean flows in October and November on stray rates because of the co-linearity between these two variables. Whether SJR-reduced pulse flow or elevated exports causes increased stray rates is unclear. Statistically speaking the results indicate that flow is the primary factor. However empirical data indicates that little if any pulse flow leaves the Delta when south Delta exports are elevated, so exports in combination with pulse flows may explain the elevated stray rates. For management purposes, we developed two statistical models that predict SJR salmon stray rate: (1) flow and export as co-independent variables; and (2) south Delta Export (E) and SJR inflow (I) in the form of an E:I ratio.

Supporting material:

Appendix A: Description of Methods

Copyright Information:

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SAN FRANCISCO ESTUARY & WATERSHED SCIENCE

Sponsored by the Delta Science Program and the UC Davis John Muir Institute of the Environment

Delta Flow Factors Influencing Stray Rate of Escaping Adult San Joaquin River Fall-run Chinook Salmon (*Oncorhynchus tshawytscha*)

Dean Marston[†1], Carl Mesick[2], Alan Hubbard[3], Dale Stanton[1], Scott Fortmann–Roe[3], Steve Tsao[1], and Tim Heyne[1]

ABSTRACT

Adult salmon that stray when they escape into non-natal streams to spawn is a natural phenomenon that promotes population growth and genetic diversity, but excessive stray rates impede adult abundance restoration efforts. Adult San Joaquin River (SJR) Basin fall-run Chinook salmon (*Oncorhynchus tshawytscha*) that return to freshwater to spawn migrate through the San Francisco Bay and Sacramento–San Joaquin River Delta (Delta). The Delta has been heavily affected by land development and water diversion. During the fall time-period for the years 1979 to 2007 Delta pumping facilities diverted on average 340% of the total inflow volume that entered the Delta from the SJR. The hypothesis tested in this paper is that river flow and Delta exports are not significantly correlated with SJR salmon stray rates. Adult coded-wire-tagged salmon recoveries from Central Valley rivers were used to estimate the percentage of SJR Basin salmon that strayed to the Sacramento River Basin. SJR salmon stray rates were negatively correlated ($P = 0.05$) with the average magnitude of pulse flows (e.g., 10 d) in mid- to late-October and positively correlated ($P = 0.10$) with mean Delta export rates. It was not possible to differentiate between the effects of pulse flows in October and mean flows in October and November on stray rates because of the co-linearity between these two variables. Whether SJR-reduced pulse flow or elevated exports causes increased stray rates is unclear. Statistically speaking the results indicate that flow is the primary factor. However empirical data indicates that little if any pulse flow leaves the Delta when south Delta exports are elevated, so exports in combination with pulse flows may explain the elevated stray rates. For management purposes, we developed two statistical models that predict SJR salmon stray rate: (1) flow and export as co-independent variables; and (2) south Delta Export (E) and SJR inflow (I) in the form of an E:I ratio.

KEY WORDS

Fall-run, Chinook salmon, stray, Sacramento–San Joaquin Delta, flow, exports, age, hatchery.

INTRODUCTION

Over the past 2 decades large scale in-river flow and small scale non-flow restoration actions have been implemented to restore fall-run Chinook salmon (*Oncorhynchus tshawytscha*) in the San Joaquin River (SJR) basin. The primary purpose of these restora-

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Author disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the California Department of Fish and Game, the U.S. Fish and Wildlife Service, and/or the University of California at Berkeley.

tion actions is to ensure that mature fall-run salmon (salmon) return to the SJR basin to spawn. Results from previous studies indicate that Sacramento–San Joaquin River Delta (Delta) flow conditions when salmon escape the ocean (salmon escapement) may influence returning SJR origin salmon stray rates (Mesick 2001). Straying by SJR salmon hinders population goals and necessitates evaluating relationships between Delta flow conditions and SJR salmon straying into the Sacramento Basin. The specific hypothesis tested in this paper is that no statistically significant relationship between fall south Delta inflow and/or export flow conditions, and SJR origin salmon stray rates exists.

It is well established that some proportion of adult salmon, both wild and hatchery origin, stray from one river basin to another upon return to their natal home from the sea (Quinn 1993). Identifying what, if any, Sacramento–San Joaquin River Delta environmental factors increase the likelihood of SJR fall-run to stray into the Sacramento River Basin will help scientists, water project managers, and state and federal government regulators better manage Delta flow conditions (Hallock and others 1970; Mesick 2001) to accomplish their ultimate goal of restoring the SJR Basin fall-run salmon population. Published results of stray rate studies conducted within California rivers are few in number and are essentially limited to Snyder's (1931) work on the Klamath River, Hallock and others' (1970) work on the San Joaquin River, Sholes and Hallock's (1979) work on the Feather River, and Mesick's (2001) work on the San Joaquin River. Where necessary and applicable, stray rate information was gleaned from published stray rate research conducted in river basins in Oregon, Washington, Alaska, and Canada. Since Mesick's (2001) work directly relates to San Joaquin River salmon stray rates, his work is extensively cited.

Adult SJR Basin fall-run Chinook salmon that return to freshwater to spawn must pass through the San Francisco Bay (Bay) and Delta (Figure 1). The Delta has been heavily affected in the last century by land development and water diversion and comprises a labyrinth of man-made and natural channels that convey Delta inflow, direct water for diversion, and/or allow ocean-going ships to dock at Stockton for commerce (Figure 2). The Delta today is effectively managed to store water upstream of the Delta and release it at times, and volumes, when pumping facilities in the south Delta can capture and convey it for agriculture and municipal use. The primary water diversions located in the south Delta are California's State Water Project (SWP) and the federal Central Valley Project (CVP) export pumping facilities located near Byron and Tracy, respectively (Figure 2). The CVP began operations in 1955, and the SWP in 1967. Smaller Delta diversions are made by the Contra Costa Canal Water District (CCC) at Rock Slough and Old River (Figure 2) and by the Solano County Water Agency from the North Bay Aqueduct (NBA) located on Barker Slough.

Historically the CVP, SWP, and CCC pumping facilities operate year-round and collectively have a combined pumping capacity of approximately 394.4 $m^3\ s^{-1}$ (14,000 $ft^3\ s^{-1}$). In the 1990s, because of concern over excessive entrainment of springtime emigrating juvenile Sacramento River and SJR salmon (various races), springtime diversions at the CVP and SWP were greatly curtailed with much of the displaced pumping moved to the fall when the adult fall-run migrate. Between 1979 and 2007, average October–November exports ranged from a low of 18% of SJR Basin flow to a maximum of more than 740%, averaging nearly 340% of the volume of water inflowing from the SJR. Water movements through the historic Old and Middle SJR channels (Figure 1) are affected by Delta pumping because these channels directly feed the CVP and SWP pumps. Most times, the river in these channels downstream of the pumps is pulled back upstream by the pumps. Rock barriers also have been placed in several locations in the south Delta to improve agricultural water quality and quantity by increasing surface water elevation. These barriers are collectively called the south Delta barriers and include the Head of Old River Barrier, Grant Line Canal Barrier, Old River at Tracy Barrier, and the Middle River Barrier (Figure 2). Some of the barriers are impassable for fish. Further, the Stockton Deep Water Ship Channel (SDWSC, Figure 2) can be a migration barrier for returning salmon during the fall because of low dissolved oxygen levels (e.g., <5 mg L^{-1}) when flows are low (Hallock and others

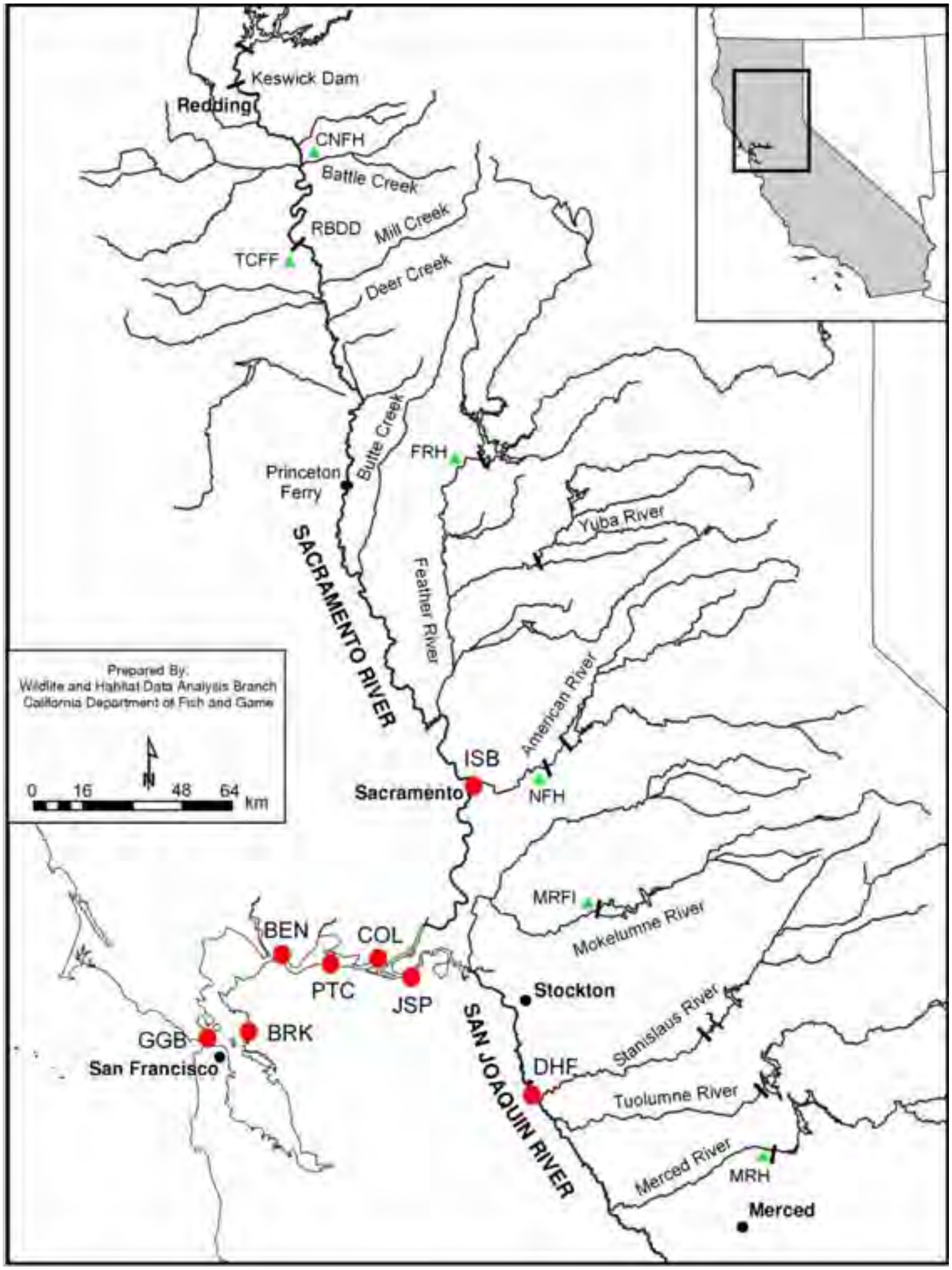

Figure 1 Map of the major Central Valley rivers, the Merced River Hatchery (MRH), Feather River Hatchery (FRH), Tehama Colusa Fish Facility (TCFF), Coleman National Fish Hatchery (CNFH), Mokelumne River Fish Installation (MRFI), and the Nimbus Fish Hatchery (NFH). Bay releases of tagged juveniles were made between Collinsville (COL) on the Sacramento River, Jersey Point (JSP) on the San Joaquin River, and the Golden Gate Bridge (GGB). Example release sites in the Bay include Berkeley (BRK), Benicia (BEN), and Port of Chicago (PTC). Delta releases were made upstream of COL and JSP to Durham Ferry (DHF) on the San Joaquin River and the I Street Bridge on the Sacramento River (ISB). Inland releases were made upstream of ISB and DHF.

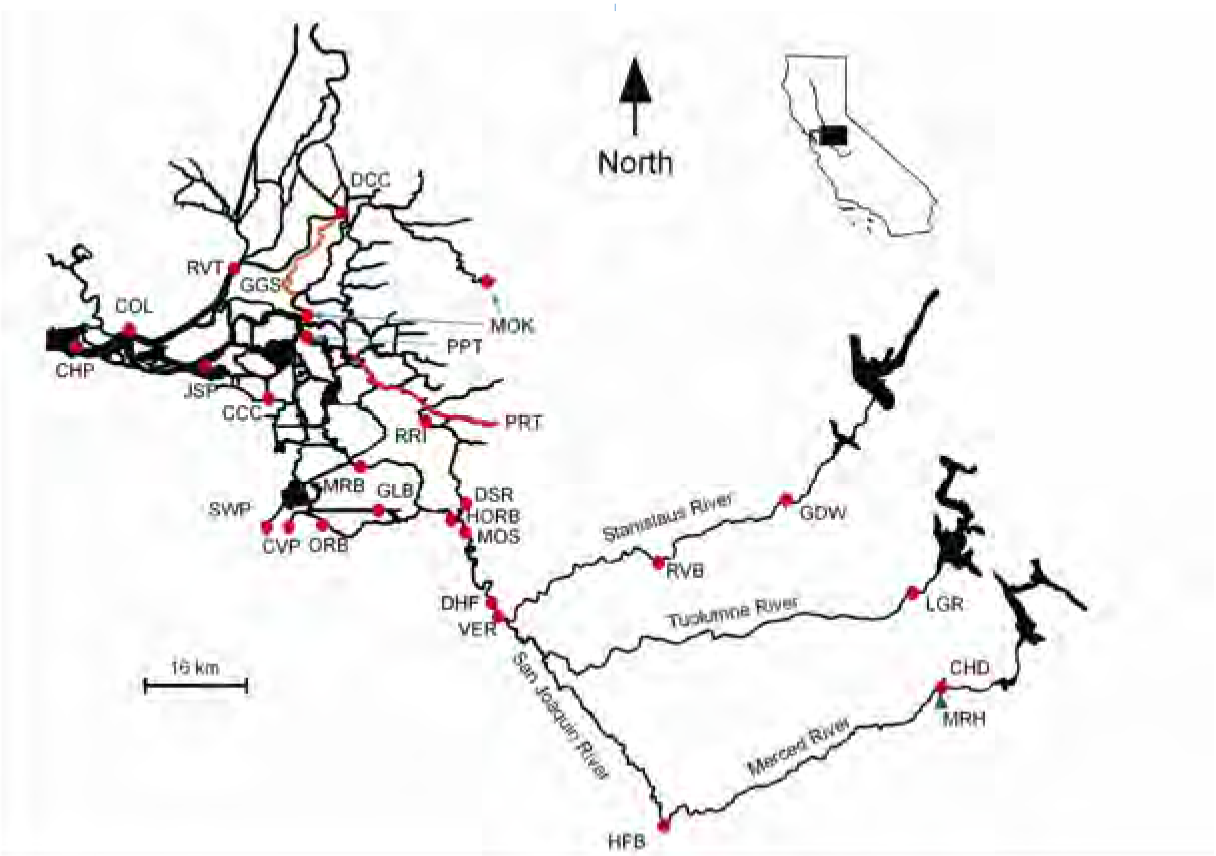

Figure 2 Map of the San Joaquin River and Delta showing the lowermost dams that block upstream passage for fall-run Chinook salmon including Goodwin Dam (GDW) on the Stanislaus River, La Grange Dam (LGR) on the Tuolumne River, Crocker-Huffman Dam (CHD) on the Merced River, and the Hills Ferry Barrier (HFB) on the mainstem San Joaquin River. The Merced River Hatchery (MRH) is shown as a green triangle. The lower Mokelumne River (MOK) is shown to its confluence with the SJR. Other study locations (red dots) include Riverbank (RVB), the State (SWP), Federal (CVP), and Contra Costa Canal (CCC) pumping facilities, stream gage at Vernalis (VER), Prisoner's Point (PPT), Durham Ferry (DHF), Mossdale (MOS), Dos Reis Road (DSR), Port of Stockton (PRT), Rough and Ready Island (RRI), Rio Vista (RVT), Delta Cross Channel (DCC), and Georgiana Slough (GGS, highlighted orange). The temporary rock barriers at the Head of the Old River (HORB), Grant Line Canal (GLB), Old River Barrier (ORB), and Middle River Barrier (MRB) are shown. The San Joaquin River mainstem downstream of the Port of Stockton (highlighted red) is dredged for ocean-going vessels. As defined here, releases of juvenile salmon in the Delta were made upstream of Jersey Point (JSP) to DHF on the San Joaquin River and upstream of Collinsville (COL) to the I Street Bridge (in the City of Sacramento, which is not shown) on the Sacramento River.

1970) or when water temperatures are high (Hallock and others 1970; Rich 2007). The SDWSC dissolved oxygen barrier can occur when SJR at Vernalis flows are less than approximately 42.5 m^3 s^{-1} (1,500 ft^3 s^{-1}). Water temperatures in the SJR can reach lethal levels and also block migration (Rich 2007) when temperatures exceed 21 °C to 22 °C (USEPA 2003). Reverse flows, physical barriers or chemical barriers that delay adult salmon migration may increase the likelihood of straying.

Chinook salmon rely primarily on olfactory cues to successfully migrate through the Delta's maze of waterways to home back to their natal river (Groves and others 1968; Mesick 2001). Juvenile salmon imprint by acquiring a series of chemical waypoints at every major confluence that enables them to relocate their river of origin (Quinn 1997; Williams 2006). Juvenile hatchery-reared salmon released downstream gather fewer chemical waypoints and are more likely to stray (CDFG and NOAA Fisheries 2001; Newman 2008). Adult SJR basin Chinook pass through the Delta from late September through November, with peak immigration usually in October (Mesick 2001).

Since olfaction plays such a strong role in a salmon's ability to return (home) to its natal river of origin (Groves and others 1968; Quinn 1997; Williams 2006), providing sufficient water to enable salmon to home in on their natal river is paramount. The Sacramento River basin is approximately 2.5 times larger than the San Joaquin River basin, has a hydrograph dominated by fall and winter rainfall compared to the spring-time snow-melt hydrograph on the SJR, and can provide ten times greater fall Delta inflows than the SJR. Comparatively, the SJR is the most heavily diverted of the two rivers. The mainstem SJR is discontinuous (dry over 90% of the time in one or more reaches) upstream of its confluence with the Merced River (Figure 2) and provides flow to the Delta only in wet years (Rose 2000). Only the major east-side SJR tributaries flow year-round. The SJR is managed to provide fall pulse inflows to the south Delta, typically for 7 to 10 days in late October. The goal is to compensate for the extreme Delta inflow differential between the Sacramento River and SJR basins, to remove the SDWSC dissolved oxygen barrier, and to decrease water temperatures. A secondary purpose of the fall pulse flows is to reduce SJR salmon from straying into the Sacramento River basin by enabling salmon to successfully locate and immigrate into the SJR basin.

The term "straying" has four spatially implied definitions: (1) adult salmon returning to a non-natal river basin; (2) adult salmon returning to a non-natal sub-basin; (3) adult salmon returning to a non-natal tributary; and (4) adult salmon returning to a hatchery in their natal river if naturally spawned. For this reason, stray rates between studies cannot be directly compared without considering which straying definition was used. For the purpose of this paper, the term "stray" means an adult salmon that strayed into the wrong sub-basin of the Central Valley (i.e. the Sacramento River basin rather than the SJR basin).

Mesick (2001) evaluated the effects of SJR flows and Delta export rates during October on adult San Joaquin Chinook salmon stray rates. Mesick reviewed the results of an earlier study (Hallock and others 1970) where adult San Joaquin salmon were tagged, then monitored (1964 to 1967), as they migrated through the Delta under varying environmental conditions (e.g. Delta inflow and export patterns, dissolved oxygen, and water temperature). Mesick also evaluated recovery data of coded-wire-tagged (CWT) adult salmon, released in years 1983 to 1996, that were reared at the California Department of Fish and Game's (CDFG's) Merced River Hatchery.

Mesick (2001) made two important observations from the Hallock and others (1970) data that describe adult migratory behavior through the Delta. First, adult San Joaquin salmon are migrating through the San Joaquin Delta near Prisoner's Point, which is about 5 km upstream from its confluence with the Mokelumne River (Figure 2), primarily during October, when they are likely to be susceptible to low SJR inflow and high Delta export conditions. Second, San Joaquin salmon migrate slowly through the Delta and do not enter the San Joaquin tributaries until approximately 4 weeks after they pass Prisoner's Point even if environmental conditions (dissolved oxygen, water temperature, and both south Delta inflow and exports levels) appear suitable for migration. These observations indicate that hydraulic conditions in the Delta are most likely to affect adult migrations during October rather than in November when they are observed on the spawning grounds in the tributaries.

Mesick (2001) found three primary flow factors that influence San Joaquin salmon stray rates. First, stray rates were directly correlated with the Delta export (E) to San Joaquin River Delta inflow (I) ratio (E:I). Second, the critical period to provide Delta flow protection (conditions conducive to SJR salmon migration) is between October 1st and 21st. Third, pulse flows from the SJR tributaries (the Merced, Tuolumne, and Stanislaus rivers) or, a reduction of Delta exports, that resulted in an E:I ratio of 3 (exports no greater than 300% of SJR inflow at Vernalis) for 8 to 12 days in mid-October were sufficient to keep stray rates at a minimum level (<3%). Mesick (2001) qualified his findings by saying that the accuracy of the estimated numbers of strays was questionable because of the uncertainties about the numbers of fish examined for CWTs within escapement surveys conducted in Central Valley rivers. As a result, he was unable to discern the specific effects of flow versus export rates on SJR Basin salmon stray rates or determine the precise period when flows and export rates had the greatest effect. He qualified his analysis of the Hallock and others (1970) data by stating that although most of the tagged fish migrated into the Sacramento and Mokelumne basins when Vernalis flows were less than about 56.7 $m^3\ s^{-1}$ (2,000 $ft^3\ s^{-1}$) and total exports exceeded 150% of Vernalis flows, there is uncertainty as to whether these were San Joaquin fish that strayed or Sacramento River fish that were captured in the San Joaquin River on their way to the Sacramento River via the Mokelumne River and Delta Cross Channel (Figure 2). He recommended that further studies were needed to refine the CWT return data in terms of the number of fish examined for tags during the carcass surveys and additional surveys for tags in all major tributaries of the Sacramento River Basin, particularly the mainstem Sacramento River.

Building on Mesick's (2001) work, we evaluated relationships between fall Delta flow conditions and San Joaquin salmon stray rates using coded-wire-tag (CWT) data collected from 1979 to 2007. We analyzed the data to determine the probability of an adult SJR salmon straying to the Sacramento River basin, given fall Delta flow conditions during their escapement. Pending analytical results, recommendations for controls that could be implemented as south Delta water quality control standards to provide a reasonable level of protection for returning adult SJR salmon could be considered and implemented. The specific hypothesis assessed, framed as a null hypothesis, is: fall south Delta inflow, export flow level, and barrier installation are not significantly correlated with SJR salmon stray rates.

METHODS

We developed three data sets in order to evaluate potential relationships between Delta flow patterns and SJR salmon stray rates. The data sets cover the years 1979 to 2007 and include those parameters we believe may significantly influence straying. The first data set includes coded wire tagged (CWT) salmon releases and recoveries of Central Valley fall-run Chinook salmon from which stray rates were determined. The second data set includes fall Delta flow and export conditions. The third data set contains south Delta Barrier (SDB) annual construction dates and operational periods. The 1979 to 2007 time-period represents the principal time-period when Central Valley salmon were coded wire tagged and released, and covers the period having complete brood-year production cohorts. Methods used to develop the stray rate data are complicated and are only summarized here. For a full description of methods used to develop the stray rate data, and to see the stray, hydrodynamic, and barrier data sets used in our analyses, please refer to the Methods Appendix.

Stray rates of ocean-escaping SJR salmon were compared with two fall south Delta inflow indices: the first using average October and November flow (base flow) and the second using a 10-day pulse flow occurring in mid-October to late October into early November. We also looked at Delta export flow levels over the same time periods. Stray rates for SJR salmon were developed from adult inland recoveries of coded-wire-tagged, hatchery-origin juvenile releases into the San Joaquin and Sacramento river basins, Delta, and Bay over a 29-year period (1979 to 2007).

Adult Salmon Stray Rates

We define salmon strays as the SJR basin fish that returned to the Sacramento River basin to spawn and the Sacramento River basin fish that returned to the SJR basin to spawn. Central Valley fall-run Chinook salmon stray rates were estimated based on CWT recoveries of adult salmon during the spawning surveys that were conducted to estimate escapement. The juvenile salmon with CWTs were produced in Central Valley hatcheries including the Merced River Hatchery (MRH) and the Mokelumne River Fish Installation (MRFI) in the San Joaquin River basin, and the Nimbus Fish Hatchery (NFH), Feather River Hatchery (FRH), and Coleman National Fish Hatchery (CNFH) in the Sacramento River basin (Figure 1). The MRH, MRFI, NFH, FRH, and CNFH are located 271, 120, 134, 236, and 446 km upstream of the Sacramento–San Joaquin River confluence respectively. Juvenile hatchery fish are trucked from the hatchery to various release locations and are not barged as occur in other river systems.

These hatchery-raised juveniles were released into three broad geographical areas identified as the Bay, Delta, and Inland release points. Bay releases occurred between Jersey Point on the San Joaquin and Collinsville on the Sacramento River, westward to the Golden Gate Bridge (Figure 1). Delta releases were made between Durham Ferry and Jersey Point on the SJR, and between the "I" Street Bridge (City of Sacramento) and Collinsville on the Sacramento River (Figure 1). Inland releases were made upstream of Durham Ferry and the "I" Street Bridge. To reduce the confounding effects of stray results caused by differences in juvenile release location (e.g. the farther downstream juveniles are released, the greater the stray probability (Quinn 1997; CDFG and NOAA Fisheries 2001; Newman 2008), only recoveries from inland releases were used to test our hypothesis.

MRH releases used in our analyses did not include any transfers of eggs or juveniles from other hatcheries; whereas, eggs and/or fry were routinely transferred from the FRH and NFH to the MRFI. In general, the MRH released juveniles as yearling-sized fish from 1978 to 1985 during October (mean weight 56 g) and November (mean weight 60 g) and as sub-yearling-sized fish from 1986 to 2006 during April (mean weight 6 g) and May (mean weight 7 g). The FRH primarily released juveniles as yearling-sized fish from 1980 to 2002 during October (mean weight 42 g) and November (mean weight 60 g) and as sub-yearling-sized fish from 1975 to 2006 during April (mean weight 6 g), May (mean weight 6 g), and June (mean weight 8 g). The CNFH primarily released juveniles as sub-yearling-sized fish from 1975 to 2006 during March (mean weight 2 g), April (mean weight 5 g), and May (mean weight 6 g).

Developing stray rate data for Central Valley fall-run salmon required a multi-step approach: (1) assembling inland escapement estimates for each Central Valley river, (2) assembling the expanded number of CWT's recovered within each Central Valley fall-run escapement survey, and (3) identifying the proportion of each CWT code recovered in each Central Valley river. We used the California Department of Fish and Game's (CDFG) fall-run escapement summary (GrandTab) for annual, river-by-river escapement data. We obtained CWT release data from the Pacific States Marine Fisheries Commission's (PSMFC's) Regional Mark Processing Center's Regional Mark Information System (RMIS) (data downloaded in 2011). We utilized CWT recovery data from annual escapement reports and/or personal contact with escapement survey crew leaders when additional information was necessary. The final form of the stray data consisted of annual summaries of the expanded number of fish that homed and strayed. Included in these expanded estimates were adjustments for number of fish that shed their tags, number of ad-clipped fish where tags were not recovered, and recovery number of untagged juvenile fish that were released alongside CWT marked juvenile releases. Annual summaries of hydrological data were also provided as discussed below.

To conduct this analysis, we assumed that CWT salmon recovery trends from juvenile salmon produced by the CDFG's MRH would also represent recoveries from naturally produced fish originating in the Merced, Tuolumne and Stanislaus rivers. Likewise, we assumed that the U.S. Fish and Wildlife Service's CNFH and the CDFG's FRH hatchery release–recovery trends would mirror those for all Sacramento Basin fall-run stocks. We believe this assumption is valid because Pacific salmon primarily home based on freshwater chemical olfactory cues imprinted when, as juveniles, they make their seaward migration (Quinn 1997; Williams 2006) and that water-borne odors would be similar for rivers within the same basin when compared with other basins. This assumption was indirectly corroborated by Barnett–Johnson and others (2008), who characterized Central Valley watersheds by Strontium isotope (^{87}Sr:^{86}Sr) ratios for purposes of identifying otolith markers for fall-run salmon, then by Miller and others (2010), who compared the water Sr:Ca (mmol mol^{-1}) and Ba:Ca (μmol mol^{-1}) ratios for Central Valley rivers to assess juvenile salmon river of origin via otolith Sr:Ca and Ba:Ca ratios. Collectively Barnett–Johnson and others (2008) and Miller and others (2010) found that water chemistry differed between the Sacramento and SJR basins. We did not include the MRFI CWT release–recovery data in our analyses for two reasons. First, the flows in the lower Mokelumne are mixed with Sacramento River basin flows (because of the Delta Cross Channel and Georgiana Slough), which can allow Mokelumne River juvenile salmon to imprint upon both Mokelumne and Sacramento basin water, thus enabling the adults to "correctly" choose either the Sacramento or Mokelumne rivers upon return. Second, egg and/or fry transfers to the MRFI from the FRH and NFH may affect the homing behavior of the MRFI releases.

Delta Flow Conditions

Delta flow data for the fall period were obtained from Dayflow, which is a program developed, operated and maintained by the California Department of Water Resources (CDWR). The program was initially developed in 1978 to serve "as an accounting tool for determining historical Delta boundary hydrology" (CDWR 2011b). CDWR significantly updated the program in 2000 using Java, enabling input data stored as a HEC-DSS file, and output presented in an ASCII file. The computational scheme was modified in February 2002 based on a better understanding of the complex Delta conveyance system.

According to CDWR, "the Dayflow program presently provides the best estimate of historical mean daily flows: (1) through the Delta Cross Channel and Georgiana Slough; (2) past Jersey Point; and (3) past Chipps Island to San Francisco Bay (net Delta outflow). The degree of accuracy of Dayflow output is affected by the Dayflow computational scheme and the accuracy and limitations of the input data. The input data include the principal Delta stream inflows, Delta precipitation, Delta exports, and Delta gross channel depletions" ("Dayflow").

All Dayflow calculations use daily flows and do not consider the travel time required for the water to move through the various channels in the Delta. The Dayflow computational scheme develops three types of quantities; net Delta outflow estimates at Chipps Island, interior Delta flow estimates at significant locations, and summary and fish-related parameters and indices.

Table 1 Delta Dayflow variables

SAC	Measured Sacramento flows at the "I" Street Bridge in Sacramento
SJR	Measured San Joaquin River flows at Vernalis
RIO	Calculated Sacramento River flows past Rio Vista
XGEO	Calculated flows of both the Delta Cross Channel and Georgiana Slough
QWEST	Calculated San Joaquin River flows at Jersey Point where reverse flows are indicated by a negative number
CCC	Measured Contra Costa Water District diversions at Rock Slough and Old River
SWP	Measured State Water Project exports from the Banks Pumping Plant or Clifton Court Intake
CVP	Measured Central Valley Project exports at Tracy
Exports	Sum of CCC + SWP + CVP

The time-period associated with the quantities generated by Dayflow range from October 1, 1955 through September 30, 2010. Our analyses included quantities from the years 1979 through 2007, to compare the results with fall-run Chinook salmon return data. The Dayflow variables are presented in Table 1 and the flow estimates are available at *http://www.water.ca.gov/dayflow/*.

Dayflow includes data representing total Delta exports (EXPORTS), which includes North Bay Aqueduct exports (NBAQ) along with the Contra Costa Water District Canal (CCC), State Water Project (SWP) and Central Valley Project (CVP) exports. NBAQ data were not used because these exports leave the Delta from the north. Therefore, in evaluating total exports for our analyses, we combined the CCC, SWP and CVP exports only. We also considered Old and Middle SJR (OMR) flows as measured at two U.S. Geological Survey (USGS) gaging stations: USGS 11312676 MIDDLE R AT MIDDLE RIVER CA and USGS 11313405 OLD R AT BACON ISLAND CA. The river at these locations is highly affected by both the SWP and CVP pumps that create reverse or upstream flows during the majority of the year. We gathered

Table 2 Cross-correlation matrix of Delta fall flow variables [a]

	SAC	Exports	SJR	XGEO	QWEST	QRIO	OMR	Pulse SAC	Pulse Exports	Pulse SJR	Pulse XGEO	Pulse QWEST	Pulse QRIO	Pulse OMR
SAC	1													
Exports	−0.11	1												
SJR	0.88	−0.21	1											
XGEO	0.77	0.06	0.67	1										
QWEST	0.82	−0.58	0.88	0.67	1									
QRIO	0.99	−0.18	0.86	0.67	0.81	1								
OMR	0.40	−0.90	0.54	0.15	0.78	0.45	1							
Pulse SAC	0.85	0.08	0.84	0.73	0.68	0.79	0.23	1						
Pulse Exports	0.03	0.91	−0.07	0.08	−0.44	−0.02	−0.74	0.28	1					
Pulse SJR	0.84	−0.18	0.98	0.63	0.84	0.82	0.52	0.84	−0.02	1				
Pulse XGEO	0.70	−0.01	0.68	0.88	0.66	0.60	0.21	0.83	0.09	0.64	1			
Pulse QWEST	0.76	−0.55	0.85	0.67	0.96	0.73	0.73	0.70	−0.45	0.82	0.73	1		
Pulse QRIO	0.80	0.13	0.79	0.58	0.60	0.78	0.18	0.96	0.35	0.80	0.65	0.60	1	
Pulse QMR	0.40	−0.90	0.54	0.15	0.78	0.45	0.94	0.23	−0.74	0.52	0.21	0.73	0.18	1

a Table showing co-linearity comparison between various Delta flow metrics, including Sacramento River at Freeport (SAC), combined South Delta Exports (Exports), San Joaquin River at Vernalis (SJR), Delta Cross Channel and Georgiana Slough flow (XGEO), San Joaquin River flow past Jersey Point (QWEST), Sacramento River flow past Rio Vista (QRIO). Pulse metrics equal the average flow during the fall pulse flow time period. Non-pulse flow metrics are average flows for the October and November time period.

OMR flow data for both the October–November base flow period and the 10-day pulse flow period.

Fall Delta base flow (mean October and November flow) and pulse flow (10-day average of highest flow in October–November) data is provided in the Methods Appendix. In addition to average base and pulse flows, flow ratios (by example: the ratio of Delta exports to SJR inflow at Vernalis) are also presented in the Methods Appendix. We also developed a cross-correlation matrix table to identify co-linearity between any flow variables (Table 2).

South Delta Barriers

We obtained south Delta barrier (SDB) operational data from CDWR’s South Delta Temporary Barriers Project (CDWR 2011a). Four barriers comprise CDWR’s SDB Project: Head of Old River (HORB), Grant Line Canal, Middle River, and Old River at Tracy. As stated by CDWR, the objectives of the SDB program are three-fold: (1) increase south Delta water levels (e.g., elevation) and circulation patterns to improve agricultural diversion water quality; (2) enhance the operational flexibility of the SWP and CVP; and (3) reduce effects on native and anadromous fish species.

The Head of Old River (HORB) barrier is a rock barrier—and the primary barrier, because it is intended to prevent SJR south Delta inflow from entering the Old River channel, which leads to the Delta export pumping facilities (i.e., the SWP and CVP), and maintains flow within the mainstem SJR and the SDWSC. The tidal effect and Sacramento River Basin flow contribution are greater downstream of the SDWSC than at the Head of the Old River and so the HORB reduces the amount of SJR flows that are diverted at the Delta pumping facilities relative to the amount of Sacramento River Basin flows diverted. Without the HORB, the majority of the SJR inflow enters the Old River depending on the diversion rate at the SWP and CVP (Jassby 2005; SJRGA 2009; ICF 2010). From a fisheries management perspective, the purpose of the HORB is to concentrate flow into the main channel to attract adult immigrating salmon into the main SJR channel during the fall (fall HORB), to deter salmon from using non-main river channels, and keep springtime (spring HORB) emigrating juvenile salmon out of the Old River channel where entrainment into the south Delta pumps is possible.

The fall HORB is installed in most years and typically operates from September 15th to November 30th, which is intended to coincide with the SJR fall Chinook immigration time-period. The remaining three barriers, also temporary rock barriers, serve as agricultural barriers designed to improve water quality and operate during the agricultural irrigation season from April 15 through September 30 each year. From 1979 to 2007, the HORB operated in 19 years, the Old River at Tracy in 15 years, the Middle River in 20 years, and the Grant Line Canal in 11 years. State (CDWR) and federal (U.S. Bureau of Reclamation) agency regulatory requirements—both landowner and local reclamation district entry permits—and physical conditions determine barrier installation and removal dates (CDWR 2011a). By example, high SJR flows that occur in wetter years when upstream reservoir storage must be evacuated might preclude installation and operation of the HORB.

To analyze the influence SDB's have on SJR salmon stray rates we used an ordinal date format to make the SDB's fall operating dates consistent across years. (The SDB operating dates are provided in the Methods Appendix.) To further ensure SDB operational consistency across years, the earliest date a barrier was considered to have been installed was September 1st (ordinal day 245). This date was chosen as the start date to coincide with Delta salmon immigration timing as described in Hallock and others (1970).

Statistical Analysis

The goals of the statistical analyses include estimating the independent associations of flow and exports upon SJR stray rates (explanatory analysis), as well as determining whether any particular combination of predictors was significantly better at predicting stray rates. The objective of the explanatory analysis was to examine the probability of escaping salmon straying relative to Delta flow conditions. Specifically, given the denominator as adjusted estimates of the number of CWT fish retrieved, we examined whether the probability of being a stray (specifically, a SJR fish returning to the Sacramento River Basin) was a function of various flows: SAC (Sacramento River at Freeport), SJR (San Joaquin River flow at Vernalis), Exports (Delta Exports), QRIO (Sacramento River flow past Rio Vista), QWEST (SJR flow past Jersey Point), and XGEO (Delta Cross Channel and Georgiana Slough flow), and OMR (combined Old and Middle River flow). The individual adult return rates for each CWT code were adjusted by (1) observed carcasses with adipose fin clips but no information for the tag code and (2) releases of unmarked juveniles with CWT marked juveniles that may have affected CWT return rates (see Methods Appendix). They also include stray rate estimates for rivers that lacked direct CWT recovery data, such as the mainstem Sacramento River from 1986 to 2000 (see Methods Appendix). The mean annual return rate for individual tag codes for each adult age was used as the unit of the statistical analysis.

As mentioned above, there is very high correlation among many of the average and pulse flow annual summaries. Due to this co-linearity, we included only pulse flows for the SJR and the corresponding SJR pulse flow period for the exports in our analysis. Also because of the co-linearity of flow variables, we did not analyze ratios between these explanatory variables—not because the other variables are not causally important, but only because the covariance among them is such that it is impossible, given the available data, to distinguish (estimate) the relative effects with the modest sample size (number of years) available. In addition, we examined the number of operating days for each barrier and its association with stray rates. (We note that the number of days and the start day for barrier operations cannot be examined independently in the same model, so we used the number of days as a proxy for both variables).

For each paired analysis between either SJR or export pulse flow level and stray rate we: (1) performed LOWESS smoothing (Cleveland 1979) on the proportions to examine (semi-parametrically) the stray response and provide in visual form the variability of stray rates around the predicted mean; (2) examined the logistic regressions of average trends (in the logit scale) of the probability of being a stray versus these flow levels, adjusting for the age of fish; and (3) derived our *P*-value for resulting trends (relative to flow independence and stray probability) via an age-conditioned pseudo-exact permutation test.

For the multivariable regression models, we used the nonparametric bootstrap (Efron and Tibshirani 1993) to derive inference, treating the year as the unit. We note that sometimes the bootstrap-based *P*-values can be quite different from the corresponding permutation ones (for analyses that are equivalent), suggesting that the dispersion can be so great relative to sample size that even robust inference can be potentially biased, which is why we emphasize the permutation method when appropriate.

For both SJR fall pulse and export flow levels, we (1) performed LOWESS smoothing on the stray proportions (Figures 3 and 4); (2) examined the logistic regressions of "average" trends in the logit scale) of the probability of being a stray versus these flow variables; and (3) derived our *P*-value for these trends (relative to flow independence and stray probability) via bootstrapping. For the bootstrapping, one thousand bootstrapped re-samplings of the data were generated. Coefficients for each re-sampling were estimated and their dispersion was used to calculate the standard error of the estimates. Such bootstrapped estimates are to some level robust when data does not necessarily fully conform to the assumptions of the normal linear regression model. In this case, the data was overdispersed (i.e., there was greater variance than would be predicted by a binomial model) and significance estimates that did not take this into account would have resulted in a high overestimation of statistical significance.

Finally for the pure prediction model procedure we compared the fit of competing models in predicting future stray rates by using a cross-validation technique, with known theoretical properties related to selecting the "optimal" model (Van der laan and others 2007), to compare five simple models (all of them containing indicators for age groups): (1) including log (SJR Pulse Flow) and log (Exports); (2) log(SJR Pulse Flow) and log (pulse OMR flows); (3) log (exports/SJR Pulse Flows) ratio; (4) log (SJR Pulse Flow) alone; and (5) log (Exports) alone. We note that both Models 4 and 5 are sub-models of 1 (for Model 4, it assumes the coefficient associated with log (SJR pulse flow) equals the negative of that on log (exports), whereas for Model 5, it just assumes the coefficient on exports is 0). Thus, under the typical assumptions, a likelihood ratio test could provide a measure of the relative fits of the model. However, in this case, we examine it empirically via 10-fold cross-validation. Specifically, the sample is divided into 10 equal parts (say validation samples) and for each of these, one (a) removes them from the data, (b) fits Models 1 through 5 on the other portion (the so-called training sample), and (c) uses these fits to predict on the left out sample. Thus, the procedure results in a column of observed stray rates, and five predicted stray rates (one for each model) where the predictions were derived independently of the corresponding outcome.

RESULTS

Stray Rates in General

Our analysis indicates that the stray rates for Sacramento Basin hatchery origin salmon, released upstream of the Delta, average less than 1% (range = 0 to 6%). Comparatively, for SJR Basin hatchery-origin salmon, stray rates average 18% (range = 0 to 70%). When stray results are considered for Delta and Bay releases, the average Sacramento hatchery-origin stray rates are 0.5% and 1%, respectively. SJR basin hatchery-origin stray rates, corresponding with Delta and Bay releases, are 35% and 85%, respectively.

Cross Correlation of Delta Flow Variables

Exports correlate negatively to the OMR flows (Old and Middle SJR). As exports increase OMR flows become more negative. All non-export Delta flow variables are highly positively correlated with one another (Table 2). That is, as one variable rises in value so do the others. The positive correlation results indicate that any of the non-export flow variables can be used to some extent as a proxy for all the flow variables. Since SJR fall pulse flow is, biologically speaking, the flow variable of importance it is used as the variable to determine if Delta inflow is significantly correlated with stray rate probability. Due to the extreme co-linearity between fall base flows and 10-day pulse flows (correlation = 0.97), we cannot determine which has the most important influence. If SJR base flow was used as the flow metric instead of pulse flow, the results for pulse flow presented below could be applied to base flow using the following linear regression equation between base and pulse flow levels:

$$SJRBaseFlow = 0.786 \text{ X } SJRPulseFlow,\ R^2 = 0.97$$

Delta Flow Variables and Stray Rates

Graphical comparisons of the probability of SJR salmon straying as a function of SJR fall pulse flow, south Delta exports, and the ratio (E:I) of south Delta exports (E) to SJR fall pulse flow (I) are provided in Figures 3, 4 and 5, respectively. Though there is a significant amount of variability between years, general trends are identifiable. For SJR fall pulse flow, salmon stray rate probability peaks (~50%) when flow levels are less than 30 m^3 s^{-1} (1,060 ft^3 s^{-1}) and are reduced substantially (~5%) when pulse flow levels increase to 150 m^3 s^{-1} (5,297 ft^3 s^{-1}). For south Delta exports, salmon stray rate probability peaks (20%) when export levels exceed 141.6 m^3 s^{-1} (5,000 ft^3 s^{-1}) and are substantially lower (~3%)

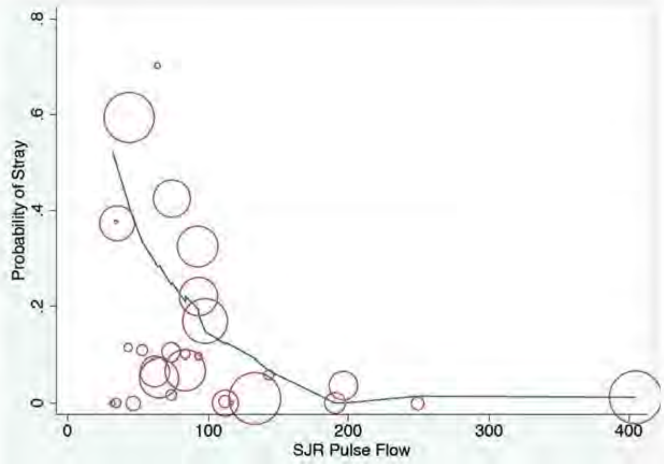

Figure 3 Plot showing the smooth of probability of San Joaquin River salmon straying as a function of San Joaquin River inflow level (m^3 s^{-1}) to the South Delta. Bubble size reflects relative number of coded-wire-tag recoveries across years. Smooth line is weighted by total recapture size.

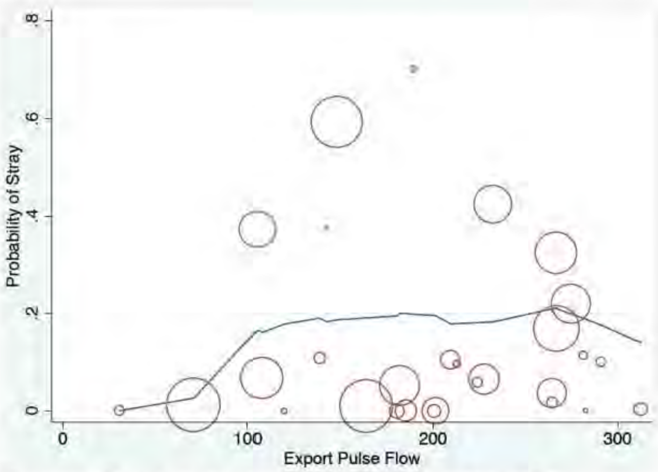

Figure 4 Plot showing the smooth of probability of San Joaquin River salmon straying as a function of South Delta export level (m^3 s^{-1}). Bubble size reflects relative number of coded-wire-tag recoveries across years. Smooth line is weighted by total recapture size.

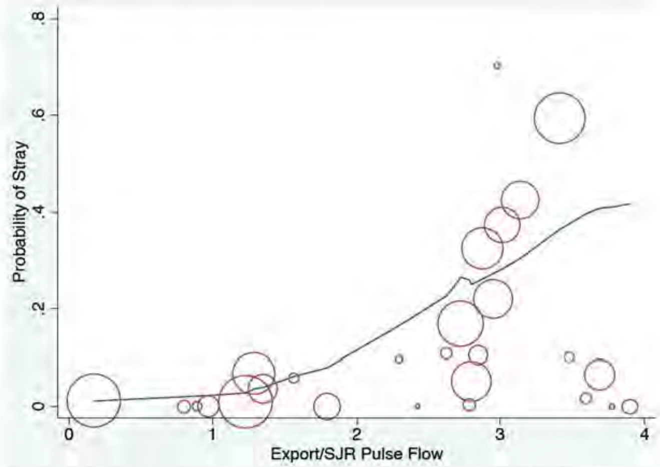

Figure 5 Plot showing the smooth of probability of San Joaquin River salmon straying as a function of South Delta export (E) (m^3 s^{-1}) to San Joaquin River Pulse Flow (I) level (m^3 s^{-1}) ratio (E:I). Bubble size reflects relative number of coded-wire-tag recoveries across years. Smooth line is weighted by total recapture size.

Table 3 Results of Delta flow variables and San Joaquin River salmon stray rate

	Coefficient[a]	Standard error[b]	*p*-value	95% confidence interval for coefficient	Unadjusted coefficient[c]	Unadjusted *p*-value[c]
Constant	5.349	9.231	0.562	−12.74 – 23.44		
ln(SJR)	−2.568	0.786	0.001	−4.108 – −1.029	−1.9	0.016
ln(Exports)	1.570	0.868	0.07	−0.131 – 3.271	0.53	0.56
Age 3[d]	−0.596	0.628	0.343	−1.827 – 0.636		
Age 4[d]	−0.846	0.726	0.244	−2.268 – 0.577		

a Example calculation using most likely coefficients. Assume a SJR pulse flow of 8,000 and an Export pulse flow of 6,000 (in cfs; U.S.) for a group of salmon aged 3. The following is used to calculate the probability of straying for this group:

$$\text{logit}\,(PStray) = 5.35 + (-2.57\ln(8{,}000) + 1.57\ln(6{,}000) + (-0.596 \times 1) + (-0.846 \times 0)$$

$$\text{logit}\,(PStray) = \ln\left(\frac{PStray}{1 - PStray}\right) = -4.68$$

$$PStray = 0.0092$$

b Standard Error calculated using nonparametric bootstrapping, randomly re-sampling years with replacement (Efron and Tibshirani 1993).

c Coefficient based on unadjusted logistic regression, p-value based on the permutation distribution of corresponding Wald Statistic.

d Age is a dummy variable that is 1 when the salmon is that age and 0 otherwise.

when export flow levels are reduced to 56.6 $m^3\ s^{-1}$ (2,000 $ft^3\ s^{-1}$). For E:I ratio, salmon stray rate probability peaks (~40%) when the ratio approaches a 4:1 level, and is substantially reduced (~10%) when the ratio is less than 2:1.

Table 3 contains the results of the logistic regression that predicts stray rates as a function of SJR fall pulse flow, export flow and salmon age. Of the independent fall Delta pulse inflow variables analyzed, only SJR flow was significant ($P = 0.05$), according to the bootstrapping estimate of error, and has a negative association with SJR salmon stray rate (Figure 3). Combined south Delta export pulse flow was close to significant ($P = 0.10$) and has a positive association with SJR salmon stray rate (Figure 4). The smooth lines depicted in Figures 3 and 4 are weighted by the proportional number of CWT recoveries. Equation 1 determines SJR salmon stray rate, by age, as a function of SJR pulse flow magnitude and south Delta combined export level in non-ratio format.

When the five competing models previously discussed—(1) log (SJR Pulse Flow) and log (Exports), (2) log (SJR Pulse Flow) and log (pulse OMR flows), (3) log (Exports/SJR Pulse Flows), (4) log (SJR Pulse Flow), and (5) log (Exports)—were compared via cross-validation, the results, given the relatively large residual variation seen in all the observed versus the cross-validated predictions (for all the competing models) were quite large, one can not definitely rank the predictive accuracy of any of them versus the others. It appears that models including either SJR flow and exports or both do relatively well, still with relatively modest cross-validated R^2 values of around 0.2. It is important to note that we repeated this analysis with many different splits, and also with different cross-validation folds (up to 40-fold) to avoid

Equation 1

$$StrayRate = \frac{1}{1 + e^{-(1.790 - 2.568\ln(SJRPulseFlow) + 1.570\ln(ExportPulseFlow) - (0.5956Age3) - (0.8455Age4)}}$$

NOTE: To calculate stray rate for age-2 salmon, set both the age-3 and the age-4 terms to zero. For age-3 salmon stray rates, set the age-3 term to 1 and the age-4 term to zero. For age-4 salmon stray rates, set the age-3 term to zero and the age-4 term to 1. For cubic feet per second (cfs; U.S.) units, simply substitute the intercept value of 1.790 with 5.349. The equation beneath Table 3 is the same equation described here but it is converted, for convenience, to standard units.

making conclusions based on any cross-validation configuration. These results suggest that, based on existing data, models that include exports and pulse flow, either as a ratio, or separate terms, appear to be as good or better than competing models with other hydrological measures. It is important to note that these cross validation results, which were intended to evaluate competing model prediction accuracy, do not contradict results obtained from a robust analysis assessing what is a significant association of stray rate. The single factor that is controlling stray rate, from a statistically significant perspective, is SJR flow.

In conclusion, since the biology of salmon indicates that a model including SJR flow is biologically necessary (salmon navigate based upon juvenile river imprinting), we must include SJR flow in a management model. There are several ways to link flow and exports to stray rates. Whether or not to include either co-variate (flow and exports), and how, depends entirely upon the objective. If the objective is explanation, then a model that includes both flow and exports independent of one another is warranted (Model 1). Alternatively, if the goal is pure prediction, then a model that has flow alone (Model 4) is acceptable given that flow is the only variable associated with SJR salmon stray rates at a statistically significant level. However, since we cannot say with statistical certainty whether flow or exports is the primary determinant influencing SJR salmon stray rates, exports can also be included in the management model in the form of an E:I ratio (Model 3). Equation 2 determines SJR salmon stray rate, by age, as a function of south Delta combined export to SJR inflow ratio (E:I).

South Delta Barriers and SJR Salmon Stray Rate

We also examined the operating days for each of the barriers and their association with stray rates. The total operating days and the initial operating day for each barrier cannot be examined independently in the same model, so we used the total barrier operating days as a proxy for both variables. None of the barriers produced a significant effect on salmon stray rates at either the $P = 0.05$ or 0.10 levels. This indicates that, for south Delta Barriers, neither barrier construction date, nor total operating days, are positively or negatively influencing SJR salmon stray rates in a statistically significant manner. The implication of this finding is that barrier operation for whatever purpose, even if to influence SJR salmon stray rate, is not reducing—or increasing—SJR salmon stray rate at a statistically detectable level.

DISCUSSION

Our results suggest that the percentage of SJR fall-run Chinook salmon straying into the Sacramento River Basin (1979 to 2007) was as high as 70% (fall 2007). Straying was inversely correlated with pulsed flows in the mainstem SJR at Vernalis ($P = 0.05$) and directly correlated with Delta export levels at a nearly significant level ($P = 0.10$). Our estimated stray rates were more than twice as high as those reported by Mesick (2001), because Mesick did not have complete estimates of the number of adult salmon carcasses that were examined for CWTs during the Sacramento River Basin surveys.

Although stray rates were most highly correlated with pulsed SJR flows, we cannot differentiate between the 10-day pulse flows in October–November and mean

Equation 2

$$StrayRate = \frac{1}{1 + e^{-(-3.25 + 2.41\ln(ExportPulseFlow/SJRPulseFlow) - (0.64\,Age3) - (1.01\,Age4))}}$$

NOTE: To calculate stray rate for age-2 salmon, set both the age-3 and the age-4 terms to zero. For age-3 salmon stray rates, set the age-3 term to 1 and the age-4 term to zero. For age-4 salmon stray rates, set the age-3 term to zero and the age-4 term to 1. No modifications to this equation are required for cubic feet per second (cfs; U.S.) unit calculations.

October and November base flows. Mean and pulse fall SJR flows are positively cross correlated to a very high degree (adjusted R-square of 0.97 at $P = 0.05$). Fall flows are highly regulated (controlled) in the SJR basin and are tied to SJR basin water year type (critical, dry, below normal, above normal, wet); whereby, annual flow schedules are derived pursuant to regulatory instream flow requirements. Thus, as water year type increases as a result of greater snowmelt runoff, both fall base and pulse flows increase concurrently. The cross correlation between mean and pulse flows makes it uncertain which of the two flow metrics is responsible for attracting SJR salmon to their natal river. However, it is logical that since adult salmon migrate over several months that the mean flow rate in September through November would affect the largest number of salmon.

It is uncertain whether SJR flows or Delta exports have the greatest effect on SJR stray rates, because exports were so high in most years that it appears that little if any SJR flow (i.e., olfactory migration cue) was conveyed to the Bay during the fall (Figure 6). The calculated QWEST (SJR flow past Jersey Point and the Central Delta outflow point) flow levels can be strongly negative even in wetter years (2005 and 2006). A negative QWEST flow means that the SJR is flowing 'backward' (i.e. upstream) and tends to occur when the combined SWP and CVP exports exceed the flow in the SJR. October and November QWEST flows for the years from 1979 through 2007 ranged from –70.8 $m^3 s^{-1}$ (–2,500 $ft^3 s^{-1}$; 2005) to 651.3 $m^3 s^{-1}$ (23,000 $ft^3 s^{-1}$; 1983). Negative fall base and pulse flows at QWEST occurred in 14 (48%) of years analyzed. Even in some years when QWEST is positive for the fall base and pulse flow period, exports may exceed SJR flow but Sacramento flow that has been diverted into the Central Delta (identified as XGEO: flow through the Cross-Delta Canal and the Georgiana Slough) adds to the QWEST. Median XGEO flows (150.4 $m^3 s^{-1}$; 5,310 $ft^3 s^{-1}$) from 1979 through 2007 are nearly double the SJR flows (66.1 $m^3 s^{-1}$; 2,333 $ft^3 s^{-1}$). Median fall pulse flows show a similar disparity between XGEO flows (145.9 $m^3 s^{-1}$; 5,152 $ft^3 s^{-1}$) and SJR flows (83.6 $m^3 s^{-1}$; 2,951 $ft^3 s^{-1}$).

Exports and SJR flow are not correlated; thus, both should be included as potential model parameters. A permutation test is the best statistical method to evaluate the individual linkage of each parameter with stray rate, which reveals flow is significant (0.05) and exports are nearly so (0.10). The permutation method does not allow simultaneous assessment of both parameters to get the best inference so another test is used (bootstrapping). The bootstrap method reveals flow is still significant but exports are not. However, we cannot say that exports are not truly significant, given the limited sample size, and, according to the competing model evaluation, a model with exports performed as well as one with SJR pulse flow alone. Therefore both flow and export parameters can be included in a single model in the form of an E:I ratio.

An example of daily SJR fall flow for a single year (2009) is provided in Figure 6 where SJR flow is measured at four gaging stations in the Delta. SJR flows, as measured at Vernalis, indicate that pulse flows experienced at Vernalis (rkm 118; rm 73) are barely detectable at Garwood Bridge (rkm 68; rm 42) and are non-detectable at both Prisoner's Point (rkm 40; rm 25) and Jersey Point (rkm 16; rm 10). In fact, not only did the SJR fall pulse flows in late October not make it to both Prisoner's Point and Jersey Point in 2009, both of these locations had strong negative flows occurring at the same time pulse flows were supposed to be flowing through the south Delta. Note that the flows depicted in Figure 6 give the impression that all SJR pulse flow is constrained within the main SJR channel, but it is not. Given the labyrinthine nature of the south Delta (Figure 2), and the ability of SJR pulse flow to enter and proceed through the SJR Old River channel, SJR pulse flow can re-enter the main SJR channel between Jersey Point (rkm 16; rm 10) and Prisoner's Point (rkm 40; rm 25). If SJR pulse flows that enter the Old River contribute to flow in the SJR at Jersey Point, it may be that SJR salmon that successfully migrate through the south Delta may be detecting the SJR via Old River, rather than mainstem SJR flow. It is also unknown how tidal influence affects fall pulse flow hydraulic continuity and ability of escaping salmon to detect the SJR. Further research is needed to determine whether SJR fall pulse flows do, or do

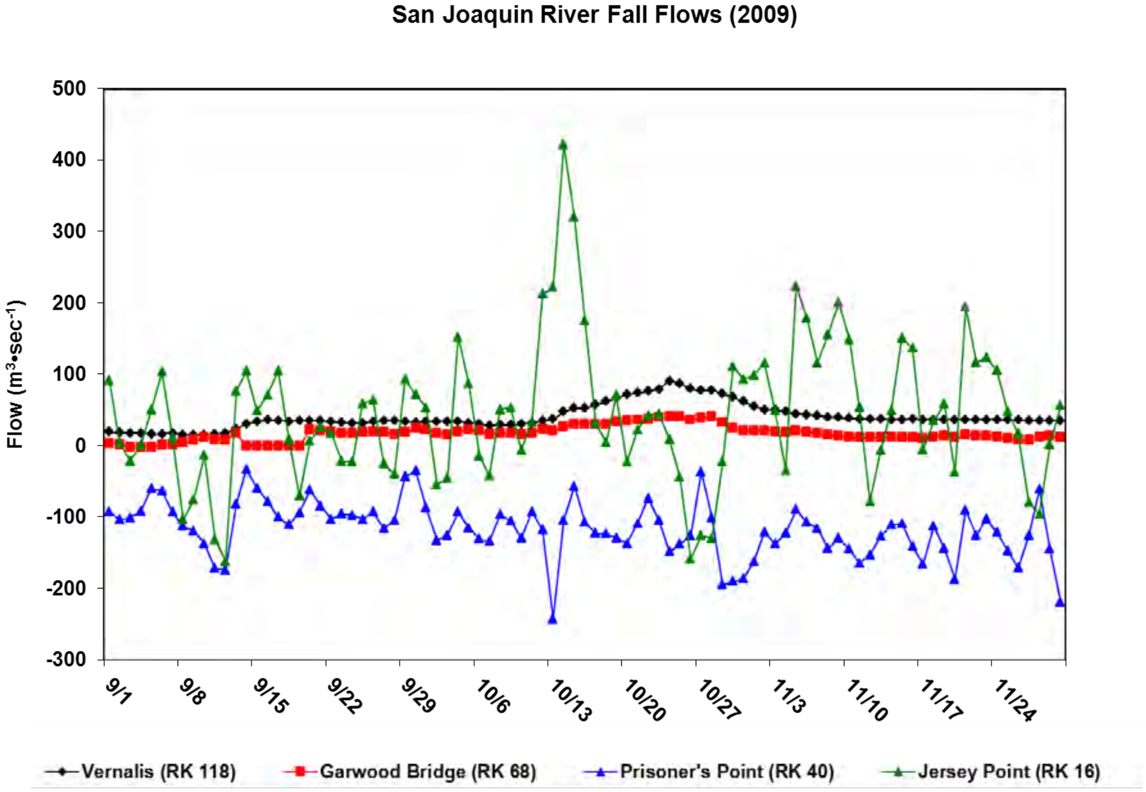

Figure 6 San Joaquin River flows at four locations from the entrance to the South Delta (Vernalis), through the interior of the Delta (Prisoner's Point and Garwood Bridge), and near the exit point of the Delta (Jersey Point). River kilometer (RK) is the distance measured from the San Joaquin-Sacramento River confluence to each location.

not, make their way to the SJR main river channel upstream of the confluence of the San Joaquin River and Sacramento River.

Our results also indicated that the south Delta barriers, including the fall HORB, have little if any influence on reducing SJR salmon stray rates. Although, the flow through the main SJR channel was reduced if the HORB was not installed, and the majority of the flow was conveyed towards the CVP and SWP pumping facilities via the Old River (Jassby 2005; SJRGA 2009; ICF 2010), the statistical analyses suggest that SJR stray rates were unaffected by whether SJR water flowed in the SDWSC or through the Old and Middle rivers. This is logical because SJR origin migrating adults would need to detect their natal SJR flow at the confluence of the San Joaquin and Sacramento Rivers to home successfully.

Juvenile Release Location and Stray Rates

Comparing stray rates for Sacramento River and SJR basin hatchery releases by broad geographical location (Figure 7) indicates that there is a ten-fold difference in stray rate for SJR salmon compared to that for Sacramento Basin salmon. Adult salmon stray rates for Sacramento Basin origin juvenile releases made upstream of the Delta averaged 0.1%; whereas, adult salmon stray rates for San Joaquin origin juvenile salmon releases made upstream of the Delta averaged 18%. For both Sacramento and San Joaquin adult salmon, straying increased sharply the farther downstream juvenile salmon were released. Sacramento salmon straying by release location averaged 0.1% (0 to 6.1%), 0.5% (0 to 3.4%), and 1.1% (0 to 7.8%), respectively for inland, Delta, and Bay releases. For San Joaquin salmon, adult straying by juvenile release location averaged 18% (0 to 70.1%), 35% (0 to 75%), and 85% (37.4% to 100%), respectively for inland, Delta, and Bay releases.

The coded-wire-tag release-recovery data indicate that releasing juvenile salmon farther downstream substantially increases juvenile-to-adult survival rates. This practice is called out-planting and while it increases survival, it appears to come at a cost in the form of higher stray rates than if releases occurred upstream at or near the hatchery (Ebel and others 1973; Slatick and others 1975; Ebel 1980). There is conflicting information in the literature about whether or not transportation of juveniles, from point of capture or rearing, to downstream locations, increases straying. Ebel and others (1973), Slatick and others (1975), and Ebel (1980), represent three separate studies documenting the effect of transporting juveniles on their survival and homing success as adult fish. Observed adult recoveries for both transported (barged) and non-transported fish in the Snake–Columbia River system, found that the homing ability of Chinook salmon was not impaired even when juveniles were transported 400 km (249 miles) downstream. Conversely, in a more recent study Keefer and others (2008), who also reported stray results from a long distance juvenile transportation study conducted in the Snake–Columbia River system, found that stray rates were higher for transported (barge) juveniles than for non-transported juveniles. Vreeland and others (1975) and Solazzi and others (1991), who conducted separate juvenile transportation studies using coho salmon (*Onchorhynchus kisutch*), found that transported (trucked) juveniles had lower homing (i.e. higher stray) rates than non-transported juveniles. These studies suggest that transportation of juveniles to downstream locations increases juvenile-to-adult survival but provide contradictory results for influ-

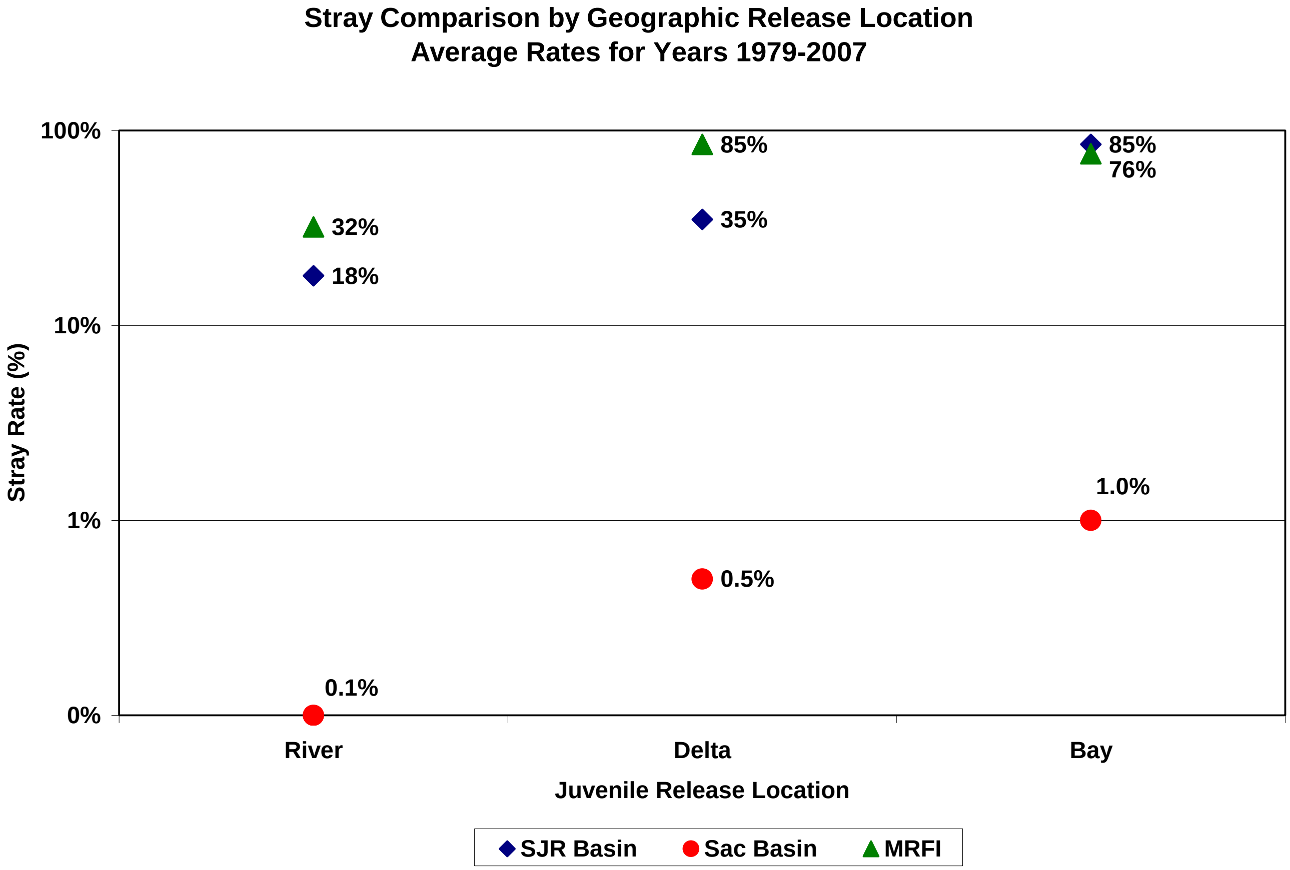

Figure 7 Plot showing stray rates for Sacramento River and San Joaquin River basin origin fall-run Chinook salmon by geographic location of release (River, Delta, and Bay) from the hatchery of origin during their juvenile emigration

ence upon adult homing. Our results indicate that juveniles released farther downstream will stray at greater rates (Figure 7).

One consequence arising from transporting hatchery juveniles to downstream releases locations is that hatchery fish from the MRH, and MRFI stray throughout the Central Valley at high rates. Though Sacramento River basin salmon exhibited relatively low stray rates (1% or less), regardless of release location in comparison to SJR basin salmon, the straying of Sacramento River basin salmon to the SJR could still be problematic given the order-of-magnitude difference in fall-run escapement between the two basins. For example, from 1979 to 2007, average annual escapement for Sacramento River and SJR adult salmon was 288,313 (ranging from 86,698 to 834,900) and 16,160 (ranging from 590 to 69,847), respectively (CDFG GrandTab 2010). If we assume a 1% stray rate and an escapement of 500,000 spawners for Sacramento River basin salmon, this would result in 5,000 salmon straying into the SJR basin. This level of Sacramento River basin salmon straying into the SJR can swamp SJR escapement, given that the combined SJR escapement has been less than 5,000 spawners in several years during the 1979 through 2007 time-period. This may have significant implications for Central Valley salmon management and may help explain why recent genetic testing indicates that the Central Valley fall-run Chinook salmon population is homogeneous (Banks and others 2000; Williamson and May 2005; Garza and others 2008; California HSRG 2012).

Stray Rate Comparisons

What is a "normal" (i.e., natural) stray rate for fall-run Chinook salmon? According to Quinn (1997), background levels of between 2% to 5% appear to be normal stray rates for hatchery salmon, but not many studies have been conducted for wild salmon. Williams (2006) reported a Mokelumne River wild fall-run Chinook stray rate of 7.3%, with the caveat that this population is heavily influenced by hatchery production and receives eggs and fry transferred from Sacramento River Basin hatcheries (FRH and NFH). CDFG Mokelumne River Hatchery annual reports confirm that large numbers of eggs and juveniles have been transported from Sacramento River Basin hatcheries (FRH and NFH) to the Mokelumne River Hatchery (Estey 1988; Anderson 2010). What a "normal" stray rate is depends on the definition of stray rate being referenced. There can be a wide range of stray rates for Chinook salmon depending on how straying is defined. Looking closely into the factors that influence straying, such as environmental conditions at the time of return (water temperature and flow rates in both natal rivers and rivers located adjacent to the natal river [Quinn 1997]), there is near unanimous agreement—from studies conducted in the lower Columbia River Basin, U.S. (Quinn 1993), Puget Sound and Strait of Georgia, Southern Canada (Candy and Beacham 2000), and New Zealand (Unwin and Quinn 1993)—that it is relatively rare that adult Chinook salmon stray into non-natal river basins to spawn. For reference and context, in this case the entire Central Valley is a single river basin. In other words, it would be a relatively rare event to have a naturally produced Central Valley salmon stray to a non-Central Valley river basin (say the Klamath River).

Whether or not there exists a difference in stray tendency for wild versus hatchery-reared salmon is largely unknown given the few homing studies conducted using wild salmon. Comparisons of straying between wild and hatchery-reared salmon, though few, have shown results indicating that tagged wild juveniles strayed less as returning adults than hatchery reared-released salmon; although, these results are not consistent. In one study, rearing of juvenile wild fall-run Chinook in a hatchery for a short time period increased their adult straying rate relative to wild fish not reared in the hatchery (McIsaac 1990). However, wild and hatchery-reared juvenile salmon showed similar stray rates in studies with coho salmon (Labelle 1992) and Atlantic salmon (*Salmo salar*; Jonsson and others 1991, as cited in Quinn 1997).

Straying by Age

The age of adults returning may contribute to stray rate variability in salmon. In some studies, older Chinook salmon strayed more than younger fish

(Quinn and Fresh 1984; McIsaac and Quinn 1988; Quinn and others 1991; Unwin and Quinn 1992; Pascual and Quinn 1994). In contrast, Hard and Heard (1999, as cited in Candy and Beacham 2000) studied stray rates among transplanted Alaskan hatchery populations of Chinook salmon and found that straying is highest for younger fish (jack males). They hypothesized that these fish may stray at higher rates in order to expand their population by straying into non-natal rivers and spawning with uncontested females. We also found that younger age SJR salmon strayed at higher rates than did older salmon though these differences in stray rates were not statistically significant. Candy and Beacham (2000) found no consistent trend of increased stray rate with age.

Coded Wire Tag Recovery Effort

Candy and Beacham (2000) reported that recovery effort influenced stray rates with the highest stray rates and number of fish recovered occurring in regions where the highest recovery effort occurred. Their finding was consistent with Pascual and others (1995) who found that the highest stray rates occurred in the lower Columbia River and attributed this finding to this area having the highest number of potential recovery sites. Development of the Central Valley fall-run Chinook salmon CWT database uncovered similar findings. Both number of fish tagged (CWT) and CWT recovery effort in the Central Valley has fluctuated widely over time. This variability in both tagging and recovery effort results in high levels of analytical uncertainty because, as described in the Methods Appendix, missing CWT data gaps need to be filled in. That said, both Central Valley CWT tagging and recovery effort have improved over time as resources to conduct monitoring (funding and staffing) have been made available. The constant fractional marking (CFM) program of hatchery produced Central Valley fall-run Chinook salmon initiated in 2007 (PSMFC 2008) will provide more reliable results as CFM continues (Newman and others 2004) and consistent recovery effort throughout the Central Valley occurs (Hicks 2003; Hankin and others 2005).

Policy and Management Implications

Although this statistical analysis shows that both south Delta exports and SJR flow affect SJR salmon stray rates, the relative role of flow and exports is uncertain, as is the period when flow management affects stray rates. Based on our statistical results alone, the SJR flow metric (either base or pulse) is more predictive metric than one that includes exports. However, since Delta exports can cause severe negative flows in the south Delta, and occurrence of negative flows are likely to negatively affect (disorient) escaping salmon populations that migrate through the Delta because of reduced chemical olfaction cue signals (Keefer and others 2006), further study is warranted to determine whether negative flows make it more difficult for returning SJR salmon to successfully locate and migrate into the SJR.

Since the Merced River (Mesick 2010), Tuolumne River (Mesick 2009), and Stanislaus River (Carl Mesick, USFWS, pers. comm., 2012) salmon populations have been identified as being at a high risk of extinction, we further suggest evaluating whether or not increasing fall south Delta inflows (pulse or base) from each of the tributaries in the SJR could reduce SJR salmon stray rates to a natural level (<5%). Each stream's fall flow contribution might also be managed to be proportional to its unimpaired watershed runoff size (i.e., ecological fair share contribution). This could ensure that each river provides equitable homing cues. Further research on such tributary effects is probably just as important as further monitoring of the effects of exports. Further research is also needed regarding the implementation of the SJR mainstem Friant Restoration Program (SJRRP 2011) and how these new fall flows influence SJR salmon straying.

The state and federal fish agencies should consider studies to determine how the following pairing of factors influences SJR salmon stray rates: (1) the relative roles of south Delta exports and SJR flow; (2) the timing of pulse flows and export reductions; and (3) the role of pulse flows versus base flows. Because of the large number of study factors involved, it may be necessary to test a different set of conditions each year until a statistically valid model can be developed (e.g., ~20 years). The test conditions should include the timing, duration, and magnitude of flow releases, including source of SJR tributary flow releases, and Delta exports. It would be important to hold these conditions constant through the migratory period each year to the extent possible. The homing success and movement timing of adult SJR salmon into and through the Delta and SJR tributaries should also be monitored. The analysis of salmon migration patterns and stray rates should include water quality indices such as water temperature and dissolved oxygen concentration as well as for flow and exports in the Delta. The role of tidal action influence upon stray rates should also be considered.

Lastly, we recommend developing a stray rate target that could consist of a single number, or range, that can be used to evaluate the effectiveness of management actions to achieve the biological management goal. An example goal could be to reduce SJR salmon stray rates to levels that are comparable with Sacramento River fall-run stray rates (i.e. <1% for river releases, see Figure 7). Equalizing salmon stray rates among the Sacramento and SJR basins would facilitate progress toward achieving SJR salmon restoration goals (i.e. reduce genetic homogenization, increase natural spawner abundance, and reduce migration barriers that impede upstream movement of spawners). The recommendation to do the aforementioned studies should not be used as a reason to defer taking action now to improve Delta flow conditions to reduce straying of SJR salmon, given that SJR flow, whether it be base or pulse, has been identified as a controlling factor. Furthering our understanding about how the above mentioned factors influence straying of SJR salmon should be built upon the premise of increasing SJR flow, base and/or pulse, into the south Delta during the fall time-period.

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REFERENCES

Anderson R. 2010. Annual report: Mokelumne River Hatchery, 2007–2008. Draft administrative report. Sacramento (CA): California Department of Fish and Game. 20 p.

Banks M, Rashbrook V, Calvetta M, Dean C, Hedgecock D. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Canadian Journal of Fisheries and Aquatic Science 57:915–927.

Barnett–Johnson R, Pearson T, Ramos F, Grimes C, McFarlane R. 2008. Tracking natal origins of salmon using isotopes, otoliths, and landscape geology. Limnology and Oceanography 53(4):1633–1642.

[California HSRG] California Hatchery Scientific Review Group. 2012. California hatchery review report. Prepared for the U.S. Fish and Wildlife Service and Pacific States Marine Fisheries Commission. 100 p.

Candy J, Beacham T. 2000. Patterns of homing and straying in Southern British Columbia coded-wire tagged Chinook salmon (*Oncorhynchus tshawytscha*) populations. Fisheries Research 47:41–46.

[CDFG] California Department of Fish and Game. 2010. Grandtab, Fisheries Branch Anadromous Resources Assessment–Chinook salmon. March 9, 2010. Available from: *http://www.calfish.org/portals/0/Programs/AdditionalPrograms/CDFGFisheriesBranch/tabid/104/Default.aspx*

[CDFG and NOAA Fisheries] California Department of Fish and Game, National Oceanic and Atmospheric Administration–Fisheries. 2001. Final report on anadromous salmonid fish hatcheries in California. Joint hatchery review. California Department of Fish and Game and National Marine Fisheries Service, Southwest Region (now National Oceanic and Atmospheric Administration–Fisheries). 35 p.

[CDWR] California Department of Water Resources. 2011a. South Delta Temporary Barriers program [website]. Available from: *http://baydeltaoffice.water.ca.gov/sdb/tbp/index_tbp.cfm.*

[CDWR] California Department of Water Resources. 2011b. DAYFLOW program documentation [website]. Available from: *http://www.water.ca.gov/dayflow/documentation/dayflowDoc.cfm#Introduction*.

Cleveland W. 1979. Robust locally weighted regression and smoothing scatterplots. Journal of the American Statistical Association. 74:829–836.

Ebel WJ. 1980. Transportation of chinook salmon, *Oncorhynchus tshawytscha*, and steelhead, *Salmo gairdneri*, smolts in the Columbia River and effects on adult returns. Fishery Bulletin 78:491–505.

Ebel W, Park D, Johnsen R. 1973. Effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fishery Bulletin 71:549–563.

Efron B, Tibshirani R. 1993. An introduction to the bootstrap. Boca Raton (FL): Chapman & Hall/CRC. 433 p.

Estey DF. 1988. Annual report: Mokelumne River Hatchery, 1987–88. Administrative Report No. 89-3. Sacramento (CA): California Department of Fish and Game. 11 p.

Garza J, Blankenship S, Lemaire C, Charrier G. 2008. Genetic population structure of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Comprehensive evaluation of population structure and diversity for Central Valley Chinook salmon. Final report for CALFED project. Santa Cruz (CA): Institute of Marine Sciences, University of California, Santa Cruz, California and NOAA Southwest Fisheries Science Center. 84 p.

Groves A, Collins G, Trefethen P. 1968. Roles of olfaction and vision in choice of spawning site by homing adult Chinook salmon. Journal of the Fisheries Research Board of Canada 25:867–76.

Hallock R, Elwell R, Fry D. 1970. Migrations of adult king salmon *Oncorhynchus tshawytscha* in the San Joaquin Delta; as demonstrated by the use of sonic tags. Fish Bulletin 151. Sacramento (CA): California Department of Fish and Game. 92 p.

Hankin D, Clark J, Deriso R, Garza J, Morishima G, Riddell B, Schwarz S. 2005. Expert panel on the future of the coded wire tag Program for Pacific Salmon. Pacific Salmon Commission Technical Report No. 18. Vancouver, BC: Pacific Salmon Commission. 230 p.

Hard J, Heard R. 1999. Analysis of straying variation in Alaskan hatchery Chinook salmon (*Onchorhynchus tshawytscha*) following transplantation. Canadian Journal of Fisheries Science 56:578–589.

Hicks A. 2003. A discussion and analysis of four constant fractional marking alternatives for California's Central Valley salmon hatcheries [master's thesis]. Available from: University of Idaho. 97 p.

[ICF] ICF International. 2010. Effects of the head of Old River barrier on flow and water quality in the San Joaquin River and Stockton Deep Water Ship Channel. ICF 01111.07. Prepared for the Department of Water Resources. 65 p.

Jassby AD. 2005. Phytoplankton regulation in a eutrophic tidal river (San Joaquin River, California). San Francisco Estuary and Watershed Science [Internet]. Available from: *http://escholarship.org/uc/item/9jb2t96d*.

Jonsson B, Jonsson N, Hansen L. 1991. Differences in life history and migratory behaviour between wild and hatchery-reared Atlantic salmon in nature. Aquaculture 98:69–71.

Keefer M, Caudill C, Peery C, Bjornn T. 2006. Route selection in a large river during the homing migration of Chinook salmon (*Oncorhyncus tshawytscha*). Canadian Journal of Fisheries and Aquatic Science 63:1752–1762.

Keefer M, Caudill C, Peery C, Lee S. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications 18:1888–1900.

Labelle M. 1992. Straying patterns of Coho salmon (*Onchorhynchus kisutch*) stocks from Southeast Vancouver Island, British Columbia. Canadian Journal of Fisheries and Aquatic Science 49:1843–1855.

McIsaac D. 1990. Factors affecting the abundance of 1977–1979 brood wild fall Chinook salmon (*Oncorhynchus tshawytscha*) in the Lewis River, Washington [dissertation]. Available from: University of Washington, Seattle. 174 p.

McIsaac D, Quinn T. 1988. Evidence for a hereditary component in homing behavior of Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 45:2201–2205.

Mesick C. 2001. The effects of San Joaquin River flows and Delta export rates during October on the number of adult San Joaquin Chinook salmon that stray. In: Brown RL, editor. Fish Bulletin 179: Contributions to the biology of Central Valley salmonids. Volume 2. Sacramento (CA): California Department of Fish and Game. p 139–161.

Mesick C. 2009. The high risk of extinction for the natural fall-run Chinook salmon population in the lower Tuolumne River due to insufficient instream flow releases. U.S. Fish and Wildlife Service Report submitted to the State Water Resources Control Board. Stockton (CA): U.S. Fish and Wildlife Service. 78 p.

Mesick C. 2010. The high risk of extinction for the natural fall-run Chinook salmon population in the lower Merced River due to insufficient instream flow releases. Report prepared for California Sportfishing Protection Alliance. El Dorado (CA): Carl Mesick Consultants. 111 p.

Miller J, Gray Q, Merz J. 2010. Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon (*Onchorhyncus tshawytscha*). Marine Ecology Progress Series 408:227–240.

Newman K. 2008. An evaluation of four Sacramento–San Joaquin River Delta juvenile salmon survival studies. Report produced for the CALFED Science Program, Project number SCI-06-G06-299. March 31, 2008. Stockton (CA): U.S. Fish and Wildlife Service, Stockton Fish and Wildlife Office 182 p.

Newman K, Hicks A, Hankin D. 2004. A marking, tagging, and recovery program for Central Valley hatchery Chinook salmon. Unpublished report to Central Valley Salmonid Project Work Team. July 7, 2004. 72 p.

Pascual M, Quinn T. 1994. Geographical patterns of straying of fall run Chinook salmon, *Oncorhynchus tshawytscha* (Walbaum), from Columbia River (USA) Hatcheries. Aquaculture and Fisheries Management 25(Supplement 2):17–30.

Pascual M, Quinn T, Fuss H. 1995. Factors affecting the homing of fall Chinook salmon from Columbia River Hatcheries. Transactions of the American Fisheries Society 124:308–320.

[PSMFC] Pacific States Marine Fisheries Commission. 2008. Constant fractional marking/tagging program for Central Valley fall-run Chinook salmon. Report produced for the CALFED Ecosystem Restoration Program, Sacramento, CA. Final project report P0685610 dated November 2008. Red Bluff (CA): Pacific States Marine Fisheries Commission. 54 p.
Quinn T. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18:29–44.

Quinn T. 1997. Homing, straying, and colonization. In: Grant, WS, editor. Genetic effects of straying of non-native fish hatchery fish into natural populations: proceedings of the workshop. U.S. Dep. Commerce, NOAA Tech Memo. NMFS-NWFSC-30. 130 p.

Quinn T, Fresh K. 1984. Homing and straying in Chinook salmon (*Onchorhynchus tshawytscha*) from Cowlitz River Hatchery, Washington. Canadian Journal of Fisheries and Aquatic Sciences 41:1078–1082.

Quinn T, Nemeth R, McIssac D. 1991. Homing and straying patterns of fall Chinook salmon in the Lower Columbia River. Transactions of the American Fisheries Society 120:150–156.

Rich A. 2007. Impacts of water temperature on fall-run Chinook salmon (*Oncorhyncus tshawytscha*) and steelhead (*O. mykiss*) in the San Joaquin River system. Publication prepared for the California Department of Fish and Game and submitted to the California Central Valley Water Resources Control Board. San Anselmo (CA): A.A. Rich and Associates. 46 p.

Rose E. 2000. The San Joaquin a river betrayed. Clovis (CA): Quill Driver Books/Word Dancer Press, Inc. 160 p.

Sholes W, Hallock R. 1979. An evaluation of rearing fall-run Chinook salmon (*Oncorhyncus tshawytscha*) to yearlings at Feather River Hatchery, with a comparison of returns from hatchery and downstream Releases. California Fish and Game 65:239–255.

[SJRGA] San Joaquin River Group Authority. 2009. San Joaquin River Agreement–Vernalis Adaptive Management Plan, Annual Technical Report 2008. Prepared for the California Water Resources Control Board in compliance with D-1641. Modesto (CA): San Joaquin River Group Authority. 132 p.

[SJRRP] San Joaquin River Restoration Program. 2011. Final Supplemental Environmental Assessment. Interim Flows Project–Water Year 2012. Sacramento (CA): U.S. Department of Interior, Bureau of Reclamation Mid-Pacific Regional Office. 94 p. Available from: *http://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=8385*.

Slatick E, Park D, Ebel W. 1975. Further studies regarding effects of transportation on survival and homing of Snake River chinook salmon and steelhead trout. Fishery Bulletin 73:925–931.

Snyder J. 1931. Salmon of the Klamath River. California Fish and Game Fish Bulletin 34:1–130.

Solazzi M, Nickelson T, Johnson S. 1991. Survival, contribution, and return of hatchery coho salmon (*Oncorhynchus kisutch*) released from freshwater, estuarine, and marine environments. Canadian Journal of Fisheries and Aquatic Sciences 48:248–253.

Unwin M, Quinn T. 1993. Homing and straying patterns of Chinook salmon (*Oncorhynchus tshawytscha*) from a New Zealand Hatchery: spatial distribution of strays and effects of release Date. Canadian Journal of Fisheries and Aquatic Sciences 50(6):1168–1175.

[USEPA] U.S. Environmental Protection Agency. 1986. Ambient water quality criteria for dissolved oxygen. EPA 440/5-86-003. Washington, D.C.: Office of Water Regulations and Standards Criteria and Standards Division, USEPA. 54 p. Available from: *http://www.epa.gov/cgi-bin/claritgw?op-Display&document=clserv:OAR:0579;&rank=4&template=epa>.*

[USEPA] U.S. Environmental Protection Agency. 2003. EPA region 10 guidance for Pacific northwest state and tribal temperature water quality standards. EPA 910-B-03-002. Washington, D.C.: Office of Water Regulations and Standards Criteria and Standards Division, USEPA. 49 p. Van Der Laan M, Polley E, Hubbard A. 2007. Super learner. Statistical Applications in Genetics and Molecular Biology 6(1):Article 25.

Vreeland R, Wahle R, Arp A. 1975. Homing behavior and contribution to Columbia River fisheries of marked coho salmon released at two locations. Fishery Bulletin 73:717–725.

Williams J. 2006. Central Valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science [Internet]. Available from: *http://escholarship.org/uc/item/21v9x1t7*.

Williamson K, May B. 2005. Homogenization of fall-run Chinook salmon gene pools in the Central Valley of California, USA. North American Journal of Fisheries Management 25:993–1009.

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RESEARCH ARTICLE

Reconstructing the Migratory Behavior and Long-Term Survivorship of Juvenile Chinook Salmon under Contrasting Hydrologic Regimes

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Abstract

The loss of genetic and life history diversity has been documented across many taxonomic groups, and is considered a leading cause of increased extinction risk. Juvenile salmon leave their natal rivers at different sizes, ages and times of the year, and it is thought that this life history variation contributes to their population sustainability, and is thus central to many recovery efforts. However, in order to preserve and restore diversity in life history traits, it is necessary to first understand how environmental factors affect their expression and success. We used otolith $^{87}Sr/^{86}Sr$ in adult Chinook salmon (*Oncorhynchus tshawytcha*) returning to the Stanislaus River in the California Central Valley (USA) to reconstruct the sizes at which they outmigrated as juveniles in a wetter (2000) and drier (2003) year. We compared rotary screw trap-derived estimates of outmigrant timing, abundance and size with those reconstructed in the adults from the same cohort. This allowed us to estimate the relative survival and contribution of migratory phenotypes (fry, parr, smolts) to the adult spawning population under different flow regimes. Juvenile abundance and outmigration behavior varied with hydroclimatic regime, while downstream survival appeared to be driven by size- and time-selective mortality. Although fry survival is generally assumed to be negligible in this system, >20% of the adult spawners from outmigration year 2000 had outmigrated as fry. In both years, all three phenotypes contributed to the spawning population, however their relative proportions differed, reflecting greater fry contributions in the wetter year (23% vs. 10%) and greater smolt contributions in the drier year (13% vs. 44%). These data demonstrate that the expression and success of migratory phenotypes vary with hydrologic regime, emphasizing the importance of maintaining diversity in a changing climate.

Introduction

Life history diversity is often cited as a crucial component of population resilience, based on theoretical and empirical evidence that asynchrony in local population dynamics reduces long-term variance and extinction risk at both regional and metapopulation scales [1]. Pacific salmon are recognized for their complex life histories, having evolved alongside the shifting topography of the Pacific Rim [2]. In the California Central Valley (CCV), four runs of imperilled Chinook salmon (*Oncorhynchus tshawytscha*) coexist, exhibiting asynchronous spatial and temporal distributions that allow them to exploit a range of ecological niches [3,4]. The maintenance of multiple and diverse salmon stocks that fluctuate independently of each other has been shown to convey a stabilizing 'portfolio effect' to the overall the stock-complex [5,6]. Such 'risk spreading' can also act at finer scales [7,8], such as within-population variation in the timing of juvenile emigration. Preserving and restoring life history diversity remains an integral goal of many salmonid conservation programs [9], yet baseline monitoring data with which to detect and respond to changes in trait expression are scarce and difficult to relate directly to population abundance.

The expression and success of certain traits can be largely driven by hydroclimatic conditions experienced during critical periods of development [10]. CCV Chinook salmon are at the southern margin of their species range, and are subjected to highly variable patterns in precipitation and ocean conditions [4,11]. It is also a highly modified system, with >70% of spawning habitat lost or degraded as a result of mining activities, dam construction, and water diversions [4,12]. The majority of salmon rivers in the CCV experience regulated flows according to 'water year type' (WYT). Optimization of reservoir releases presents considerable challenges, given often limited availability and multiple uses of the water resource, inability to predict annual precipitation, and uncertainty surrounding the direct and indirect effects of flow on salmon survival [13]. Such challenges are particularly critical for the more southerly San Joaquin basin, whose salmon populations fluctuate considerably with river flows experienced during juvenile rearing (Fig 1).

Juvenile Chinook salmon exhibit significant variation in the size, timing and age at which they outmigrate from their natal rivers [3,14]. Selection for one strategy over another may vary as a function of freshwater and/or marine conditions [10,15]. In the CCV, fall-run juveniles typically rear in freshwater for one to four months before smoltification prompts downstream migration toward the ocean [16]. In this system, contributions of the smaller fry and parr outmigrants to the adult population are often assumed to be negligible, as survival tends to correlate with body size [17,18] and there is little evidence for downstream rearing in the San Francisco estuary [19]. However, this has never been explicitly tested for smaller size classes. Indeed, salmon fry are frequently observed rearing in tidal marsh and estuarine habitats in other systems [3], and have been observed in non-natal habitats in the CCV, such as the mainstem Sacramento and San Joaquin Rivers, freshwater delta, and estuary [20]. Juvenile salmon that enter the ocean at a larger size and have faster freshwater growth have demonstrated a survival advantage when faced with poor ocean conditions [18]. Yet intermediate size classes can be better represented in the adult population [21,22], and size-selective mortality can be moderated by a variety of other processes [23]. In a regulated system such as the CCV, identifying the relationships between observable traits, hydroclimatic regime and survival would be invaluable for reducing uncertainty and predicting how populations may respond to climate change and management actions related to water operations.

Quantifying the relative contribution of fry, parr and smolt outmigrants to the adult population has, until now, been largely limited by the methodological challenges associated with reconstructing early life history movements of the adults. Mark-recapture studies using acoustic and coded wire tags (CWT) have provided empirical indices of juvenile survival through stretches of the Sacramento-San Joaquin River Delta (hereafter, "the Delta") [24,25], but are hindered by low rates of return and tend to utilize hatchery fish that may exhibit different rearing behavior and sea-readiness to their wild counterparts [26]. Furthermore, 'fry pulses' tend to be dominated by individuals <45mm FL, which are difficult to mark externally without causing damage or behavioral modifications. No study to date has tracked habitat use of individual salmon over an entire lifecycle to estimate the relative success of juvenile outmigration phenotypes under different flow conditions. Previous studies have tended to rely on correlations between environmental conditions (e.g. flow) experienced during outmigration and the abundance of returns (Fig 1) [27]. Recent advances in techniques using chemical markers recorded in biomineralised tissues provide rare opportunity to retrospectively "geolocate" individual fish in time and space [28]. Given their incremental growth and metabolically inert

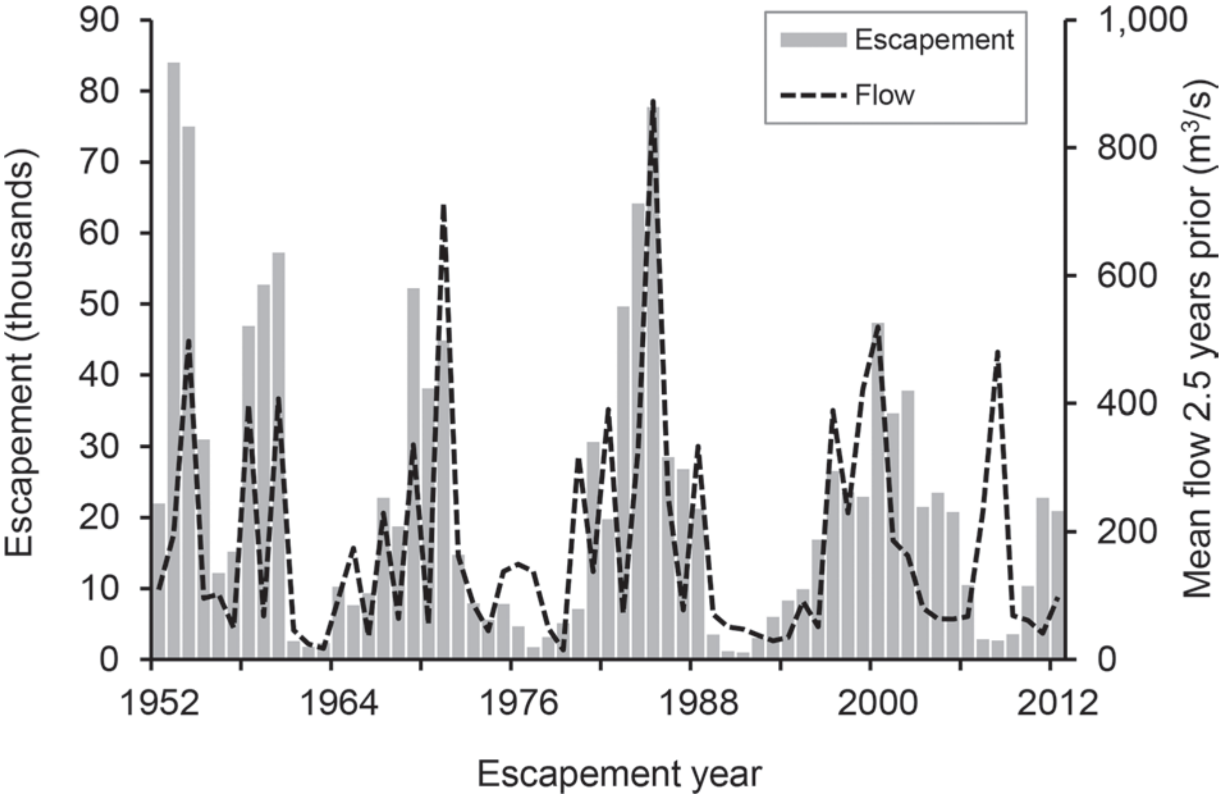

Fig 1. Relationship between adult salmon returns to the San Joaquin basin and the river flows experienced as juveniles. Fall-run Chinook salmon returns ('escapement') to the San Joaquin basin from 1952 to 2011 (CDFW GrandTab, www.CalFish.org) relative to mean flows at Vernalis (USGS gauge 11303500, http://waterdata.usgs.gov/nwis) for the January to June outmigration period they experienced 2.5 years previous. Note that adult abundance estimates have not been corrected for age distributions (we assumed that all adults returned at age 3), inter-annual variation in harvest rates or out-of-basin straying. The large deviation in 2007 reflected poor returns that were attributed to poor ocean conditions [96] and resulted in the closure of the fishery. Adapted from [97].

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nature, otoliths ('ear stones') represent a unique natural tag for reconstructing movement patterns of individual fish [29]. The technique relies on differences in the physicochemical environment producing distinct and reproducible "fingerprints" in the otolith. In the CCV, strontium isotopes ($^{87}Sr/^{86}Sr$) are ideal markers because the water composition varies among many of the rivers and is faithfully recorded in the otoliths of Chinook salmon [30–32]. Changes in otolith $^{87}Sr/^{86}Sr$ values can be used to reconstruct time- and age-resolved movements as salmon migrate through the freshwater and estuarine environments [33]. Furthermore, otolith size is significantly related to body size [34,35], allowing back-calculation of individual fork length (FL) at specific life history events [36].

Here, we document metrics of juvenile life history diversity (phenology, size, and abundance) of fall-run Chinook salmon as they outmigrated from the Stanislaus River during an 'above normal' (2000) and 'below normal' (2003) WYT. We used otolith $^{87}Sr/^{86}Sr$ and radius measurements to reconstruct the size at which returning (i.e. "successful") adults from the same cohort had outmigrated, then combined juvenile and adult datasets to estimate the relative contribution and survival of fry, parr and smolt outmigrants. Our main objectives were to determine (1) if a particular phenotype contributed disproportionately to the adult spawning population, (2) whether this could be attributed to selective mortality, and (3) if patterns in phenotype expression and success varied under contrasting flow regimes.

Study Area

The Stanislaus River (hereafter, "the Stanislaus") is the northernmost tributary of the San Joaquin River, draining 4,627 km^3 on the western slope of the Sierra Nevada (Fig 2) [37]. The basin has a Mediterranean climate and receives the majority of its annual rainfall between November and April. Contrasting with the Sacramento watershed in the north, the hydrology of the San Joaquin basin is primarily snowmelt driven [4]. There are over 40 dams in the Stanislaus, which collectively have a capacity of 240% of the average annual runoff [38]. Historically, the Stanislaus contained periodically-inundated floodplain habitat and supported spring- and fall-run Chinook salmon; however, spring-run salmon were extirpated by mining and dam construction, reducing habitat quality and preventing passage to higher elevation spawning grounds [4].

Materials and Methods

Ethics statement

This research was conducted in strict accordance with protocols evaluated and approved by the University of California, Santa Cruz Institutional Animal Care and Use Committee for this specific study (permit number BARNR1409). Otolith and scale samples were collected by California Department of Fish and Wildlife (CDFW) staff from adult salmon carcasses (i.e. already expired) as part of their annual carcass survey, permitted under the State legislative mandate to perform routine management actions. No tissue collections were taken from any state- or federally-listed endangered or protected species for this study.

Juvenile sampling and hydrologic regime

Typically, fall-run Chinook salmon return to the San Joaquin basin from September to early January, and their offspring outmigrate the following January to June [16,39]. Juveniles were sampled as they left the Stanislaus using rotary screw traps (RST) at Caswell Memorial State Park (Fig 2, N 37°42'7.533", W 121°10'44.882). Sampling was terminated when no juveniles had been captured for at least seven consecutive days in June or July [40]. Here, we focused on

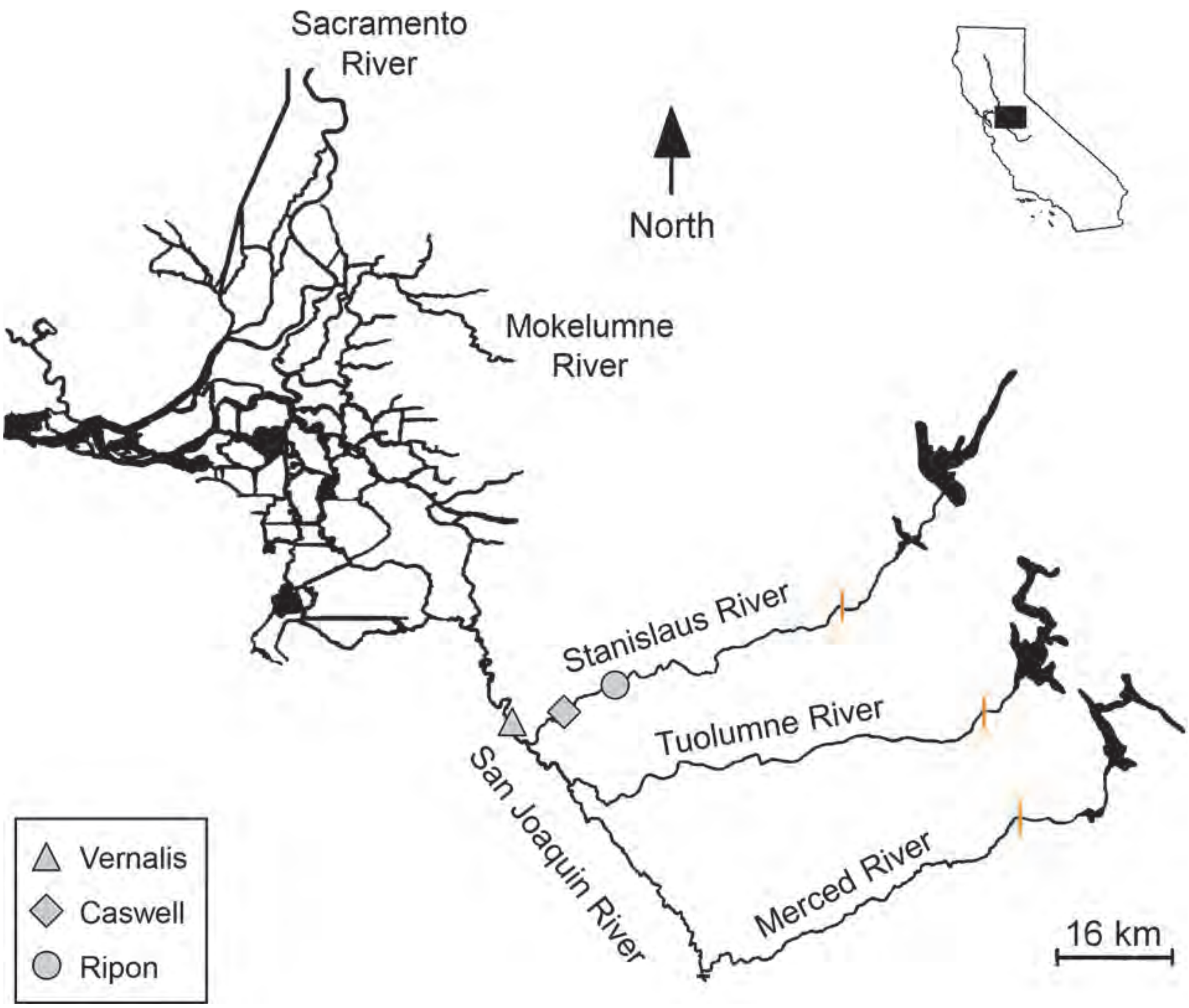

Fig 2. The San Joaquin basin of the Central Valley, California (inset). Map showing the major rivers in the San Joaquin basin, and the location of the rotary screw trap site at Caswell Memorial State Park and USGS gauges at Ripon and Vernalis. The upstream barriers to salmon migration in the three main tributaries are indicated by orange bars.

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an 'above normal' (2000) and 'below normal' (2003) WYT, and defined the outmigration period as January 1 to June 30, inclusive. When traps were checked, all fish were counted and up to 50 were randomly selected for fork length (FL) and weight measurements. Given potential subjectivity in visual staging criteria [41], we defined migratory phenotypes (fry, parr and smolt) by size: $\leq$55mm, $>$55 to $\leq$75mm, and $>$75mm FL, respectively (after [21]). Unmeasured fish were assigned to phenotype using the observed proportions in the measured fish for the same date. For each phenotype, we interpolated missing catch values with a triangular weighted mean [42].

Marked fish were periodically released to develop a statistical model of trap efficiency, which was used to expand counts of fry, parr and smolt-sized outmigrants. Trap efficiency was estimated using a GLM with a quasibinomial error distribution because of overdispersion in capture probabilities. We used the same efficiency model as [42], only using phenotype (fry, parr, smolt) to characterize fish size, rather than FL. We propagated uncertainty by deriving estimated expanded counts from repeated Monte Carlo draws (n = 2000) from the estimated sampling distribution of the estimated coefficients from the logistic efficiency model using R package mvtnorm [43]. Daily flow observations (USGS gauge no. 11303000 at Ripon, www.waterdata.usgs.gov/nwis) were used with the randomly-sampled model coefficients to simulate daily trap efficiency. Passage estimates were then simulated using daily catch and simulated trap efficiencies. We incorporated extra-binomial variation by generating simulated daily catch values from a beta-binomial distribution (based on the simulated efficiencies and passage estimates, as well as the dispersion estimated from the efficiency model). Finally, new daily passage estimates were calculated using simulated catch and trap efficiencies. Thus the final passage estimates incorporate both sampling error (catch) and estimation error (efficiency model). Annual passages estimates and confidence intervals (2.5% and 97.5% quantiles) were generated by summing daily passage estimates for the 6 month outmigration period (i.e. n = 2000 x 180 days).

Measured daily size-frequency distributions were applied directly to the expanded abundance estimates, then grouped into 2mm FL bins. We attempted to produce passage estimates by FL, but the distribution used in the uncertainty propagation procedure (see above) is asymmetric at low catches, resulting in zero-inflation and the median of the resampled distribution often being lower than the observed raw catch.

Turbidity was measured at Caswell using a LaMott turbidity meter [40]; mean daily flow and maximum daily temperature were measured at Ripon (gauge details above). Daily passage estimates, turbidity, flow and temperature were $\log_{10}$ transformed, then averaged for the 6-month outmigration period and compared among years by ANOVA, adjusting for temporal autocorrelation using the Durbin-Watson (DW) test [44]. Pearson's chi-squared test was used to identify differences in the proportion of phenotypes among years. Fry, parr and smolt phenology was summarized using three metrics associated with their date of passage past the trap: the range, interquartile range (IQR), and median (or "peak") outmigration date. Phenotype "migratory periods" were defined as the maximum IQR for both years combined.

Adult sampling and cohort reconstruction

To track outmigration cohorts 2000 and 2003 into the adult escapement, sagittal otoliths were extracted from Chinook salmon carcasses (aged 2–4 years, 45–112 cm FL) collected in the 2001–2006 CDFW Carcass Surveys (Table 1). Unmarked fish were sampled randomly, but in earlier years, known-hatchery fish with CWTs and clipped adipose fins ("adclipped") were preferentially sampled to assess the accuracy of age estimations. We utilized all otoliths collected from all unmarked fish, but included a subset of CWT fish from outmigration year 2000 (n = 27), which we analyzed blind to assess the accuracy of our natal assignments. Ages were estimated by counting scale annuli [45,46]. Each scale was aged by at least two independent readers and discrepancies resolved by additional reading(s).

Table 1. Adult sample sizes, age structure and collection periods.

	Outmigration cohort 2000 (wetter)			Outmigration cohort 2003 (drier)		
Age	N	%	Collection period	N	%	Collection period
2	6	7%	11/20/01–12/06/01	2	2%	11/08/04–11/12/04
3	80	87%	10/07/02–12/12/02	56	67%	11/02/05–12/15/05
4	6	7%	11/12/03–12/04/03	25	30%	11/15/06–12/06/06

Otoliths were analyzed from salmon carcasses belonging to adults that had outmigrated in 2000 and 2003, including 27 known-origin fish included as a blind test of our natal assignments.

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Otolith $^{87}Sr/^{86}Sr$ analyses

Otolith strontium isotope ratios ($^{87}Sr/^{86}Sr$) were measured along a standardized 90° transect [47] by multiple collection laser ablation inductively coupled plasma mass spectrometry (MC-LA-ICPMS; Nu plasma HR interfaced with a New Wave Research Nd:YAG 213 nm laser). Spot analyses were used to allow coupling of chemical data with discrete microstructural features, but otherwise preparation and analysis methods followed those of Barnett-Johnson et al. [32,48]. In brief, otoliths were rinsed 2–3 times with deionized water and cleaned of adhering tissue. Once dry, otoliths were mounted in Crystalbond resin and polished (600 grit, 1500 grit then 3 μm lapping film) until the primordia were exposed. Depending on sample thickness and instrument sensitivity, a 40–55μm laser beam diameter was used with a pulse rate of 10-20Hz, 3–7 J/cm^2 fluence, and a dwell time of 25–35 seconds, resulting in individual ablations roughly equivalent to 10–14 days of growth. Where individual ablations exhibited isotopic changes with depth (e.g. at habitat transition zones), only the start of the ablation was used (e.g. S1 Fig). Helium was used as the laser cell carrier gas (0.7–1.0 L/min) to improve sample transmission and was mixed with argon before reaching the plasma source. Krypton interference (^{86}Kr) was blank-subtracted by measuring background voltages for 30 s prior to each batch of analyses, and ^{87}Rb interferences were removed by monitoring ^{85}Rb. Isotope voltages were integrated over 0.2 s intervals then aggregated into 1 s blocks. Outliers (>2SD) were rejected. Marine carbonate standards ('UCD Vermeij Mollusk' and *O. tshawytscha* otoliths) were analyzed periodically to monitor instrument bias and drift, producing a mean mass-bias corrected $^{87}Sr/^{86}Sr$ ratio (normalized to $^{86}Sr/^{88}Sr = 0.1194$) within 1SD of the global marine value of 0.70918 (0.70922 ± 0.00008 2SD).

Strontium isotopes to reconstruct natal origin and size at outmigration

The baseline of natal $^{87}Sr/^{86}Sr$ signatures described in [32] was updated and expanded upon to increase sample sizes and among-year representation, resulting in an 'isoscape' that encompassed all major CCV sources, with many sampled across multiple years and hydrologic regimes. Linear discriminant function analysis (LDFA) was used to predict the natal origin of the sampled adult spawners, assuming equal prior probabilities for all sites (S1 Text). Differences in natal $^{87}Sr/^{86}Sr$ values were tested between years and sites (S1 Text, S1 Table and S2 Fig), and the performance of the LDFA was assessed using known-origin reference samples (S2 Table). Adults in this study were considered strays (not produced in the Stanislaus) when their natal $^{87}Sr/^{86}Sr$ were closer to other sources in the isoscape, and were excluded from further analysis.

For adults that had successfully returned to the Stanislaus, we monitored the change in $^{87}Sr/^{86}Sr$ across the otolith to identify the point at which they had outmigrated as juveniles. The Stanislaus has a significantly lower isotopic value (0.70660 ± 0.00008 SD) than the mainstem San Joaquin River immediately downstream from it (0.70716 ± 0.00013 SD), resulting in a clear increase and inflection point in otolith $^{87}Sr/^{86}Sr$ at natal exit (e.g. Fig 3B). If the inflection point was unclear, sequential spot analyses were analyzed by LDFA, and exit was defined as a >0.3 decrease in posterior probability of Stanislaus-assignment to a probability <0.5. Deviation from the mean $^{87}Sr/^{86}Sr$ Stanislaus value was assumed to reflect considerable time spent in non-natal water, as (1) the Stanislaus $^{87}Sr/^{86}Sr$ signature shows minor variation in otoliths (S1 Table) and water samples collected immediately upstream of the confluence, (2) the RST location is 13.8rkm upstream of the confluence (Fig 2) and (3) the length of time integrated by each laser spot is ~12 days. Therefore, the distance used to back-calculate exit size was from the otolith core to the last natal spot. To improve resolution and accuracy, additional ablations were performed around the transition zone, typically resulting in sub-weekly resolution.

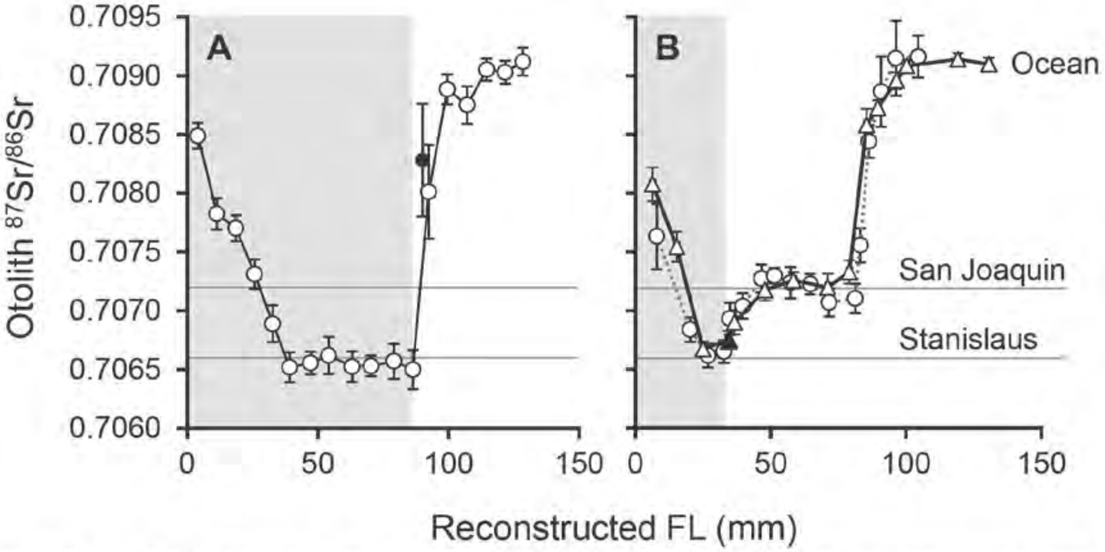

Fig 3. Otolith $^{87}Sr/^{86}Sr$ reconstructions of a smolt and fry outmigrant. Otolith $^{87}Sr/^{86}Sr$ profiles against back-calculated FL for two adult Chinook salmon that returned to the Stanislaus River having outmigrated as (A) a smolt and (B) a fry. The shaded box indicates the time spent rearing in the natal river. The fry outmigrant reared for several weeks downstream in the San Joaquin River before migrating out to the ocean, as indicated by both the left (triangles, solid line) and right (circles, dashed line) otolith (back-calculated FL = 33.3mm *vs.* 34.9mm). Mean $^{87}Sr/^{86}Sr$ signatures for the Stanislaus and San Joaquin Rivers, and modern-day ocean are displayed. Black filled symbols indicate 're-spots' carried out to improve sampling resolution. Error bars = 2SE.

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Reconstructed size at outmigration in the returning adults

The relationship between otolith radius (OR) and FL was first calibrated using juveniles collected from multiple sites in the CCV (S3 Table). All individuals belonged to the same Evolutionarily Significant Unit, which is critical for producing unbiased back-calculation models [49]. As there was no difference in the OR of paired otoliths from single individuals ($n = 30$, $\bar{x}\triangle =$ 2.5μm, 95% CI = -5.6–10.6μm), left and right otoliths were used interchangeably. OR was measured along the same 90° transect used for isotope analyses, using a Leica DM1000 microscope and Image Pro Plus (7.0.1).

Reconstructed sizes were grouped into 2mm FL bins and categorized as fry, parr or smolt outmigrants based on the criteria of [21]. Size-frequency distributions were compared between the juvenile and adult samples to identify trends indicative of size-selective mortality. The error around the OR-FL calibration line was used to estimate 95% CI around the proportions of fry, parr and smolt outmigrants using random resampling ($n = 5000$) of the residuals. This allowed us to derive the relative contribution of each phenotype to the adult spawning population.

Survival of juvenile migratory phenotypes

To generate survival indices, we normalized the contribution of each phenotype to the adult population by their abundance within each outmigration cohort based on RST sampling. To estimate spawner abundance ("natural escapement"), we removed adclipped strays from total escapement estimates (GrandTab, available at www.calfish.org) using river- and year-specific tag recovery rates (S4 Table), then separated cohorts using annual age distributions [50] and removed unmarked strays using our otolith natal assignments (see results and S4 Table). We evaluated the use of spawner abundance *vs.* "adult production" (after [51]). While production accounts for different harvest rates among years [52], the two metrics produced similar trends in survival ($r^2 = 0.98$), and we found that escapement, which includes harvest, bycatch and natural mortality between outmigration and spawning, to be more intuitive to interpret.

The otolith-derived proportions (±95% CI) of phenotype i in the escapement (β_i) were applied to our natural escapement estimates (E_n) to estimate the number of fry, parr and smolt spawners (E_i), then E_i was compared with the number of outmigrants of phenotype i (J_i) to estimate their relative survival (S_i):

$$E_i = E_n\beta_i \qquad S_i = E_i/J_i$$

To estimate 95% CI for S_i we combined error in β_i and J_i using the delta method. The 95% CI for S_i depends on the estimate and its standard error (SE): $\hat{S}_i,\ SE(\hat{S}_i)$. Assuming independence of β_i and J_i, we estimated variance as $SE(\log(\hat{S}_i)) \cong \sqrt{\left(\frac{1}{J_i}\right)^2 SE^2(\hat{J}_i) + \left(\frac{1}{\beta_i}\right)^2 SE^2(\hat{\beta}_i)}$. From this, we derived 95% CI for S_i as $\left(e^{\log(\hat{S}_i)-1.96\times SE(\log(\hat{S}_i))}, e^{\log(\hat{S}_i)+1.96\times SE(\log(\hat{S}_i))}\right)$. Note that uncertainties in adult escapement were not incorporated into these confidence intervals; however, the RST-expansions used to estimate J_i were deemed likely to introduce the largest amount of error.

Results

Juvenile outmigration relative to hydrologic regime

Mean flow and turbidity for the 6 month outmigration period were higher in 2000 than 2003 (DW-adjusted $F_{1,\ 361} = 7.52$, $p = 0.006$ and $F_{1,\ 257} = 14.53$, $p = 0.0002$, respectively) (Fig 4). In the drier year (2003) the river was warmer during the smolt migratory period (Apr 15-May 18: DW-adjusted $F_{1,\ 60} = 4.54$, $p = 0.037$) and peak daily temperatures first exceeded 15°C three weeks earlier (Fig 4).

Peak flows were about five times higher in 2000 than 2003, and accompanied by spikes in turbidity and juvenile migration (Fig 4). The number of outmigrants was an order of magnitude higher in 2000 (Table 2), reflecting significantly higher daily abundances of fry, parr and smolt outmigrants (DW adjusted $F_{1,\ 161} = 11.23$, $p < 0.001$; $F_{1,\ 196} = 47.99$, $p < 0.001$; $F_{1,\ 199} = 6.45$, $p = 0.0118$, respectively). While fry dominated in both years, phenotype contributions differed significantly between years ($X^2 = 223{,}683$, $p < 0.001$), with parr approximately twice as abundant as smolts in 2000, but vice versa in 2003 (Table 2). One yearling (FL = 140mm) was

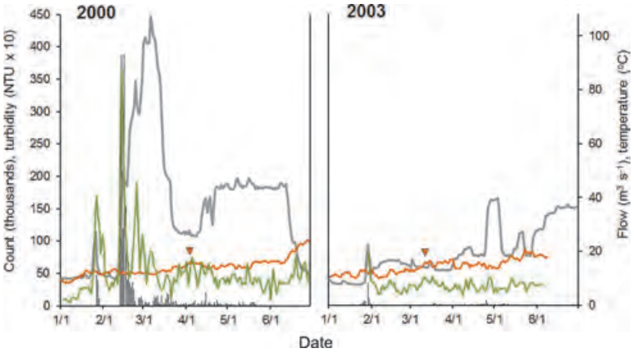

Fig 4. Daily abundance of juvenile salmon outmigrating in 2000 and 2003 relative to ambient environmental conditions. Juvenile salmon were sampled by rotary screw traps at Caswell as they outmigrated from the Stanislaus, and raw counts were expanded into daily abundance estimates (vertical bars) based on trap efficiency models. River flow (grey line) and maximum daily temperature (orange line) were measured at Ripon (data available at http://cdec.water.ca.gov/). Turbidity (green line) was measured at Caswell [40]. The first instance of temperatures reaching 15°C is indicated by an arrow on each plot.

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Table 2. Abundance and migration timing of juvenile migratory phenotypes.

Outmigration cohort	Migratory phenotype	N (95% CI)	Proportion of the sample	Duration of migratory period (range)	Duration of "peak" migratory period (interquartile range)	Peak migration date (median)
2000 (wetter)	Fry	1,837,656 (1,337,351–2,495,523)	0.85	115 d (Jan 2-Apr 25)	4 d (Feb 14-Feb 17)	Feb 16
	Parr	212,042 (141,238–310,174)	0.10	116 d (Feb 4-May 29)	29 d (Mar 18-Apr 15)	Apr 1
	Smolt	101,467 (70,181–145,793)	0.05	110 d (Mar 8-Jun 25)	34 d (Apr 15-May 18)	May 9
	TOTAL	2,151,165 (1,577,638–2,911,393)				
2003 (drier)	Fry	79,862 (59,795–103,916)	0.50	80 d (Jan 23-Apr 12)	4 d (Jan 27-Jan 30)	Jan 29
	Parr	25,729 (17,889–36,282)	0.16	118 d (Feb 5-June 2)	27 d (Mar 18-Apr 13)	Mar 21
	Smolt	55,465 (38,415–76,289)	0.34	107 (Feb 24-Jun 10)	21 d (Apr 18-May 8)	Apr 25
	TOTAL	161,056 (119,868–209,151)				

The abundance and proportions of fry, parr and smolt outmigrants sampled by rotary screw traps, and the timing of their outmigration from the Stanislaus River in 2000 and 2003.

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captured in the RST in 2000, but none in 2003, otherwise the size range of outmigrants was similar between years (25-115mm in 2000 *vs*. 27-115mm in 2003).

Phenology varied between phenotypes and years (Table 2 and Fig 5). In general, migratory windows were shorter and earlier in the drier year, with smolt outmigration ceasing 15 days earlier in 2003 than in 2000. The peak migratory periods were similar across years for fry and parr, the former exhibiting a compressed interquartile range (4 d) that was tightly correlated with the start of winter flow pulses (Fig 5).

Natal origin of unmarked adults

The unmarked adults from outmigration cohorts 2000 and 2003 comprised 18% and 51% hatchery strays, respectively, primarily from the Mokelumne, Merced, and Feather River

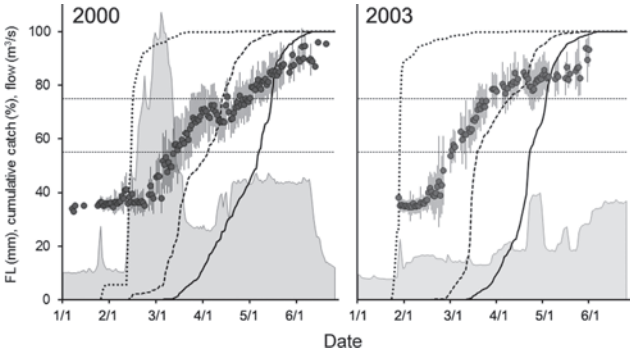

Fig 5. Size and phenology of juveniles outmigrants relative to river flow in 2000 and 2003. Mean (±SD) daily fork length (FL) of juvenile outmigrants, and cumulative percentage of fry (short dashed line), parr (long dashed line) and smolt (solid line) outmigrants relative to flow (filled area). Reference lines indicate the size categories used to define the migratory phenotypes: fry (≤55mm), parr (55-75mm) and smolts (>75mm).

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Table 3. Natal assignments of unmarked adults based on otolith $^{87}Sr/^{86}Sr$.

Natal source	Outmigration cohort 2000 (%)	Outmigration cohort 2003 (%)
Stanislaus River	82	49
Mokelumne River Hatchery	11	39
Merced River Hatchery	2	1
Feather River Hatchery	5	7
Nimbus Hatchery	2	2
Thermalito Rearing Annex [a]		1

Natal assignments of unmarked adults fish captured in the Stanislaus River between 2001 and 2006 that outmigrated in 2000 and 2003.

[a] Part of the Feather River Hatchery

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Hatcheries (Table 3). These individuals were removed from subsequent analyses, ensuring that size back-calculations were calculated only for Stanislaus-origin fish that had experienced the same outmigration conditions as the RST-sampled juveniles.

Back-calculation of size at outmigration

A strong, positive relationship was observed between OR and FL ($r^2 = 0.92$, n = 224, $p < 0.001$; FL = 0.171 (±0.003 SE) x OR—12.76 (±1.54 SE)), remaining linear across the full range of FLs reconstructed in the current study. This relationship was used to reconstruct FLs for individual $^{87}Sr/^{86}Sr$ profiles (e.g. Fig 3). The back-calculated size at which returning adults had outmigrated from the Stanislaus ranged from 31.3mm to 86.6mm in 2000, and 46.0mm to 90.5mm in 2003 (Fig 6). No yearlings were detected in the adult returns in either year.

To explore reproducibility of the method, paired left and right otoliths were analyzed from a subset of adults (n = 3 fry and n = 1 smolt outmigrant). All fish were assigned to the same migratory phenotype using either otolith, and the mean difference between back-calculated FLs was 2.3mm (e.g. Fig 3B).

Contribution and survival of juvenile migratory phenotypes

The relative abundance of the migratory phenotypes in the escapement differed significantly to the outmigrating juvenile population in both 2000 ($X^2 = 20{,}931$, $p<0.0001$) and 2003 ($X^2 = 1{,}381$, $p<0.0001$). The phenotype composition of the adult population also differed significantly between years ($X^2 = 749$, $p<0.0001$), reflecting higher fry contributions in the wetter year (23% in 2000 *vs.*10% in 2003) and higher smolt contributions in the drier year (44% in 2003 *vs.* 13% in 2000). Despite representing only 10–16% of the outmigrating juveniles (Table 2), parr were the most commonly observed phenotype in the surviving adult populations (46–64%, Table 4), although parr and smolt contributions to the escapement were near-identical in 2003 (46% vs. 44%, respectively). Conversely, fry outmigrants represented 10–23% of the adult escapement, despite representing 50–85% of the juvenile sample (Tables 2 & 4). The lowest survival was observed in individuals <45mm, particularly in 2003, when the smallest outmigrant in the adult sample had left the river at 46mm FL, while the smallest individual captured in the RST was 27mm FL (Fig 6). Conversely, in 2000, 11% of the adults had left at FLs ≤46mm (the smallest at 31.3mm), compared with 80% of the original juvenile population (the smallest at 25mm; Fig 6).

In both years, fry survival downstream of the Stanislaus (S_{fry}) was significantly lower than parr or smolt survival ($p<0.05$). S_{parr} was approximately double S_{smolt} in both years, but the confidence intervals were overlapping (Table 4). Generally, outmigrant survival downstream of

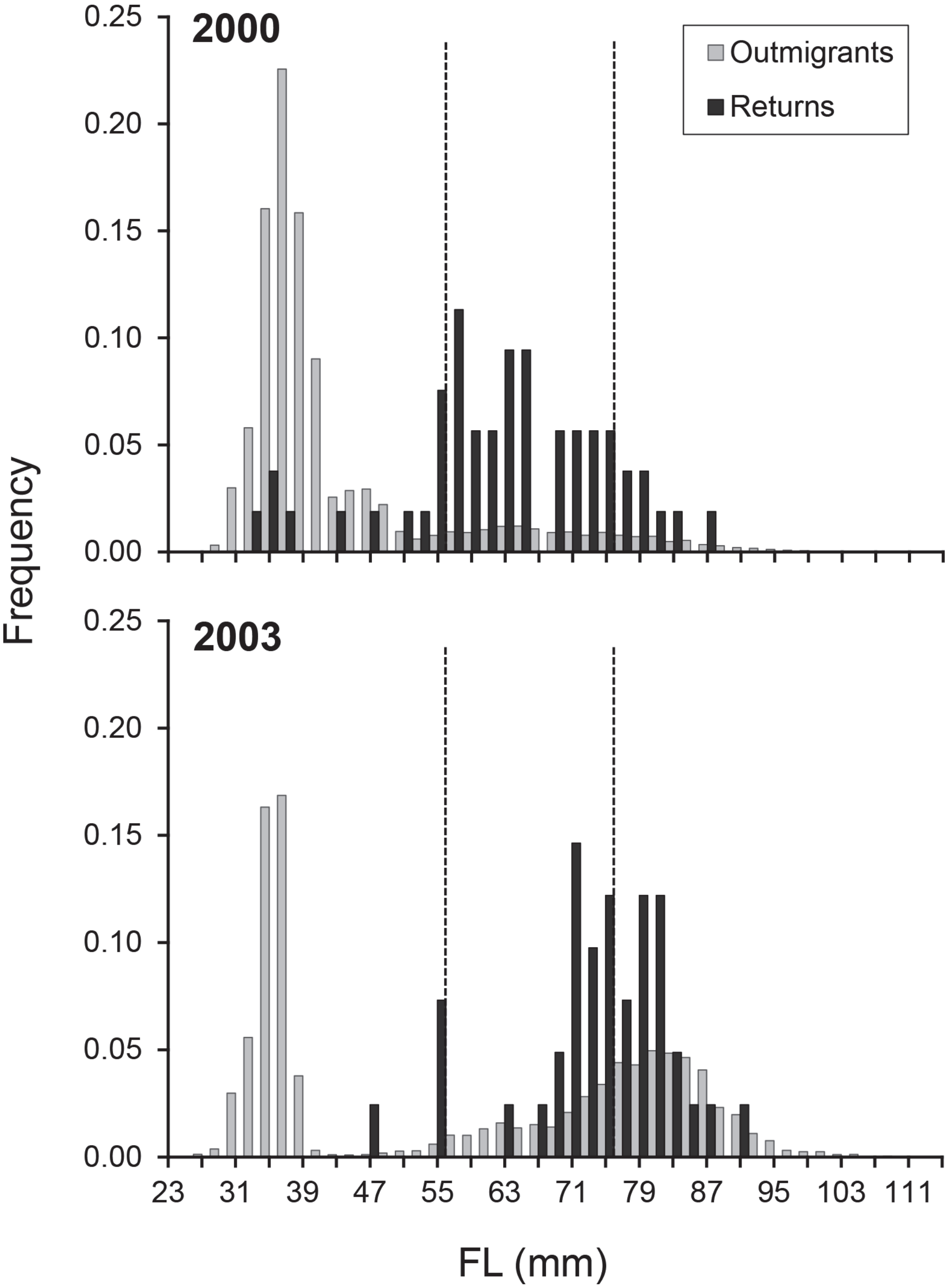

Fig 6. Size-at-outmigration of the juveniles and surviving adults that left freshwater in 2000 and 2003. Size-frequency distributions showing the fork length (FL) at which juveniles outmigrated from the Stanislaus River in 2000 and 2003 (grey bars) and the reconstructed size-at-outmigration of the returning (i.e. "successful") adults from the same cohort (black bars). FLs given in 2mm bins (where the x-axis represents ≤ that value, e.g. "55" = FL 53.01–55.0mm). Size classes used to categorize fry, parr and smolt outmigrants are indicated by dashed lines.

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the Stanislaus was slightly higher in the drier year (2003) than the wetter year (2000), but significant differences were not detected (Table 4).

Table 4. Contribution and survival of fry, parr and smolt outmigrants to the adult escapement.

Outmigration cohort	Phenotype	Contribution to the adult escapement (%) [a]	No. spawners produced [a]	Survival (%) [b]
2000 (wetter)	Fry	23 (19–36)	1,334 (1112–2113)	0.07 (0.04–0.12)
	Parr	64 (43–66)	3,781 (2557–3892)	1.78 (1.15–2.76)
	Smolt	13 (9.4–25)	778 (556–1446)	0.77 (0.39–1.52)
2003 (drier)	Fry	10 (2.4–12)	148 (37–186)	0.19 (0.1–0.33)
	Parr	46 (34–61)	705 (520–928)	2.74 (1.73–4.34)
	Smolt	44 (34–59)	668 (520–891)	1.2 (0.78–1.87)

[a] 95% CI in parentheses, derived from error around the FL back-calculation model.

[b] 95% CI in parentheses, derived from error around the FL back-calculation and RST efficiency models

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Discussion

In this study we document the expression of juvenile salmon migratory phenotypes under two contrasting flow regimes and provide new insights into their contribution to the adult spawning population and ultimate survival. We observed variable expression and survivorship of fry, parr and smolt life histories within and between years, yet all three phenotypes consistently contributed to the adult spawning population. This result challenges the common perception in the CCV, that smolt outmigrants are the dominant phenotype driving adult population abundance. Our key findings in the context of the salmon life cycle in order to link the datasets, methods, and processes examined in the study (Fig 7). Overall, the wetter year (2000) was characterized by higher numbers of juvenile outmigrants and adult returns, despite fewer adult spawners contributing to the cohort the previous fall. Using the number of parental spawners as a coarse proxy for juvenile production, these trends suggest higher in-river mortality in the drier year (2003). Given similar downstream (outmigration-to-return) survival rates, these data suggest that for the two focus years of the study, cohort strength was primarily determined within the natal river, prior to juvenile outmigration.

Juvenile outmigration behavior and phenotype expression

Juvenile outmigration timing in salmonids is inextricably linked to large-scale patterns in hydroclimatic regime and local-scale patterns in the magnitude, variation, and timing of flows [14,42]. In the Stanislaus, increases in flow were accompanied by pulses of outmigrants in both years, though greatly amplified during the turbid storm events of 2000. Correlations between fry migration, flow, and turbidity are commonly reported in the literature [14,53,54], and are suggested to have evolved as a result of reduced predation from visual piscivores [14,27,55,56]. The peak in migration in late January 2003 contained 85% of the year's total fry outmigrants and coincided with a managed water release that resulted in mean river flows of 28.4 $m^3 s^{-1}$ [57]. This pulse flow appeared to stimulate fry migration, but comprised relatively clear water (~8 NTU) and contained outmigrants almost entirely <40mm FL (Fig 5). In both years, the larger parr- and smolt-sized fish also appeared to respond to instream flows, exhibiting smaller migration pulses from March through May, coincident with both natural and managed flows (Fig 4) [58,59].

The date and periods of peak migration were generally earlier and shorter in 2003, particularly for smolts. While warmer conditions can result in faster growth rates [60], smoltification in juvenile Chinook salmon is significantly impaired at temperatures above 15°C [61] and this critical temperature was reached at Ripon three weeks earlier in 2003, prior to the onset of peak parr migration. As the reduction in juvenile abundance in 2003 occurred in spite of greater

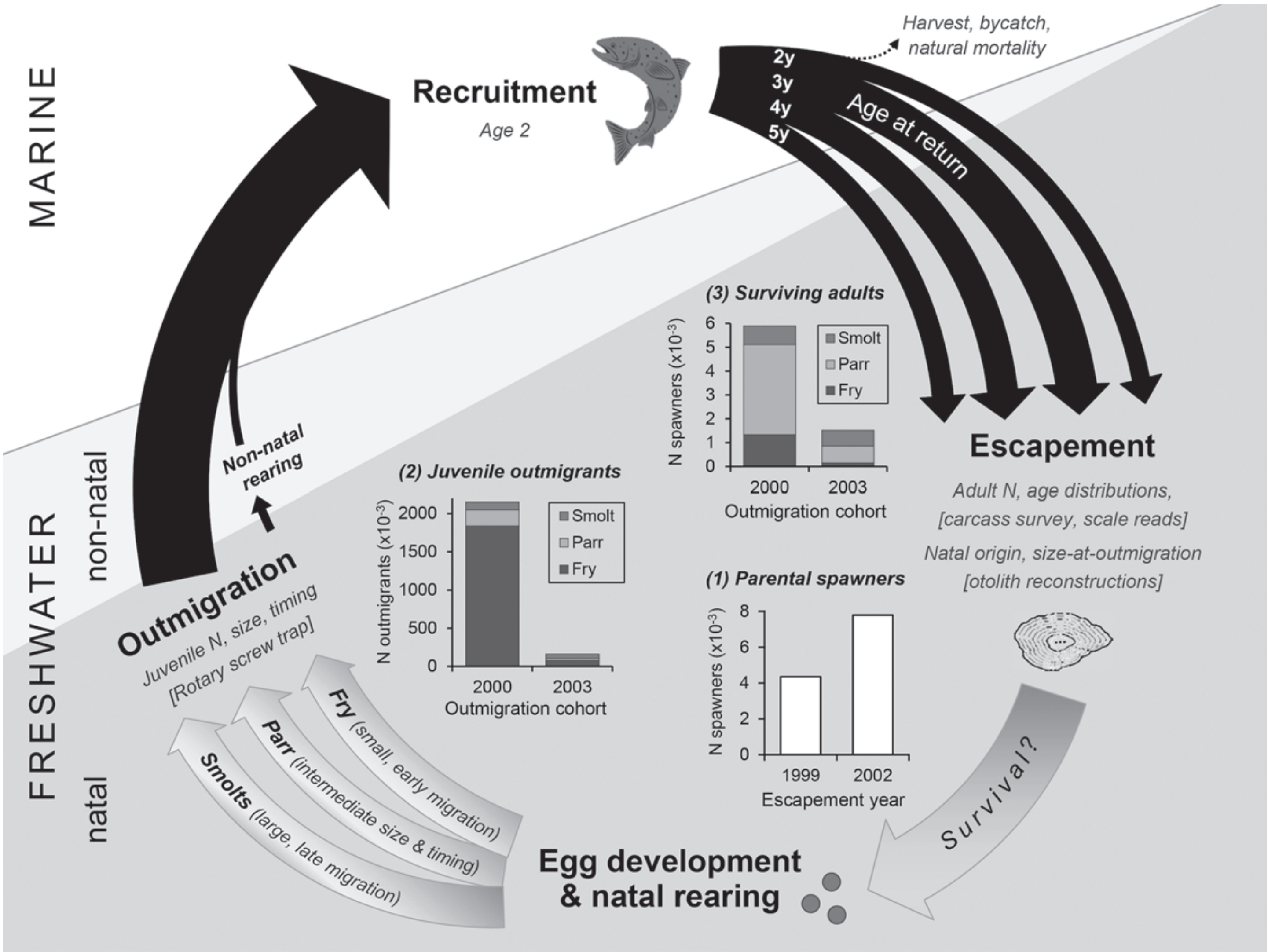

Fig 7. Schematic to conceptualize the data sources, methods and results presented in this study. This figure outlines the life cycle of fall-run Chinook salmon in the California Central Valley. Inset plot (1) demonstrates the abundance of parental spawners in the 1999 and 2002 escapement that contributed to the two focus years. Inset plots (2) and (3) illustrate the abundance and proportions of migratory phenotypes (fry, parr and smolts) observed in the juvenile sample (based on RST sampling) and in the adult escapement (based on otolith reconstructions), respectively. Arrow widths (not to scale) illustrate the typical proportions of 2, 3, 4 and 5 year olds observed in the adult escapement; note that age 5 fish tend to comprise <1% of the returns [50].

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numbers of parental spawners (Fig 7), we hypothesize that the truncation of migratory periods was driven by in-river mortality rather than altered migration timing or faster transitions between size classes. Juveniles tend to encounter less floodplain habitat, and increased predation rates and physiological stress in warmer, drier years [62], which likely resulted in a lower carrying capacity in the natal tributary [63] and increased density dependent mortality [64,65].

Survival of migratory phenotypes

Although lower flows and warmer temperatures in the Stanislaus may have contributed to the lower outmigrant production observed in 2003, our results suggest that after exiting the natal river, there was no significant difference in juvenile survival. Survival rates were, if anything, marginally higher in 2003, contradicting many tagging studies which find reduced salmon survival through the freshwater delta during low flow conditions [24,66–68]. This discrepancy is likely due to differences in the sampling design and the time period represented by the different indices. Tagging studies generally release larger hatchery fish in similar sized batches during the later months of the outmigration season, when warmer conditions likely increase their vulnerability to predation [62]. Conversely, our survival estimates were based on variable numbers of fish over a larger size spectrum and broader migratory window, incorporating mortality events in all habitats downstream of the natal river, including the mainstem river, delta, estuary and ocean. However, we assume that differences in our survival indices would be driven by selective mortality events occurring during outmigration and early ocean residence. In support of this, there was no relationship between back-calculated size at outmigration and return FL ($r^2 < 0.01$, $p > 0.05$), implying that size-selective mortality did not vary by phenotype in the adult fish. However, marine distributions of adult salmon can be non-random [69], and if driven by timing at ocean entry, the migratory phenotypes could have been subjected to different ocean processes and mortality rates even as adults.

Parr and smolt outmigrants. Life history theory predicts selection to favor different phenotypes under different hydrologic regimes, maintaining behavioral and phenotypic diversity [70]. Yet in the current study, parr consistently exhibited the greatest contribution to the adult population and the highest survival rates. Greater representation of intermediary-sized juveniles has also been observed in some years in the ocean fisheries of Chinook [21] and Atlantic salmon [22], contradicting the expected directionality of size-selective mortality. Generally, larger or faster-growing individuals within a population are thought to have a selective advantage as a result of greater feeding opportunities, lower vulnerability to predation and greater tolerance of environmental perturbations [71]. However, the strength of size-selection in juvenile CCV Chinook salmon can vary as a function of ocean productivity [18], highlighting the importance of maintaining life history diversity in outmigration strategies. Without large-scale field experiments, it is not possible to definitively ascertain why smolts were not the most successful phenotype, however the San Joaquin basin is at the southernmost reaches of the species distribution [3] and its salmon populations are exposed to high temperatures, poor water quality, and significant water diversions [72,73]. This frequently results in river conditions that could impair growth and smoltification, and increased vulnerability to predation and disease [62], particularly at the end of the season when smolt-sized fish are most prevalent. Thus, the survival advantage of parr is likely attributable to both size and migration timing, analogous to the marine-orientated "critical size and period hypothesis" proposed by Beamish and Mahnken [74]. Furthermore, current flow practices in the San Joaquin basin include managed releases in April and May, intended to improve the survival of smolts [75]. These managed flows typically occur after most parr have left their natal tributaries, potentially selecting for this phenotype by providing downstream benefits as they migrate through (or rear in) the San Joaquin River and freshwater Delta.

Fry outmigrants. Little is known about the factors driving fry behavior or survival, yet the numbers that outmigrated during the wetter year (2000) were orders of magnitude higher, when they also contributed more than double the number of adult survivors (23% in 2000 *vs.* 10% in 2003). While fry consistently exhibited lower survival rates than their conspecifics (Table 4), reflecting the typical direction for size-selective mortality [71], the fact that any survived to contribute to the adult population, let alone contributing >20% of the adult returns, is a significant finding. Based on these data, their sheer abundance during high flow conditions at least partially helps to explain the increases in returns following wet outmigration conditions in the San Joaquin watershed (Fig 1). Early-migrating fry and parr may represent a significant portion of the population that can access favorable downstream rearing habitats in high flow years and survive to contribute to the adult population. Indeed, our otolith reconstructions indicated that all of the smallest ($\leq$46mm FL) fry outmigrants in the surviving adult population (n = 4 in 2000, n = 1 in 2003) had spent several weeks rearing in the San Joaquin mainstem prior to leaving freshwater (e.g. Fig 3B). These data corroborate the extended transit times of CWT-tagged fish released in the San Joaquin basin and freshwater Delta in wetter years (averages of 16 d in 2000 vs. 6 d in 2003), although their mean size also differed (81mm vs. 87mm, respectively) [58]. Fry are observed in downstream freshwater and estuarine habitats in the CCV [20,76], and were probably more common when the Delta was a large tidal wetland [14,24,53]. This study confirms that these individuals can survive and contribute meaningfully to adult returns.

Currently there are no genetic data to support or refute a heritable component to early outmigration behavior, but it could otherwise meet the criteria of an adaptive trait, given that its expression is associated with "differential survival" and there is evidence for "a mechanism of selection" [77]. There is still some debate as to whether fry pulses during high flow events represent displacement due to reduced swimming ability or a deliberate behavior that might be considered a 'strategy' [3,14]. While catastrophic floods undoubtedly result in riverbed scouring and some fry displacement, not all individuals outmigrate during these events. Conversely, some fry migration is observed during periods with no pulse flows [78]. Given the frequency with which this phenotype is reported and the considerable rearing potential of downstream habitats, it is conceivable that fry dispersal is a heritable strategy, representing a 'migratory contingent' within the population [79,80]. Indeed, their consistent contribution to the adult population (observed here and in [21]) conclusively demonstrates that fry migration can be successful. If, however, early outmigration is purely an expression of phenotypic plasticity, it is likely that multiple factors are involved in stimulating the behavioral switch, including hydrology, intraspecific interactions [3] and density dependent mechanisms [65,81–83]. Irrespective of the underlying mechanisms, quantifying the relative success of migratory phenotypes across a broader range of hydrologic regimes is fundamental to understanding how environmental conditions and water operations contribute to salmon population dynamics.

Otolith strontium isotopes and sources of uncertainty

One of the most significant advances of the current study was the pairing of RST sampling with otolith reconstructions. This process enabled us to compare fish size at a specific time and location across life stages, and provided a unique method for generating survival estimates into adulthood. CWT studies and acoustic telemetry have provided valuable insights into survival through particular stretches of the CCV [25,75], but tend to focus on larger fish and provide no information about the long-term success of particular traits. In addition, acoustic tags have focused on understanding flow-survival relationships for smolts, which are physiologically ready for seaward migration and likely use the mainstem rivers, delta, and estuary differently than fry or parr, which may exhibit prolonged rearing. Otolith $^{87}Sr/^{86}Sr$ ratios are an ideal natural tag as they vary among many of the rivers in the CCV, resulting in high classification scores for natal assignments (S1 and S2 Tables) [30,32,84]. Sr isotopes also represent a unique and sensitive marker for reconstructing downstream movements and non-natal rearing patterns in the freshwater system (e.g. Fig 3B). While seasonal variation in $^{87}Sr/^{86}Sr$ values have been reported in certain systems [85] and interannual variations were detected for some sites (S1 Table), these were minor compared with most of the geographic differences, with the majority of sites exhibiting classification scores >70% even when pooled across years (S2 Table). Importantly, the Stanislaus exhibited a stable and distinct isotopic signature; with 96% of juveniles correctly classified using jack-knife resampling (S2 Table). Identification of natal origin represents a significant advantage of using otolith Sr isotopes over element concentrations. This was critical for pairing RST- and otolith-derived datasets and providing confidence that our size reconstructions were not skewed by hatchery smolts.

A high occurrence of straying of fall-run Chinook salmon occurs between the San Joaquin and Sacramento basins [86–88], potentially due to the relative outflows during the return migration as well as hatchery release practices [89]. However the extent to which hatchery fish are functioning to sustain the San Joaquin salmon populations has gone largely undetected until recently [86,87]. In the current study, hatchery strays represented 18–51% of the unmarked fish, reducing the number of samples available to inform outmigration strategies of wild fish and increasing analytical costs. However, the removal of strays was vital to ensure that FL reconstructions were only performed on individuals that had experienced the same conditions as the RST-sampled juveniles. The implementation of 100% visual identification of hatchery fish [90] would increase the feasibility and efficiency of future life history diversity studies in this system.

We attempted to reduce and account for sources of uncertainty, but the low number of focus years and sample sizes, and the potential for error propagation limit the strength of our inferences. With greater representation of 2 and 4 year olds in our adult sample, a more sophisticated analysis using age-specific natal assignments could have been carried out. While no yearlings were detected in the surviving adults, their rarity in the RST-sampled outmigrant population indicate that larger sample sizes would be required to ascertain the success of this strategy with any confidence. Similarly, our approach for assigning natal origin based on otolith chemistry following yolk sac absorption means that individuals that outmigrated as yolk sac fry could have been misclassified as strays. However, yolk sac fry are rarely observed in the outmigrant population (0.1% of the 2001–2011 RST catch at Caswell), so this was deemed unlikely to significantly influence our results.

Management implications

The complex biophysical properties of freshwater systems have led to the evolution of dynamic habitat mosaics [91] and diverse salmon life histories and distributions. The observed life history diversity likely provides within-population buffering, an as yet understudied component of the portfolio effect [5,6]. These data add to the mounting evidence that managing and conserving life history diversity is necessary to support resilient salmon populations, particularly in the face of climate change and projected human population growth [9,10]. Diversity in phenotypic traits is thought to produce a more stable population complex by decoupling population dynamics and buffering variance [6]. However, population resilience does not necessarily immediately translate into population abundance. In a highly regulated system such as the CCV, there is debate as to whether environmental unpredictability dictates a need to manage salmon stocks for diversity and resilience, or whether our understanding of (and control over) the relevant processes is sufficient to manage purely for abundance. Such topics are complicated by socio-economic and ecological trade-offs, however, by improving our understanding of how juvenile life history strategies are expressed and respond to different flow regimes, we may be able to optimize both. Currently, the portfolio effect for CCV salmon stocks is weak and deteriorating [92] and San Joaquin populations face serious future challenges, given predicted 25–40% reductions in snowmelt by 2050 [93]. CCV salmon exhibit diverse outmigration timings that have evolved over geological time scales in response to the unpredictable hydroclimatic conditions characteristic of the region [11]. Yet modern-day water and hatchery management practices tend to constrain outmigration timing. For example, alterations to the natural hydrograph, such as suppression of winter pulse flows, likely to truncate migratory windows, reduce the variability in outmigration timing, and significantly suppress the fry life history type. Such simplification and truncation of life history diversity could significantly reduce the resiliency of the stock-complex and exacerbate the risk of a temporal mismatch with favorable ocean conditions [94]. Indeed, the only clear deviation from the flow-driven relationship in Fig 1 was attributed to juveniles entering the ocean during a suboptimal period and resulted in the closure of the fishery in 2008. Perhaps with more diverse, resilient stocks, the consequences would have been less extreme. Largely without direct empirical support, hatchery and flow management practices tend to focus on optimizing the success of the largest, smolt-sized juveniles that are assumed to contribute the most to adult returns [14,21,24]. Here, we found that all phenotypes contributed to the reproductive adult population, with smolts comprising less than half of the surviving adults following two contrasting flow regimes. Without otolith reconstruction data for additional years, species, and watersheds, the broader inferences one can make regarding the influence of hydroclimatic regime on juvenile salmon survival are limited. However our data and a previous study [21] indicate that assumptions regarding size-selective mortality and smolt-focused management schemes need to be tested on a species, system and hydroclimatic basis.

This study has demonstrated the value of a combined RST and otolith geochemistry study to reconstruct patterns in the expression and survival of salmon migratory phenotypes. The results show that under paired years of low and high flow conditions, parr outmigrants comprised a significant portion of the returning adult population, while fry made smaller, but substantial contributions. Future efforts should focus on reducing the error in juvenile production estimates in order to produce more meaningful survival estimates, and understanding the demographic role that fry and parr play in salmon population dynamics. Management actions that promoted the expression and survival of fry in natal and downstream rearing habitats could result in demographic and genetic benefits to the population. Recognition of the importance of hydrodynamic regime and life history diversity should provide guidance to system managers when reassessing goals and future management strategies [5,95]. It is also important that management actions consider carefully-designed monitoring programs to detect changes in stock abundance and life history diversity at appropriate temporal and spatial scales.

Supporting Information

S1 Text. Testing the performance of the Sr isoscape.
(DOCX)

S1 Fig. Time-resolved plot of a single spot ablation at a habitat transition. This plot (macro developed by C. Donohoe) shows how the isotopic composition of the otolith can change with sample depth (equivalent to analysis time). Typically we would use ~20 seconds of data per spot (A), but in cases like this we would use only the surface material (B) to avoid signal attenuation and to ensure consistency between otolith $^{87}Sr/^{86}Sr$, microstructure and distance analyses.
(DOCX)

S2 Fig. Median $^{87}Sr/^{86}Sr$ natal values for major sources of Chinook salmon in the California Central Valley. Values are based on juvenile otoliths and/or water samples. The mainstem San Joaquin River (SJR) isotopic signature is displayed, but was not included as a potential natal source. Boxes represent 25-75th percentiles, whiskers represent 5-95th percentiles. Site codes are defined in S1 Table. Isotopic signatures not significantly different ($p > 0.05$, Tukey's test) are joined by brackets. Mean ocean $^{87}Sr/^{86}Sr$ is indicated by a dashed line.
(TIF)

S1 Table. $^{87}Sr/^{86}Sr$ isoscape used to train the LDFA and assign unknown adult otoliths to natal location. Data based on known-origin otolith (O) and/or water (W) samples. Interannual differences were tested by ANOVA or Welch's Test when data exhibited unequal variance. Differences among sites are shown in S2 Fig Underlined years represent water samples collected Oct 1997 to Apr 1998 that were pooled into a single water year (1998).
(DOCX)

S2 Table. Natal assignments and correct classification scores of known-origin samples. Assignments based on $^{87}Sr/^{86}Sr$ values and jackknife resampling. Site codes are defined in S1 Table. Equal prior probabilities were given to all sites and sites are ordered by increasing mean $^{87}Sr/^{86}Sr$ value. The training dataset (n = 290) comprised both juvenile otoliths and water samples. Counts are for actual rows by predicted columns. Samples from the Stanislaus River (STA) are highlighted in bold, while groups of sites with statistically overlapping $^{87}Sr/^{86}Sr$ signatures ($p>0.05$, Tukey's test) are shown in italics and S2 Fig
(DOCX)

S3 Table. Reference samples used to calibrate the fork length back-calculation model.
(DOCX)

S4 Table. The number of adult spawners produced by the 2000 and 2003 outmigration cohorts ("natural escapement")
(DOCX)

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Author Contributions

Conceived and designed the experiments: RCJ JDW. Performed the experiments: AMS RCJ TH JJG PKW GEW. Analyzed the data: AMS RCJ TMH AEH CM. Contributed reagents/materials/analysis tools: TH. Wrote the paper: AMS RCJ.

References

1. Hanski I (1998) Metapopulation dynamics. Nature 396: 41–49.
2. Montgomery DR (2000) Coevolution of the Pacific salmon and Pacific Rim topography. Geology 28: 1107–1110.
3. Healey MC (1991) Life history of chinook salmon (*Oncorhynchus tshawytscha*). In: Groot C, Margolis L, editors. Pacific salmon life histories. Vancouver: UBC Press. pp. 311–394.

4. Yoshiyama RM, Gerstung ER, Fisher FW, Moyle PB (2001) Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California. In: Brown RL, editor. Contributions to the biology of Central Valley salmonids. Vol 1 Fish Bulletin No 179. Sacramento. pp. 71–176.
5. Hilborn R, Quinn TP, Schindler DE, Rogers DE (2003) Biocomplexity and fisheries sustainability. Proceedings of the National Academy of Sciences 100: 6564–6568. PMID: 12743372
6. Schindler DE, Hilborn R, Chasco B, Boatright CP, Quinn TP, Rogers LA, et al. (2010) Population diversity and the portfolio effect in an exploited species. Nature 465: 609–612. doi: 10.1038/nature09060 PMID: 20520713
7. Greene CM, Hall JE, Guilbault KR, Quinn TP (2010) Improved viability of populations with diverse life-history portfolios. Biology Letters 6: 382–386. doi: 10.1098/rsbl.2009.0780 PMID: 20007162
8. Bolnick DI, Amarasekare P, Araújo MS, Bürger R, Levine JM, Novak M, et al. (2011) Why intraspecific trait variation matters in community ecology. Trends in Ecology & Evolution 26: 183–192.
9. Ruckelshaus MH, Levin P, Johnson JB, Kareiva PM (2002) The Pacific Salmon Wars: What Science Brings to the Challenge of Recovering Species. Annual Review of Ecology and Systematics 33: 665–706.
10. Beechie T, Buhle E, Ruckelshaus M, Fullerton A, Holsinger L (2006) Hydrologic regime and the conservation of salmon life history diversity. Biological Conservation 130: 560–572.
11. Spence BC, Hall JD (2010) Spatiotemporal patterns in migration timing of coho salmon (*Oncorhynchus kisutch*) smolts in North America. Canadian Journal of Fisheries and Aquatic Sciences 67: 1316–1334.
12. Moyle PB (1994) The Decline of Anadromous Fishes in California. Conservation Biology 8: 869–870.
13. Jager HI, Rose KA (2003) Designing Optimal Flow Patterns for Fall Chinook Salmon in a Central Valley, California, River. North American Journal of Fisheries Management 23: 1–21.
14. Williams JG (2006) Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science 4.
15. Wells BK, Grimes CB, Waldvogel JB (2007) Quantifying the effects of wind, upwelling, curl, sea surface temperature and sea level height on growth and maturation of a California Chinook salmon (*Oncorhynchus tshawytscha*) population. Fisheries Oceanography 16: 363–382.
16. Yoshiyama RM, Fisher FW, Moyle PB (1998) Historical Abundance and Decline of Chinook Salmon in the Central Valley Region of California. North American Journal of Fisheries Management 18: 487–521.
17. Reisenbichler RR, McIntyre JD, Hallock RJ (1982) Relation between size of chinook salmon, Oncorhynchus tshawytscha, released at hatcheries and returns to hatcheries and ocean fisheries 57–59 p.
18. Woodson LE, Wells BK, Johnson RC, Weber PK, MacFarlane RB, Whitman GE (2013) Using size, growth rate and rearing origin to evaluate selective mortality of juvenile Chinook salmon *Oncorhynchus tshawytscha* across years of varying ocean productivity. Marine Ecology Progress Series 487: 163–175.
19. MacFarlane RB, Norton EC (2002) Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fishery Bulletin 100: 244–257.
20. Kjelson M, Raquel P, Fisher F (1982) Life-history of fall run Chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. In: Kennedy VS, editor. Estuarine Comparisons. New York, NY: Academic Press. pp. 393–411.
21. Miller JA, Gray A, Merz J (2010) Quantifying the contribution of juvenile migratory phenotypes in a population of Chinook salmon *Oncorhynchus tshawytscha*. Marine Ecology Progress Series 408: 227–240.
22. Ewing RD, Ewing GS (2002) Bimodal length distributions of cultured chinook salmon and the relationship of length modes to adult survival. Aquaculture 209: 139–155.
23. Good SP, Dodson JJ, Meekan MG, Ryan DA (2001) Annual variation in size-selective mortality of Atlantic salmon (Salmo salar) fry. Canadian Journal of Fisheries and Aquatic Sciences 58: 1187–1195.
24. Brandes P, McLain J (2001) Juvenile chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin estuary. In: Brown RL, editor. Contributions to the biology of Central Valley salmonids. Vol 2 Fish Bulletin No 179. Sacramento: California Department of Fish and Game. pp. 39–138.
25. Perry R, Brandes P, Burau J, Klimley AP, MacFarlane B, Michel C, et al. (2013) Sensitivity of survival to migration routes used by juvenile Chinook salmon to negotiate the Sacramento-San Joaquin River Delta. Environmental Biology of Fishes 96: 381–392.

26. Berejikian BA, Tezak EP, Schroder SL, Flagg TA, Knudsen CM (1999) Competitive differences between newly emerged offspring of captive-reared and wild Coho salmon. Transactions of the American Fisheries Society 128: 832–839.

27. Unwin MJ (1997) Survival of chinook salmon, *Oncorhynchus tshawytscha*, from a spawning tributary of the Rakaia Rivet. New Zealand, in relation to spring and summer mainstem flows. Fishery Bulletin 95: 812–825.

28. Campana SE, Thorrold SR (2001) Otoliths, increments, and elements: keys to a comprehensive understanding of fish populations? Canadian Journal of Fisheries and Aquatic Sciences 58: 30–38.

29. Sturrock AM, Trueman CN, Darnaude AM, Hunter E (2012) Can otolith elemental chemistry retrospectively track migrations in fully marine fishes? Journal of Fish Biology 81: 766–795. doi: 10.1111/j.1095-8649.2012.03372.x PMID: 22803735

30. Ingram LB, Weber PK (1999) Salmon origin in California's Sacramento–San Joaquin river system as determined by otolith strontium isotopic composition. Geology 27: 851–854.

31. Kennedy B, Folt C, Blum J, Chamberlain C (1997) Natural isotope markers in salmon. Nature 387: 766.

32. Barnett-Johnson R, Pearson T, Ramos F, Grimes C, MacFarlane R (2008) Tracking natal origins of salmon using isotopes, otoliths, and landscape geology. Limnology and Oceanography 53: 1633–1642.

33. Kennedy BP, Klaue A, Blum JD, Folt C, Nislow KH (2002) Reconstructing the lives of fish using Sr isotopes in otoliths. Canadian Journal of Fisheries and Aquatic Sciences 59: 925–929.

34. Campana SE, Neilson JD (1985) Microstructure of fish otoliths. Canadian Journal of Fisheries and Aquatic Sciences 42: 1014–1032.

35. Neilson JD, Geen GH (1982) Otoliths of Chinook salmon (*Oncorhynchus tshawytscha*): daily growth increments and factors influencing their production. Canadian Journal of Fisheries and Aquatic Sciences 39: 1340–1347.

36. Titus RG, Volkoff MC, Snider WM (2004) Use of Otolith Microstructure to Estimate Growth Rates of Juvenile Chinook Salmon from a Central Valley, California Stock. American Fisheries Society Symposium 39: 181–202.

37. Kondolf GM, Falzone A, Schneider KS (2001) Reconnaissance-level assessment of channel change and spawning habitat on the Stanislaus River below Goodwin Dam. Report to U.S. Fish and Wildlife Service, Sacramento, CA.

38. Schneider KS, Kondolf GM, Falzone A (2000) Channel-floodplain disconnection on the Stanislaus River. University of California, Berkeley 94720: 165–170.

39. Fisher FW (1994) Past and Present Status of Central Valley Chinook Salmon. Conservation Biology 8: 870–873.

40. Cramer Fish Sciences (2012) Juvenile Salmonid Out-migration Monitoring at Caswell Memorial State Park in the Lower Stanislaus River, California. 2010–2011 Biennial Report. Grant No. 813326G008. 48pp. p.

41. PSMFC (2014) Juvenile Salmonid Emigration Monitoring in the Lower American River, California. http://www.fws.gov/sacramento/Fisheries/CAMP-Program/Documents-Reports/Documents/2014_American_River_rotary_screw_trap_annual_report.pdf. 107 p.

42. Zeug SC, Sellheim K, Watry C, Wikert JD, Merz J (2014) Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America. Fisheries Management and Ecology: n/a-n/a.

43. Genz A, Bretz F, Miwa T, Mi Z, Leisch F, Scheipl F, et al. (2014) Multivariate Normal and t Distributions. In: CRAN, editor. http://cran.r-project.org/web/packages/mvtnorm/mvtnorm.pdf.

44. van Belle G (2008) Statistical Rules of Thumb, 2nd Edition. Hoboken, New Jersey: John Wiley & Sons, Inc.

45. Guignard J (2008) Addendum to the Stanislaus River fall Chinook salmon escapement survey 2006: age determination report. Report to the United States Bureau of Reclamation, contract # R0640001.

46. Guignard J (2007) Addendum to the Stanislaus River fall Chinook salmon escapement survey 2005: age determination report. Report to the United States Bureau of Reclamation, contract # R0540004.

47. Barnett-Johnson R, Grimes C, Royer C, Donohoe C (2007) Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags. Canadian Journal of Fisheries and Aquatic Sciences 64: 1683–1692.

48. Barnett-Johnson R, Ramos F, Grimes C, MacFarlane R (2005) Validation of Sr isotopes in otoliths by laser ablation multicollector inductively coupled plasma mass spectrometry (LA-MC-ICPMS): opening avenues in fisheries science applications. Canadian Journal of Fisheries and Aquatic Sciences 62: 2425–2430.

49. Zabel R, Haught K, Chittaro P (2010) Variability in fish size/otolith radius relationships among populations of Chinook salmon. Environmental Biology of Fishes 89: 267–278.

50. Mesick C, Marston D, Heyne T (2009) Estimating recruitment for fall-run Chinook salmon populations in the Stanislaus, Tuolumne, and Merced Rivers. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/cspa.shtml: Instream Energy Flow Branch USFWS.

51. USFWS (2014) "Chinookprod" database. Unpublished database maintained by the Anadromous Fish Restoration Program and Comprehensive Assessment and Monitoring Program, Lodi and Sacramento, California.

52. PFMC (2014) Appendix Tables A1 & 5 from Stock Assessment and Fishery Evaluation Review of 2013 Ocean Salmon Fisheries. http://www.pcouncil.org/wp-content/uploads/salsafe2013_appdxa.pdf.

53. Williams JG (2012) Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in and Around the San Francisco Estuary. San Francisco Estuary and Watershed Science 10.

54. Vasques J, Kundargi K (2001) 1999–2000 Grayson Screw Trap Report. San Joaquin Valley Southern Sierra Region (Region 4).

55. Gray A, Jones K, Watry C, Merz J (2012) Stanislaus River juvenile Chinook salmon out-migration population dynamics (1996–2009) and potential river management implications. U.S. Fish and Wildlife Service's Comprehensive Assessment and Monitoring Program. 85 p.

56. Gregory RS, Levings CD (1998) Turbidity Reduces Predation on Migrating Juvenile Pacific Salmon. Transactions of the American Fisheries Society 127: 275–285.

57. Demko D (2003) Chapter 6 Complimentary Studies Related to the VAMP. Evaluation of Chinook salmon fry survival in the Stanislaus River: biological response to supplemental winter flow pulse In: SJRGA, editor. 2003 Annual Technical Report.

58. SJRGA (2003) Chapter 5 Salmon Smolt Survival Investigations.

59. SJRGA (2000) VAMP 2000 Salmon smolt survival investigations.

60. Beckman BR, Larsen DA, Lee-Pawlak B, Dickhoff WW (1998) Relation of Fish Size and Growth Rate to Migration of Spring Chinook Salmon Smolts. North American Journal of Fisheries Management 18: 537–546.

61. U.S. Environmental Protection Agency (2003) EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. Seattle, WA.: Region 10 Office of Water.

62. Marine KR, Cech JJ (2004) Effects of High Water Temperature on Growth, Smoltification, and Predator Avoidance in Juvenile Sacramento River Chinook Salmon. North American Journal of Fisheries Management 24: 198–210.

63. Burns JW (1971) The carrying capacity for juvenile salmonids in some northern California streams. California Fish and Game 57: 44–57.

64. Greene CM, Beechie TJ (2004) Consequences of potential density-dependent mechanisms on recovery of ocean-type chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 61: 590–602.

65. Achord S, Levin PS, Zabel RW (2003) Density-dependent mortality in Pacific salmon: the ghost of impacts past? Ecology Letters 6: 335–342.

66. Cavallo B, Merz J, Setka J (2013) Effects of predator and flow manipulation on Chinook salmon (*Oncorhynchus tshawytscha*) survival in an imperiled estuary. Environmental Biology of Fishes 96: 393–403.

67. Kjelson M, Raquel P, Fisher F (1981) Influences of freshwater inflow on Chinook salmon (*Oncorhynchus tshawystcha*) in the Sacramento-San Joaquin Estuary. In: Cross RD, Williams DL, editors. Proceedings of the National Symposium on Freshwater Inflow to Estuaries: U.S. Fish and Wildlife Service. pp. 88–108.

68. SJRGA (2013) Chapter 5: Salmon smolt survival investigations. In: San Joaquin River Group Authority, editor. On implementation and monitoring of the San Joquin River Agreement and the Vernalis Adaptive Management Plan (VAMP): 2011 Annual Technical Report: California Water Resources Control Board in compliance with D-1641.

69. Weitkamp LA (2010) Marine Distributions of Chinook Salmon from the West Coast of North America Determined by Coded Wire Tag Recoveries. Transactions of the American Fisheries Society 139: 147–170.

70. Sterns SC (1992) The evolution of life histories. New York: Oxford University Press.

71. Sogard SM (1997) Size-Selective Mortality in the Juvenile Stage of Teleost Fishes: A Review. Bulletin of Marine Science 60: 1129–1157.

72. Moyle PB, Israel JA, Purdy SE (2008) Salmon, steelhead, and trout in California status of an emblematic fauna. Center for Watershed Sciences, UC Davis.

73. Myrick CA, Cech JJ (2004) Temperature effects on juvenile anadromous salmonids in California's central valley: what don't we know? Reviews in Fish Biology and Fisheries 14: 113–123.

74. Beamish RJ, Mahnken C (2001) A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography 49: 423–437.

75. SJRGA (2011) On implementation and monitoring of the San Joquin River Agreement and the Vernalis Adaptive Management Plan (VAMP): 2010 Annual Technical Report.

76. Speegle J, Kirsch J, Ingram J (2013) Annual Report: Juvenile fish monitoring during the 2010 and 2011 field seasons within the San Francisco Estuary, California. Lodi, California.

77. Taylor EB (1991) A review of local adaptation in Salmonidae, with particular reference to Pacific and Atlantic salmon. Aquaculture 98: 185–207.

78. Cramer Fish Sciences (2006) 2006 Stanislaus River Data Report—Final Data.

79. Secor D (1999) Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries Research 43: 13–34.

80. Hjort J (1914) Fluctuations in the great fisheries of Northern Europe. Conseil Permanent International Pour L'Exploration De La Mer 20: 1–228.

81. Via S, Gomulkiewicz R, De Jong G, Scheiner SM, Schlichting CD, Van Tienderen PH (1995) Adaptive phenotypic plasticity: consensus and controversy. Trends in Ecology & Evolution 10: 212–217.

82. Waples RS, Teel DJ, Myers JM, Marshall AR (2004) Life-History Divergence in Chinook Salmon: Historic Contingency and Parallel Evolution. Evolution 58: 386–403. PMID: 15068355

83. Greene CM, Beamer EM (2011) Monitoring Population Responses to Estuary Restoration by Skagit River Chinook salmon.

84. Barnett-Johnson R, Teel D, Casillas E (2010) Genetic and otolith isotopic markers identify salmon populations in the Columbia River at broad and fine geographic scales. Environmental Biology of Fishes 89: 533–546.

85. Semhi K, Clauer N, Probst JL (2000) Strontium isotope compositions of river waters as records of lithology-dependent mass transfers: the Garonne river and its tributaries (SW France). Chemical Geology 168: 173–193.

86. Kormos B, Palmer-Zwahlen M, Low A (2012) Recovery of coded-wire tags from Chinook salmon in California's Central Valley Escapement and Ocean Harvest in 2010.

87. Johnson R, Weber P, Wikert J, Workman M, MacFarlane R, Grove M, et al. (2012) Managed Metapopulations: Do Salmon Hatchery 'Sources' Lead to In-River 'Sinks' in Conservation? Plos One 7.

88. Mesick C (in review) The proportion of hatchery fish in California's Central Valley fall-run Chinook salmon escapements from 1980 to 2010.

89. Marston D, Mesick C, Hubbard A, Stanton D, Fortmann-Roe S, Tsao S, et al. (2012) Delta Flow Factors Influencing Stray Rate of Escaping Adult San Joaquin River Fall-Run Chinook Salmon (*Oncorhynchus tshawytscha*). San Francisco Estuary and Watershed Science 10.

90. Selective Fisheries Evaluation Committee S (2012) Summary of mass marking activities and mark selective fisheries conducted by Canada and the United States, 2005–2009.

91. Hauer FR, Lorang M (2004) River regulation, decline of ecological resources, and potential for restoration in a semi-arid lands river in the western USA. Aquatic Sciences 66: 388–401.

92. Carlson SM, Satterthwaite WH (2011) Weakened portfolio effect in a collapsed salmon population complex. Canadian Journal of Fisheries and Aquatic Sciences 68: 1579–1589.

93. DWR (2010) Climate Change Characterization and Analysis in California Water Resources Planning Studies, Final Report.

94. Satterthwaite WH, Carlson SM, Allen-Moran SD, Vincenzi S, Bograd SJ, Wells BK (2014) Match-mismatch dynamics and the relationship between ocean-entry timing and relative ocean recoveries of Central Valley fall run Chinook salmon. Marine Ecology Progress Series 511: 237–248.

95. Wood CC, Bickham JW, John Nelson R, Foote CJ, Patton JC (2008) Recurrent evolution of life history ecotypes in sockeye salmon: implications for conservation and future evolution. Evolutionary Applications 1: 207–221. doi: 10.1111/j.1752-4571.2008.00028.x PMID: 25567627

96. Lindley ST, Grimes CB, Mohr MS, Peterson W, Stein J, Anderson JT, et al. (2009) What caused the Sacramento River fall Chinook stock collapse?: Pacific Fishery Management Council.

97. The Bay Institute (2013). http://thebayinstitutetypepadcom/my-blog/2013/01/end-the-drought-nowhtml.

State Water Resources Control Board
California Environmental Protection Agency

Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem

Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009

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STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

August 3, 2010

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State Water Resources Control Board
California Environmental Protection Agency

Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem

Prepared Pursuant to the Sacramento-San Joaquin Delta Reform Act of 2009

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The State Water Resources Control Board (State Water Board or Board) acknowledges the following for their contributions and participation in the Board's Delta Flow Criteria proceding:

- The professors, researchers, and staff from various resource agencies that comprise the Delta Environmental Flows Group (DEFG) for providing valuable information and insights that informed the Delta flow criteria informational proceeding, and whose work was cited liberally throughout this report
- The UC Davis Delta Solutions Group, a subset of the DEFG for providing additional insights in their reports on habitat variability, flow presecriptions, and ecosystem investments
- The California Department of Fish and Game for working collaboratively with the State Water Board on development of species life history requirements and for reviewing portions of the draft report
- The United States Fish and Wildflie Service and National Marine Fisheries Service for reviewing portions of the draft report
- All the participants of the proceeding for providing information and serving on panels to answer questions during the proceeding

The State Water Board, however, is responsible for any errors and for all interpretations of the information in this report.

STATE WATER RESOURCES CONTROL BOARD
RESOLUTION NO. 2010-0039

DETERMINING DELTA FLOW CRITERIA PURSUANT TO THE DELTA REFORM ACT

WHEREAS:

1. Water Code section 85086, contained in the Sacramento-San Joaquin Delta Reform Act of 2009 (Stats. 2009 (7th Ex. Sess.) ch. 5) (commencing with Wat. Code, § 85000), requires the State Water Resources Control Board (State Water Board) to develop, within nine months of enactment of the statute, new flow criteria for the Sacramento-San Joaquin Delta (Delta) ecosystem that are necessary to protect public trust resources. The purpose of the flow criteria is to inform planning decisions for the Delta Plan and the Bay Delta Conservation Plan. The statute specifies that the flow criteria shall not predetermine any issue that may arise in the State Water Board's subsequent consideration of a permit.

2. In accordance with Water Code section 85086, subdivision (c)(1), the State Water Board conducted a public process in the form of an informational proceeding to collect information used to develop the flow criteria. The State Water Board conducted the informational proceeding on March 22-24, 2010, and considered the information submitted in connection with that proceeding in developing the flow criteria.

3. The State Water Board has prepared a report determining flow criteria for the Delta ecosystem necessary to protect public trust resources. In developing the flow criteria, the State Water Board reviewed existing water quality objectives and used the best available scientific information. The flow criteria include the volume, timing, and quality of flow necessary under different hydrologic conditions.

THEREFORE BE IT RESOLVED THAT:

1. In accordance with the Delta Reform Act, the State Water Board approves the report determining new flow criteria for the Delta ecosystem that are necessary to protect public trust resources.

2. The Executive Director is directed to submit the Delta flow criteria report to the Delta Stewardship Council for its information within 30 days of the adoption of this resolution.

CERTIFICATION

The undersigned Clerk to the Board does hereby certify that the foregoing is a full, true, and correct copy of a resolution duly and regularly adopted at a meeting of the State Water Board held on August 3, 2010.

AYE: Chairman Charles R. Hoppin
Vice Chair Frances Spivy-Weber
Board Member Arthur G. Baggett, Jr.
Board Member Tam M. Doduc
Board Member Walter G. Pettit

NAY: None

ABSENT: None

ABSTAIN: None

Jeanine Townsend

Jeanine Townsend
Clerk to the Board

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Acronyms and Abbreviations

AFRP	Anadromous Fish Restoration Program
AR	American Rivers
Bay-Delta	San Francisco Bay/Sacramento-San Joaquin Delta Estuary including Suisun Marsh
Bay-Delta Plan	Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
BDCP	Bay Delta Conservation Program
CCWD	Contra Costa Water District
Central Valley Regional Board	Central Valley Regional Water Quality Control Board
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
cfs	cubic feet per second
Council	Delta Stewardship Council
CSPA	California Sportfishing Protection Alliance
CVP	Central Valley Project
CWIN	California Water Impact Network
DEFG	Delta Environmental Flows Group
Delta	Confluence of the Sacramento River and San Joaquin River (as defined in Water Code section 12220)
Delta Plan	Delta Stewardship Council comprehensive, long-term management plan for the Delta
Delta Reform Act	Sacramento-San Joaquin Delta Reform Act of 2009
DFG	California Department of Fish and Game
DO	dissolved oxygen
DOI	United States Department of the Interior
DSM2	Delta Simulation Model
DWR	California Department of Water Resources
DWSC	Stockton Deep Water Ship Channel
E/I	Export/Inflow ratio
EC	Electrical Conductivity
EDF	Environmental Defense Fund
ESA	Endangered Species Act
FERC	Federal Energy Regulatory Commission
FMWG	Fisheries Management Work Group
FMWT	Fall mid-water trawl
IEP	Interagency Ecological Program
LSZ	Low Salinity Zone
MAF	million acre-feet
mg/L	milligrams per liter
mmhos/cm	millimhos per centimeter
NAS	National Academy of Sciences
NCCPA	State Natural Community Conservation Planning Act
NDOI	Net Delta Outflow Index
NEPA	National Environmental Policy Act
NHI	Natural Heritage Institute

NMFS	National Marine Fisheries Service
NRDC	Natural Resources Defense Council
OCAP	Long-Term Operations Criteria and Plan for Coordination of the Central Valley Project and the State Water Project
OMR	Old and Middle River
Opinion	Biological Opinion
PCFFA	Pacific Coast Federation of Fishermen's Associations
POD	Pelagic Organism Decline
ppt	parts per thousand
psu	practical salinity unit
PTM	Particle Tracking Model
RMP	Regional Monitoring Program
RPA	Reasonable and Prudent Alternatives
San Francisco Regional Board	San Francisco Bay Regional Water Quality Control Board
SB 1	Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7th Ex. Sess.) ch. 5, § 39)
SFWC	State and Federal Water Contractors
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
SJRRP	San Joaquin River Restoration Program
SRWTP	Sacramento Regional Wastewater Treatment Plant
State Water Board	State Water Resources Control Board
SWG	Smelt Working Group
SWP	State Water Project
TBI	The Bay Institute
TNC	The Nature Conservancy
USACE	U.S. Army Corps of Engineers
USBR	United States Bureau of Reclamation
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WOMT	Water Operations Management Team

1. Executive Summary

The Sacramento-San Joaquin Delta (Delta) is a critically important natural resource for California and the nation. It is both the hub of California's water supply system and the most valuable estuary and wetlands on the western coast of the Americas. The Delta is in ecological crisis, resulting in high levels of conflict that affect the sustainability of existing water policy in California. Several species of fish have been listed as protected species under the California Endangered Species Act (CESA) and under the federal Endangered Species Act (ESA). These two laws and other regulatory constraints have restricted water diversions from the Delta in an effort to prevent further harm to the protected species.

In November 2009, California enacted a comprehensive package of four policy bills and a bond measure intended to meet California's growing water challenges by adopting a policy of sustainable water supply management to ensure a reliable water supply for the State and to restore the Delta and other ecologically sensitive areas. One of these bills, Senate Bill No. 1 (SB 1) (Stats. 2009 (7th Ex. Sess.) ch 5, § 39) contains the Sacramento-San Joaquin Delta Reform Act of 2009 (Delta Reform Act), Water Code section 85000 et seq. The Delta Reform Act establishes a Delta Stewardship Council (Council), tasked with developing a comprehensive, long-term management plan for the Delta, known as the Delta Plan, and providing direction to multiple state and local agencies that take actions related to the Delta. The comprehensive bill package also sets water conservation policy, requires increased groundwater monitoring, and provides for increased enforcement against illegal water diversions.

The Delta Reform Act requires the State Water Board to use a public process to develop new flow criteria for the Delta ecosystem. During this process, participants cautioned the the State Water Board on the limitations of any flow criteria (Fleenor *et al*., 2010):

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality, improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note. The State Water Board further cautions that flow and physical habitat interact in many ways, but they are not interchangeable.

The best available science suggests that current flows are insufficient to protect public trust resources.

1.1 Legislative Directive and State Water Board Approach

Legislative Directive

Water Code section 85086 (See Appendix B), contained in the Delta Reform Act, was enacted as part of the comprehensive package of water legislation adopted in November 2009. Water Code section 85086 requires the State Water Resources Control Board (State Water Board) to use the best available scientific information gathered as part of a public process conducted as an informational proceeding to develop new flow criteria for the Delta ecosystem to protect public trust resources. The purpose of the flow criteria is to inform planning decisions for the Delta Plan and the BDCP. The Legislature intended to establish an accelerated process to determine the instream flow needs of the Delta in order to facilitate the planning decisions required to meet the objectives of the Delta Plan. Accordingly, Water Code section 85086 requires the State Water Board to develop the flow criteria within nine months of enactment of the statute and to submit its flow criteria determinations to the Council within 30 days of their development.

State Water Board Approach

In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. Given the accelerated time frame in which to develop the criteria, the State Water Board's approach to developing criteria was limited to review of instream needs in the Delta ecosystem, specifically fish species and Delta outflows, while also receiving information on hydrodynamics and major tributary inflows. The State Water Board's flow criteria determinations are accordingly limited to protection of aquatic resources in the Delta.

Limitations of State Water Board Approach

When setting flow objectives with regulatory effect, the State Water Board reviews and considers all the effects of the flow objectives through a broad inquiry into all public trust and public interest concerns. For example, the State Water Board would consider other public trust resources potentially affected by Delta outflow requirements and impose measures for the protection of those resources, such as requiring sufficient water for cold water pool in reservoirs to maintain temperatures in Delta tributaries. The State Water Board would also consider a broad range of public interest matters, including economics, power production, human health and welfare requirements, and the effects of flow measures on non-aquatic resources (such as habitat for terrestrial species). The limited process adopted for this proceeding does not include this comprehensive review.

The State Water Board's Public Trust Responsibilities in this Proceeding

Under the public trust doctrine, the State Water Board must take the public trust into account in the planning and allocation of water resources, and to protect public trust uses whenever feasible. (*National Audubon Society v. Superior Court* (1983) 33 Cal.3d 419, 446.) Public trust values include navigation, commerce, fisheries, recreation, scenic, and ecological values. "[I]n determining whether it is 'feasible' to protect public trust values like fish and wildlife in a particular instance, the [State Water] Board must determine whether protection of those values, or what level of protection, is 'consistent with the public interest.'" (*State Water Resources*

Control Bd. Cases (2006) 136 Cal.App.4th 674, 778.) The State Water Board does not make any determination regarding the feasibility of the public trust criteria and consistency with the public interest in this report.

In this forum, the State Water Board has not considered the allocation of water resources, the application of the public trust to a particular water diversion or use, water supply impacts, or any balancing between potentially competing public trust resources (such as potential adverse effects of increased Delta outflow on the maintenance of coldwater resources for salmonids in upstream areas). Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem and determining the flow criteria, as directed by Water Code section 85086.

Future Use of This Report

None of the determinations in this report have regulatory or adjudicatory effect. Any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning, water rights processes, or public trust proceedings in conformance with applicable law. In the State Water Board's development of Delta flow objectives with regulatory effect, it must ensure the reasonable protection of beneficial uses, which may entail balancing of competing beneficial uses of water, including municipal and industrial uses, agricultural uses, and other environmental uses. The State Water Board's evaluation will include an analysis of the effect of any changed flow objectives on the environment in the watersheds in which Delta flows originate, the Delta, and the areas in which Delta water is used. It will also include an analysis of the economic impacts that result from changed flow objectives.

Nothing in either the Delta Reform Act or in this report amends or otherwise affects the water rights of any person. In carrying out its water right responsibilities, the State Water Board may impose any conditions that in its judgment will best develop, conserve, and utilize in the public interest the water to be appropriated. In making this determination, the State Water Board considers the relative benefit to be derived from all beneficial uses of the water concerned and balances competing interests.

The State Water Board has continuing authority over water right permits and licenses it issues. In the exercise of that authority and duty, the State Water Board may, if appropriate, amend terms and conditions of water right permits and licenses to impose further limitations on the diversion and use of water by the water right holder to protect public trust uses or to meet water quality and flow objectives in Water Quality Control Plans it has adopted. The State Water Board must provide notice to the water permit or license holder and an opportunity for hearing before it may amend a water right permit or license.

If the DWR and/or the USBR in the future request the State Water Board to amend the water right permits for the State Water Project (SWP) and/or the Central Valley Project (CVP) to move the authorized points of diversion for the projects from the southern Delta to the Sacramento River, Water Code section 85086 directs the State Water Board to include in any order approving a change in the point of the diversion of the projects appropriate Delta flow criteria. At that time, the State Water Board will determine appropriate permit terms and conditions. That decision will be informed by the analysis in this report, but will also take many other factors into consideration, including any newly developed scientific information, habitat conditions at the time, and other policies of the State, including the relative benefit to be derived from all beneficial uses of water. The flow criteria in this report are not pre-decisional in regard to any State Water Board action. (See e.g., Wat. Code, § 85086, subd. (c)(1).)

The information in this report illustrates to the State Water Board the need for an integrated approach to management of the Delta. Best available science supports that it is important to directly address the negative effects of other stressors, including habitat, water quality, and invasive species, that contribute to higher demands for water to protect public trust resources. The flow criteria highlight the continued need for the BDCP to develop an integrated set of solutions and to implement non flow measures to protect public trust resources.

1.2 Summary Determinations

This report contains the State Water Board's determinations as to the flows that protect public trust resources in the Delta, under the narrow circumstances analyzed in this report. As required, the report includes the volume, timing, and quality of flow for protection of public trust resources under different hydrologic conditions. The flow criteria represent a technical assessment only of flow and operational requirements that provide fishery protection under existing conditions. The flow criteria contained in this report do not represent flows that might be protective under other conditions. The State Water Board recognizes that changes in existing conditions may alter the need for flow. Changes in existing conditions that may affect flow needs include, but are not limited to, reduced reverse flows in Delta channels, increased tidal habitat, improved water quality, reduced competition from invasive species, changes in the point of diversion of the SWP and CVP, and climate change.

Flow Criteria and Conclusions

The numeric criteria determinations in this report must be considered in the following context:

- The flow criteria in this report do not consider any balancing of public trust resource protection with public interest needs for water.
- The State Water Board does not intend that the criteria should supersede requirements for health and safety such as the need to manage water for flood control.
- There is sufficient scientific information to support the need for increased flows to protect public trust resources; while there is uncertainty regarding specific numeric criteria, scientific certainty is not the standard for agency decision making.

The State Water Board has considered the testimony presented during the Board's informational proceeding to develop flow criteria and to support the following summary conclusions. Several of these summary conclusions rely in whole or in part on conclusions and recommendations made to the State Water Board by the Delta Environmental Flows Group (DEFG)[1] and the University of California at Davis Delta Solutions Group[2].

1. The effects of non-flow changes in the Delta ecosystem, such as nutrient composition, channelization, habitat, invasive species, and water quality, need to be addressed and integrated with flow measures.

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[1] The Delta Environmental Flows Group of experts consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga.

[2] The Delta Solutions Group consists of William Bennett, William Fleenor, Jay Lund, and Peter Moyle.

2. Recent Delta flows are insufficient to support native Delta fishes for today's habitats.[3] Flow modification is one of the immediate actions available although the links between flows and fish response are often indirect and are not fully resolved. Flow and physical habitat interact in many ways, but they are not interchangeable.

3. In order to preserve the attributes of a natural variable system to which native fish species are adapted, many of the criteria developed by the State Water Board are crafted as percentages of natural or unimpaired flows. These criteria include:

    - 75% of unimpaired Delta outflow from January through June;
    - 75% of unimpaired Sacramento River inflow from November through June; and
    - 60% of unimpaired San Joaquin River inflow from February through June.

    It is not the State Water Board's intent that these criteria be interpreted as precise flow requirements for fish under current conditions, but rather they reflect the general timing and magnitude of flows under the narrow circumstances analyzed in this report. In comparison, historic flows over the last 18 to 22 years have been:

    - approximately 30% in drier years to almost 100% of unimpaired flows in wetter years for Delta outflows;
    - about 50% on average from April through June for Sacramento River inflows; and
    - approximately 20% in drier years to almost 50% in wetter years for San Joaquin River inflows.

4. Other criteria include: increased fall Delta outflow in wet and above normal years; fall pulse flows on the Sacramento and San Joaquin Rivers; and flow criteria in the Delta to help protect fish from mortality in the central and southern Delta resulting from operations of the State and federal water export facilities.

5. The report also includes determinations regarding variability and the natural hydrograph, floodplain activation and other habitat improvements, water quality and contaminants, cold water pool management, and adaptive management:
    - Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph.

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[3] This statement should not be construed as a critique of the basis for existing regulatory requirements included in the 2006 Bay-Delta Plan and biological opinions. Those requirements were developed pursuant to specific statutory requirements and considerations that differ from this proceeding. Particularly when developing water quality objectives, the State Water Board must consider many different factors including what constitutes reasonable protection of the beneficial use and economic considerations. In addition, the biological opinions for the SWP and CVP Operations Criteria and Plan were developed to prevent jeopardy to specific fish species listed pursuant to the federal Endangered Species Act; in contrast, the flow criteria developed in this proceeding are intended to halt population decline and increase populations of certain species.

- Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated.
- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.
- The Central Valley and San Francisco Regional Water Quality Control Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Water Quality Control Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.
- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.
- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Council, the Delta Science Program, BDCP, the Interagency Ecological Program (IEP), and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria included in this report are all criteria that are only appropriate for the current physical system and climate; as other factors change the flow needs advanced in this report will also change. As physical changes occur to the environment and our understanding of species needs improves, the long-term flow needs will also change. Actual flows should be informed by adaptive management.
- Only the underlying principles for the numeric criteria and other measures are advanced as long term criteria.

6. Past changes in the Delta may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta. It is important to establish seaward gradients and create more slough networks with natural channel geometry. Achieving a variable more complex estuary requires establishing seasonal gradients in salinity and other water quality variables and diverse habitats throughout the estuary. These goals in turn encourage policies which establish internal Delta flows that create a tidally-mixed upstream- downstream gradient (without cross-Delta flows) in water quality. Continued through-Delta conveyance is likely to continue the need for in-Delta flow requirements and restrictions to protect fish within the Delta.

7. Restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species.

8. The Delta ecosystem is likely to dramatically shift within 50 years due to large scale levee collapse. Overall, these changes are likely to promote a more variable, heterogeneous estuary. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse.

9. Positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife.

10. In order to prevent further channelization of riparian corridors and infill of wetland habitats, the Delta Stewardship Council should consider developing a plan to coordinate land use policy within the Delta between the city, county, State, and federal governments.

Ecosystems are complex; there are many factors that affect the quality of the habitat that they provide. These factors combine in ways that can amplify the effect of the factors on aquatic resources. The habitat value of the Delta ecosystem for favorable species can be improved by habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, and island flooding. Each of these non-flow factors has the potential to interact with flow to affect available aquatic habitat in Delta channels.

The State Water Board supports the most efficient use of water that can reasonably be made. The flow improvements that the State Water Board identifies in this report as being necessary to protect public trust resources illustrate the importance of addressing the negative effects of these other stressors that contribute to higher than necessary demands for water to provide resource protection. Future habitat improvements or changes in nutrients and contaminants, for example, may change the response of fishes to flow. Addressing other stressors directly will be necessary to assure protection of public trust resources and could change the demands for water to provide resource protection in the future. Uncertainty regarding the effects of habitat improvement and other stressors on flow demands for resource protection highlights the need for continued study and adaptive management to respond to changing conditions.

The flow criteria identified in this report highlight the need for the BDCP to develop an integrated set of solutions, to address ecosystem flow needs, including flow and non-flow measures. Although flow modification is an action that can be implemented in a relatively short time in order to improve the survival of desirable species and protect public trust resources, public trust resource protection cannot be achieved solely through flows – habitat restoration also is needed. One cannot substitute for the other; both flow improvements and habitat restoration are essential to protecting public trust resources.

1.3 Background and Next Steps

Informational Proceeding

The State Water Board held an informational proceeding on March 22, 23, and 24, 2010, to receive scientific information from technical experts on the Delta outflows needed to protect public trust resources. The State Water Board also received information at the proceeding on flow criteria for inflow to the Delta from the Sacramento and San Joaquin rivers and Delta hydrodynamics. The State Water Board did not solicit information on the need for water for other beneficial uses, including the amount of water needed for human health and safety, during the informational proceeding. Nor did the State Water Board consider other policy considerations, such as the state goal of providing a decent home and suitable living environment for every Californian.

Analytical Methods

The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Recommendations were also received on non-flow related measures. State Water Board determinations of flow criteria rely upon four types of information:

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- Ecological functions-based analysis for desirable species and ecosystem attributes

The State Water Board emphasizes, however, information based on ecological functions, followed by information on statistical relationships between flow and native species abundance.

In all cases, the flow criteria contained in this report are those supported by the best available scientific information submitted into the record for this proceeding. The conceptual bases for all of the criteria in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for flows necessary to support particular functions. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Criteria are therefore divided into two categories: Category “A” criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category “B” criteria. The State Water Board followed the following steps to develop flow criteria and other measures:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance.
3. Review and summarize species life history requirements
4. Summarize numeric and other criteria for each of: Delta outflow, Sacramento River inflow, San Joaquin River inflow, and Hydrodynamics, including Old and Middle River flows
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

In developing its flow criteria, the State Water Board reviewed the life history requirements of the following pelagic and anadromous species:

- Chinook Salmon (various runs)
- American Shad.
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

The flow criteria needed to protect public trust resources are more than just the sum of each species-specific flow need. The State Water Board also considered the following issues to make its flow criteria determinations:

- Variability, flow paths, and the natural hydrograph
- Floodplain activation and other habitat improvements

- Water quality and contaminants
- Cold water pool management
- Adaptive management

The Board also made other specific determinations for other measures based on review of these issues.

Regulatory Authority of the State Water Board

The State Water Board was established in 1967 as the State agency with jurisdiction to administer California's water resources. The State Water Board is responsible for water allocation as well as for water quality planning and water pollution control. In carrying out its water quality planning functions under both State and federal law, the State Water Board formulates and adopts state policy for water quality control, which includes water quality principles and guidelines for long-range resource planning, water quality objectives, and other principles and guidelines deemed essential by the State Water Board for water quality control. The State Water Board has adopted a Water Quality Control Plan for the Delta (Bay-Delta Plan). The plan is implemented in part through conditions imposed in both water quality and water right permits.

The State Water Board administers the water rights program for the State, including issuing water right permits. More than two-thirds of the residents of California and more than two million acres of highly productive farmlands receive water exported from the Delta, primarily, although not exclusively, through the SWP and CVP. In addition to the SWP and CVP, there are many other diversions from the Delta and from tributaries to the Delta including the East Bay Municipal Utilities District, the San Francisco Public Utilities Commission, and Contra Costa Water District, to name a few.

Regulatory Actions by Other Agencies

In addition to the State Water Board, other state and federal agencies have authority to take regulatory action that can affect Delta inflows, outflows, and hydrodynamics. As indicated below, the United States Fish and Wildlife Service (USFWS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Game (DFG) have authority to impose regulatory conditions that affect water diversions from the Delta. The Federal Energy Regulatory Commission (FERC) also has authority over non-federal hydropower projects that can change the timing and quantity of inflows to the Delta. Over the next six years, there are 16 hydropower projects on tributaries to the Sacramento and San Joaquin rivers with potential to affect Delta tributary flows that have ongoing or pending proceedings before the FERC.

Next Steps

The State Water Board will submit its flow criteria determinations to the Council for its information within 30 days of completing its determinations as required by Water Code section 85086.

The flow criteria contained in this report will be submitted to the Council to inform the Delta Plan. The Council is required to develop the Delta Plan to implement the State's co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The Council is to develop the Delta Plan by January 2012.

The flow criteria will also inform the BDCP. The BDCP is a multispecies conservation plan being developed pursuant to the ESA and the State Natural Community Conservation Planning Act (NCCPA), administered by the USFWS and the NMFS and the DFG, respectively. The

CESA and the federal ESA generally prohibit the "take" of species protected pursuant to the acts. Both acts contain provisions that allow entities to seek approvals from the resources agencies, which approvals allow limited take of protected species under some circumstances. The BDCP is intended to meet all regulatory requirements necessary for USFWS and NMFS to issue Incidental Take Permits to allow incidental take of all proposed covered species as a result of covered activities undertaken by DWR, certain SWP contractors, and Mirant Corporation, and to issue biological opinions under the ESA to authorize incidental take for covered actions undertaken by USBR and CVP contractors. The BDCP is also intended to address all of the requirements of the NCCPA for aquatic, wetland, and terrestrial covered species of fish, wildlife, and plants and Delta natural communities affected by BDCP actions and is intended to provide sufficient information for DFG to issue permits under the CESA for the taking of the species proposed for coverage under the BDCP.

Finally, the flow criteria in this report will also inform the State Water Board's on-going and subsequent proceedings, including the review and development of flow objectives in the San Joaquin River, a comprehensive update to the 2006 Bay-Delta Plan, and the associated water rights proceedings to implement these Bay-Delta Plan updates.

2. Introduction

The purpose of this report is to identify new flow criteria for the Sacramento-San Joaquin Delta (Delta) ecosystem to protect public trust resources in accordance with the Delta Reform Act of 2009, Water Code § 85000 et seq. The flow criteria, which do not have any regulatory or adjudicative effect, may be used to inform planning decisions for the new Delta Plan being prepared by the newly created Delta Stewardship Council (Council) and the Bay Delta Conservation Plan (BDCP). The public trust resources that are the subject of this proceeding include those resources affected by flow, namely, native and valued resident and migratory aquatic species, habitats, and ecosystem processes. The State Water Resources Control Board (State Water Board or Board) has developed flow criteria to protect these resources that incorporate measures regarding Delta outflows and Delta inflows and has recommended other measures relevant to the protection of public trust resources. After approval by the State Water Board, this report will be submitted to the Council.

3. Purpose and Background

3.1 Background and Scope of Report

Pursuant to Water Code section 85086, subdivision (c), enacted on November 12, 2009, in Senate Bill No. 1 of the 2009-2010 Seventh Extraordinary Session (Stats. 2009 (7th Ex. Sess.) ch. 5, § 39) (SB 1), the State Water Board is required to "develop new flow criteria for the Delta ecosystem necessary to protect public trust resources." The purpose of this report is to comply with the Legislature's mandate to the State Water Board.

Given the limited amount of time the State Water Board had to develop the criteria, the Board initially focused on Delta outflow conditions as a primary driver of ecosystem functions in the Delta. In determining the extent of protection to be afforded public trust resources through the development of the flow criteria, the State Water Board considered the broad goals of the planning efforts the criteria are intended to inform, including restoring and promoting viable, self-sustaining populations of aquatic species. The specific goals for protection are discussed in more detail below.

The notice for this proceeding focused the proceeding on Delta outflows. During the proceeding, however, the State Water Board received useful information from participants regarding Sacramento River inflows, San Joaquin River inflows, and Delta hydrodynamics (including Old and Middle River flows, San Joaquin River at Jersey Point flows, and San Joaquin River inflow to export ratios) that is relevant to protection of public trust resources in the Delta ecosystem. The hydrodynamic criteria included in this reportare largely dependent on exports and on San Joaquin River inflows, and do not directly affect the outflows considered in this proceeding. The State Water Board believes, however, that this information should be transmitted to the Council for its use in informing the Delta Plan and BDCP. Because the notice for the proceeding focused on Delta outflows, and some of the participants did not submit scientific information on inflows and hydrodynamics for the State Water Board's consideration, the record for inflows and hydrodynamics may not be as complete, and the analyses for these flow parameters accordingly may be limited. As a result, these criteria do not constitute formal criteria within the scope of the informational proceeding as noticed, but instead are submitted to the Council with the acknowledgement that they are based on the limited information received by the State Water Board.

3.1.1 The Legislative Requirements

In November 2009, legislation was enacted comprising a comprehensive water package for California. In general, the legislation is designed to achieve a reliable water supply for future generations and to restore the Delta and other ecologically sensitive areas. The package includes a bond bill and four policy bills, one of which is SB 1.

In the Delta Reform Act, the Legislature found and declared, among other matters, that:

> "The Sacramento-San Joaquin Delta watershed and California's water infrastructure are in crisis and existing Delta policies are not sustainable. Resolving the crisis requires fundamental reorganization of the state's management of Delta watershed resources. (Wat. Code, § 85001, subd. (a).)
>
> By enacting this division, it is the intent of the Legislature to provide for the sustainable management of the Sacramento-San Joaquin Delta ecosystem, to provide for a more reliable water supply for the state, to protect and enhance the quality of water supply from the Delta, and to establish a governance structure that will direct efforts across state agencies to develop a legally enforceable Delta Plan." (Wat. Code, § 85001, subd. (c).)

Among other provisions, SB 1 establishes the Delta Stewardship Council, which is charged with responsibility to develop, adopt, and commence implementation of a Delta Plan, a comprehensive, long-term management plan for the Delta, by January 1, 2012. The legislation also establishes requirements for inclusion of the BDCP, a multispecies conservation plan, into the Delta Plan. For purposes of informing the planning efforts for the Delta Plan and BDCP, SB 1 requires the State Water Board, pursuant to its public trust obligations, to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c).) Regarding the flow criteria, the Legislature provided that the flow criteria shall:

- include the volume, quality, and timing of water necessary for the Delta ecosystem;
- be developed within nine months of enactment of SB 1;

- be submitted to the Council within 30 days of completion;
- inform planning decisions for the Delta Plan and the BDCP;
- be based on a review of existing water quality objectives and the use of the best available scientific information;
- be developed in a public process by the State Water Board as a result of an informational proceeding conducted under the board's regulations set forth at California Code of Regulations, title 23, sections 649-649.5, in which all interested persons have an opportunity to participate.
- not be considered predecisional with regard to any subsequent State Water Board consideration of a permit, including any permit in connection with a final BDCP;
- inform any State Water Board order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River;

3.1.2 The State Water Board's Public Trust Obligations

As stated above, SB 1 requires the State Water Board to develop new flow criteria to protect public trust resources in the Delta ecosystem pursuant to the Board's public trust obligations. The purpose of the public trust is to protect commerce, navigation, fisheries, recreation, ecological values, and fish and wildlife habitat. Under the public trust doctrine, the State of California has sovereign authority to exercise continuous supervision and control over the navigable waters of the state and the lands underlying those waters. (*National Audubon Society v*. *Superior Court* (*Audubon*) (1983) 33 Cal.3d 419.) A variant of the public trust doctrine also applies to activities that harm a fishery in non-navigable waters. (*People v. Truckee Lumber Co.* (1897) 116 Cal. 397, see *California Trout, Inc. v. State Water Resources Control Board* (1989) 207 Cal.App.3d 585, 630.)

In *Audubon*, the California Supreme Court held that California water law is an integration of the public trust doctrine and the appropriative water right system. (*Audubon*, *supra*, 33 Cal.3d at p. 426.) The state has an affirmative duty to take the public trust into account in the planning and allocation of water resources. The public trust doctrine requires the State Water Board to consider the effect of a diversion or use of water on streams, lakes, or other bodies of water, and "preserve, so far as consistent with the public interest, the uses protected by the trust." (*Audubon*, *supra*, 33 Cal.3d at p. 447.) Thus, before the State Water Board approves a water diversion, it must consider the effect of the diversion on public trust resources and avoid or minimize any harm to those resources where feasible. (*Id.* at p. 426.) Even after an appropriation has been approved, the public trust imposes a duty of continuing supervision. (*Id.* at p. 447*.)*

The purpose of this proceeding is to receive scientific information and develop flow criteria pursuant to the State Water Board's public trust obligations. In this forum, the State Water Board will not consider the allocation of water resources, the application of the public trust to a particular water diversion or use, or any balancing between potentially competing public trust resources. The State Water Board has also not considered minimum or maximum flows needed to protect public health and safety. Any such application of the State Water Board's public trust responsibilities, including any balancing of public trust values and water rights, would be conducted through an adjudicative or regulatory proceeding. Instead, the State Water Board's focus here is solely on identifying public trust resources in the Delta ecosystem within the scope of SB 1 and determining the flows necessary to protect those resources.

3.1.3 Public Process

The Water Code directs the State Water Board to develop the flow criteria in a public process in the form of an informational proceeding conducted pursuant to the Board's regulations. (Wat. Code, § 85086, subd. (c)(1); Cal. Code Regs., tit. 23, §§ 649-649.5.) The State Water Board conducted this informational proceeding to receive the best available scientific information to use in carrying out its mandate to develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. (Wat. Code, § 85086, subd. (c)(1).) On December 16, 2009, the State Water Board issued the notice for the public informational proceeding to develop the flow criteria. For the informational proceeding, the State Water Board required the participants to submit a Notice of Intent to Appear by January 5, 2010. The State Water Board received 55 Notices of Intent to Appear for the informational proceeding.

On January 7, 2010, the State Water Board conducted a pre-proceeding conference to discuss the procedures for the informational proceeding mandated by Water Code section 85086, subdivision (c). Topics for the pre-proceeding conference included coordination of joint presentations, use of presentation panels, time limits on presentations, and electronic submittal of written information. The conference was used only to discuss procedural matters and did not address any substantive issues.

On January 29, 2010, the State Water Board issued a revised notice amending certain procedural requirements and posted a preliminary list of reference documents. Written testimony, exhibits, and written summaries, along with lists of witnesses and lists of exhibits, were due on February 16, 2010. The State Water Board gave participants and interested parties an opportunity to submit written questions regarding the written testimony, exhibits, and written summaries by March 9, 2010. All submittals were posted on the State Water Board's website.

On March 22 through 24, the State Water Board held the public informational proceeding to develop flow criteria for the Delta ecosystem. The State Water Board received a technical introduction by the Delta Environmental Flows Group (DEFG)[4] at the beginning of the proceeding. The group prepared two documents and an associated list of references that were submitted as State Water Board exhibits:

- Key Points on Delta Environmental Flows for the State Water Resources Control Board, February 2010
- Changing Ecosystems: a Brief Ecological History of the Delta, February 2010

A subset of the group, the UC Davis Delta Solutions Group, prepared three additional papers (which were also submitted as State Water Board exhibits):

- Habitat Variability and Complexity in the Upper San Francisco Estuary
- On Developing Prescriptions for Freshwater Flows to Sustain Desirable Fishes in the Sacramento-San Joaquin Delta

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[4] The Delta Environmental Flows Group consists of William Bennett, Jon Burau, Cliff Dahm, Chris Enright, Fred Feyrer, William Fleenor, Bruce Herbold, Wim Kimmerer, Jay Lund, Peter Moyle, and Matthew Nobriga. This group of professors, researchers, and staff from various resource agencies was assembled by State Water Board staff with the intent of informing the Delta flow criteria informational proceeding.

- Ecosystem Investments for the Sacramento-San Joaquin Delta: Development of a Portfolio Framework

Over the course of the hearing, the State Water Board received information from expert witnesses in response to questions posed by Board members. The expert witnesses, representing various participants, as well as experts from the DEFG, were grouped into five panels in order to focus the discussions on specific aspects of the Delta flow criteria. These panels addressed the following topics: hydrology, pelagic fish, anadromous fish, other stressors, and hydrodynamics.

At the conclusion of the informational proceeding, participants were given approximately 20 days to submit closing comments. On July 21, 2010, the draft report was released for public review and comment.

3.1.4 Scope of This Report

Due to the limited nine-month time period in which the State Water Board must develop new flow criteria, the notice for the informational proceeding requested information on what volume, quality, and timing of Delta outflows are necessary under different hydrological conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Delta outflows are of critical importance to various ecosystem functions, water supply, habitat restoration, and other planning issues. The effect of Delta outflows in protecting public trust resources necessarily involves complex interactions with other flows in the Delta and with non-flow parameters including water quality and the physical configuration of the Delta. This report recognizes the role of source inflows used to meet Delta outflows, Delta hydrodynamics, tidal action, hydrology, water diversions, water project operations, and cold water pool storage in upstream reservoirs, and relies upon information submitted on these related topics to inform its determinations.

The State Water Board intends that the flow criteria developed in this proceeding should meet the following general goal regarding the protection of public trust resources:

- Halt the population decline and increase populations of native species as well as species of commercial and recreational importance by providing sufficient flow and water quality at appropriate times to promote viable life stages of these species.

To meet this goal, the State Water Board also sought to develop criteria that are comprehensive and that can be implemented without undue complexity. This report is limited to consideration of flow criteria needed under the existing physical conditions, so therefore does not consider or anticipate changes in habitat or modification of water conveyance facilities. The State Water Board does, however, identify other measures that should be considered in conjunction with, and to complement, the flow criteria.

A number of factors outside the scope of the legislative mandate to develop new flow criteria could affect public trust resources and some other factors could affect the interaction of flows with the environment. These factors include contaminants, water quality parameters, future habitat restoration measures, water conveyance facilities modification, and the presence of non-native species.

3.1.5 Concurrent State Water Board Processes

The State Water Board has a number of ongoing proceedings that may be informed by the development of flow criteria. Some of these proceedings will result in regulatory requirements that affect flow, or otherwise affect the volume, quality, or timing of flows into, within, or out of the Delta. In July 2008, the State Water Board adopted a strategic work plan for actions to protect beneficial uses of the San Francisco Bay/Delta (Bay-Delta). In accordance with the work plan, the State Water Board recently completed a periodic review of the 2006 Water Quality Control Plan for the Bay-DeltaEstuary (Bay-Delta Plan) that recommended the Delta Outflow objectives, as well as other flow objectives, for further review in the water quality control planning process. Currently, the State Water Board is in the process of reviewing the southern Delta salinity and the San Joaquin River flow objectives contained in the Bay-Delta Plan.

Clean Water Act Water Quality Certifications

Several non-federal hydropower projects with potential to affect Delta tributary flows have ongoing or pending proceedings before the Federal Energy Regulatory Commission (FERC) that will result in the issuance of new licenses that will govern operations for the 30-50 year term. The relicensing process allows state and federal agencies to prescribe conditions to achieve certain objectives such as state water quality standards and the protection of listed species. New license conditions may include instreams flows requirements or other conditions to protect aquatic species. For example, the new license for the Oroville Dam will require changes in minimum flow requirements and changes in facilities and operations to meet certain water temperature requirements to protect Chinook salmon, steelhead, and green sturgeon. By 2016, more than 25 Delta tributary dams will go through the relicensing process.

The State Water Board will rely upon the FERC license application and the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) documents prepared for the projects, and may require submittal of additional data or studies, to inform its Clean Water Act Section 401 Water Quality Certifications for the projects. The Board’s water quality certification will be issued as soon as possible after the environmental documents and any other needed studies are complete, after which FERC will issue a new license. The conditions in the water quality certification are mandatory and must be included in the FERC license.

Information developed as part of the relicensing of these projects will be used to inform on-going Bay Delta proceedings, and any information developed in the State Water Board’s Bay Delta proceedings will be used to inform the two water quality certifications.

Table 1 summarizes the dams, tributaries, and license expiration dates for FERC projects in the Delta watershed. Several of these projects are upstream of major dams and reservoirs in the Sacramento and San Joaquin river watershed so operational changes would have little or no direct effect upon Delta flows.

Table 1. Delta Watershed FERC Projects

River	Dam(s)	Storage Capacity (acre-feet)	Owner	Status of Proceeding	FERC License Expiration
Feather	Oroville	3.5 million	Department of Water Resources (DWR)	Near completion	January 2007
West Branch Feather	Philbrook, Round Valley	6,200	Pacific Gas and Electric Company (PG&E)	Near Completion	October 2009
South Feather	Little Grass Valley	90,000	South Feather Water and Power Agency	Near completion	March 2009
Upper North Fork Feather	Lake Almanor	1.1 million	PG&E	Near Completion	October 2004
Pit River	McCloud, Iron Canyon,Pit 6, 7	110,000	PG&E	Ongoing	July 2011
North Yuba	New Bullards Bar	970,000	Yuba County Water Agency	Pre-Licensing meetings started	March 2016
Middle and South Yuba, Bear	Yuba-Bear Project, 10+ dams	210,000	Nevada Irrigation District	Ongoing	April 2013
Middle & South Yuba, Bear	Drum-Spaulding Project, 10+ dams	150,000	PG&E	Ongoing	April 2013
Middle Fork American River	French Meadows, Hell Hole	340,000	Placer County Water Agency	Ongoing	February 2013
South Fork American River	Loon Lake, Slab Creek	400,000	Sacramento Municipal Utility District	Near completion	July 2007
South Fork American River	Chili Bar	1,300	PG&E	Near completion	July 2007
Tuolumne	New Don Pedro	2 million	Turlock Irrigation District	To commence late 2010	April 2016
Merced	New Exchequer/ McSwain	1 million	Merced Irrigation District	Ongoing	February 2014
Merced	Merced Falls	650	PG&E	Ongoing	February 2014
San Joaquin	Mammoth Pool	120,000	Southern California Edison	Near Completion	November 2007
San Joaquin	Huntington, Shaver, Florence	320,000	Southern California Edison	Near Completion	February 2009

3.1.6 Delta Stewardship Council and Use of This Report

In accordance with the legislative requirements described above, the State Water Board will submit this report, containing its Delta flow criteria determinations, to the Council within 30 days after this report has been completed. This report will be deemed complete on the date the State Water Board adopts a resolution approving transmittal of the report to the Council.

Additionally, SB 1 requires any order approving a change in the point of diversion of the State Water Project (SWP) or the Central Valley Project (CVP) from the southern Delta to a point on the Sacramento River to include appropriate flow criteria and to be informed by the analysis in this report. (Wat. Code, § 85086, subd. (c)(2).) The statute also specifies, however, that the criteria shall not be considered predecisional with respect to the State Water Board's subsequent consideration of a permit. (*Id.*, § 85086, subd. (c)(1).) Thus, any process with regulatory or adjudicative effect must take place through the State Water Board's water quality control planning or water rights processes in conformance with applicable law. Any person who wishes to introduce information produced during this informational proceeding, or the State Water Board's ultimate determinations in this report, into a later rulemaking or adjudicative proceeding must comply with the rules for submission of information or evidence applicable to that proceeding.

3.2 Regulatory Setting

3.2.1 History of Delta Flow Requirements

The State Water Rights Board (a predecessor to the State Water Board) first had an opportunity to consider flow requirements in the Delta when it approved water rights for much of the U.S. Bureau of Reclamation's (USBR) CVP in Water Right Decision 990 (D-990) (adopted in 1961), but it did not impose any fish protection conditions in D-990. In 1967, the State Water Rights Board included fish protections in D-1275 approving the water right permits for the SWP. Effective December 1, 1967, the State Water Rights Board and the State Water Quality Control Board were merged in a new agency, the State Water Board, which exercises both the water quality and water rights adjudicatory and regulatory functions of the state. The State Water Board adopted a new water quality control policy for the Delta and Suisun Marsh in October 1968, in Resolution 68-17. The resolution specified that the objectives would be implemented through conditions on the water rights of the CVP and SWP.

To implement the water quality objectives, the State Water Board adopted Water Right Decision 1379 (D-1379) in 1971[5]. D-1379 established new water quality requirements in both the SWP and CVP permits, including fish flows, and rescinded the previous SWP requirements from D-1275 and D-1291. D-1379 was stayed by the courts and eventually was superseded by Water Right Decision 1485 (D-1485).

In April 1973, in Resolution 73-16, the State Water Board adopted a water quality control plan to supplement the State water quality control policies for the Delta.

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[5] In 1971, the State Water Board approved interim regional water quality control plans for the entire State, including the Delta and Suisun Marsh. Subsequently, the State Water Board approved long-term objectives for the Delta and Suisun Marsh in the regional plans for the Sacramento-San Joaquin Delta Basin and the San Francisco Bay Basin.

In August 1978, the State Water Board adopted both D-1485 and the 1978 Delta Plan. Together the 1978 Delta Plan and D-1485 revised existing objectives for flow and salinity in the Delta's channels and ordered USBR and DWR to meet the objectives. In 1987, the State Water Board commenced proceedings to review the 1978 Delta Plan and D-1485. The Board held a hearing at numerous venues in California and released a draft water quality control planin 1988, but subsequently withdrew it and resumed further proceedings.

In 1991, the State Water Board adopted the 1991 water quality control plan. This is the first Bay-Delta plan to adopt objectives for dissolved oxygen (DO) and temperature. The 1991 Bay-Delta plan did not amend either the flow or water project operations objectives adopted in the 1978 Delta Plan.[6] The United States Environmental Protection Agency (USEPA) approved the objectives in the plan for salinity for municipal, industrial, and agricultural uses, and approved the new DO objectives for fish and wildlife, but disapproved the Delta outflow objectives for the protection of fish and wildlife carried over from the 1978 Delta Plan. The USEPA adopted its own Delta outflow standards in 1994 to supersede the State's objectives.

In the summer of 1994, after the USEPA had initiated its process to develop standards for the Delta, the State and federal agencies with responsibility for management of Bay-Delta resources signed a Framework Agreement, agreeing that: (1) the State Water Board would update and revise its 1991 Bay-Delta Plan to meet federal requirements and would initiate a water right proceeding to implement the plan, after which the USEPA would withdraw its fish and wildlife objectives; (2) a group would be formed to coordinate operations of the SWP and CVP with all regulatory requirements in the Delta; and (3) the State and federal governments would undertake a joint long-term solution finding process to resolve issues in the Bay-Delta. In December 1994, representatives of the State and federal governments, water users, and environmental interests agreed to the implementation of a Bay-Delta protection plan. The plan and institutional documents to implement it are contained in a document titled "Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government." This is commonly referred to as the "Bay-Delta Accord" or "Principles Agreement."

In 1995 the State Water Board adopted the 1995 Bay-Delta Plan, which is consistent with the Principles Agreement.[7] In response to a water right change petition filed by DWR and USBR, the State Water Board then adopted Water Right orders that temporarily allowed DWR and USBR to operate the SWP and CVP in accordance with the 1995 Plan while the State Water Board conducted water right proceedings for a water right decision that would implement the 1995 Bay-Delta Plan. The hearing commenced in 1998 and concluded in 1999. During the 1998-99 water right hearing, DWR and USBR and their water supply contractors negotiated with a number of parties. In 1999, the State Water Board adopted Decision 1641 (D-1641) and subsequently revised D-1641 in 2000.

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[6] After adopting the 1991 Plan, the State Water Board conducted a proceeding to establish interim water right requirements for the protection of public trust uses in the Delta. The State Water Board released a draft water right decision known as "Decision 1630" (D-1630), but did not adopt it.

[7] USEPA approved the 1995 Bay-Delta Plan. By approving the 1995 Bay-Delta Plan, the USEPA supplanted its own water quality standards with the standards in the 1995 Bay-Delta Plan. (*State Water Resources Control Board Cases* (2006) 136 Cal.App.4th 674,774-775 [39 Cal.Rptr.3d 189]; 33 U.S.C. § 1313(c)(2)(A),(c)(3).)

3.2.2 Current State Water Board Flow Requirements

The current Bay-Delta flow requirements are contained in the 2006 Bay-Delta Plan and in D-1641. D-1641 implements portions of the 1995 Bay-Delta Plan. D-1641 accepts the contribution that certain entities, through their agreements, will make to meet the flow-dependent water quality objectives in the 1995 Plan, and continues the responsibility of DWR and USBR for the remaining measures to meet the flow-dependent objectives and other responsibilities. In addition, D-1641 recognizes the San Joaquin River Agreement (SJRA) and approves, for a period of twelve years, the conduct of the Vernalis Adaptive Management Plan (VAMP) under the SJRA instead of meeting the San Joaquin River pulse flow objectives in the 1995 Plan. The 2006 Bay-Delta Plan is consistent with D-1641 and makes only minor changes to the 1995 Bay-Delta Plan, allowing the staged implementation of the San Joaquin River spring pulse flow objectives and other minor changes. The 2006 Bay-Delta Plan also identifies a number of issues requiring additional review and planning including: the pelagic organism decline (POD), climate change, Delta and Central Valley salinity, and San Joaquin River flows.

Current Delta outflow requirements, set forth in Tables 3 and 4 in both the 2006 Bay-Delta Plan and D-1641, take two basic forms based on water year type and season: 1) specific numeric Delta outflow requirements; and 2) position of X2, the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). The Delta outflow requirements are expressed in Table 3 as a Net Delta Outflow Index (NDOI). The NDOI is a calculated flow expressed as Delta Inflow, minus net Delta consumptive use, minus Delta exports. Each component is calculated as described in the 2006 Bay-Delta Plan and D-1641. An electrical conductivity (EC) measurement of 2.64 mmhos/cm at Collinsville station C2 can be substituted for the NDOI during February through June. The most downstream location of either the maximum daily average or the 14-day running average of this EC level is commonly referred to as the position of "X2" in the Delta. Table 4 specifies EC measurements at two specific locations and alternatively allows an NDOI calculation at these locations.

3.2.3 Special Status Species

The California Endangered Species Act (CESA) states that all native species of fishes, amphibians, reptiles, birds, mammals, invertebrates, and plants, and their habitats, threatened with extinction and those experiencing a significant decline which, if not halted, would lead to a threatened or endangered designation, will be protected or preserved. The federal Endangered Species Act of 1973 (ESA) provides for the conservation of species that are endangered or threatened throughout all or a significant portion of their range, and the conservation of the ecosystems on which they depend. A number of species discussed in this report are afforded protections under CESA and ESA. These species and the protections are discussed below.

The longfin smelt (*Spirinchus thaleichthys*) is currently a candidate for threatened species status under the CESA. (DFG 1, p. 9.) In March 2009, the California Fish and Game Commission (Commission) made a final determination that the listing of longfin smelt as a threatened species was warranted and the rulemaking process to officially add the species to the CESA list of threatened species found in the California Code of Regulations was initiated. Upon completion of this rulemaking process, the longfin smelt's status will officially change from candidate to threatened. (DFG 1, p. 9.) Its status remains unresolved at the federal level. (USFWS 2009.) The delta smelt (*Hypomesus transpacificus*) is listed as endangered and threatened pursuant to the CESA and ESA, respectively. (DFG 1, p. 14; USFWS 1993.) In April 2010, the United States Fish and Wildlife Service (USFWS) considered a petition to reclassify the delta smelt from threatened to endangered. After review of all available scientific and commercial information, the USFWS found that reclassifying the delta smelt from a threatened to an endangered species is warranted, but precluded by other higher priority listing actions. (USFWS 2010.)

Sacramento winter-run Chinook salmon *(Oncorhynchus tshawytscha)* is listed as endangered pursuant to the CESA and ESA. (NMFS 1994; NMFS 2005; DFG 2010.) Central Valley spring-run Chinook salmon (*O. tshawytscha*) is listed as threatened pursuant to both the CESA and ESA. (NMFS 1999; NMFS 2005; DFG 2010.) Central Valley fall/late fall-run Chinook salmon (*O. tshawytscha*) are classified as species of special concern by the National Marine Fisheries Service (NMFS). (NMFS 2004.) Central Valley steelhead (*O. mykiss*) is listed as threatened under the ESA (NMFS 1998; NMFS 2006a.) Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*) is listed as threatened under the ESA. (NMFS 2006b.)

3.2.4 State Incidental Take Permit for Longfin Smelt

The CESA prohibits the take[8] of any species of wildlife designated as an endangered, threatened, or candidate species[9] by the Commission. The Department of Fish and Game (DFG), however, may authorize the take of such species by permit if certain conditions are met (Cal. Code Regs., tit 14, § 783.4). In 2009, DFG issued an Incidental Take Permit for Longfin Smelt to the DWR for the on-going and long-term operation of the SWP. The permit specifies a number of conditions, including two flow measures (Conditions 5.1 and 5.2) intended to minimize take of the longfin smelt and provide partial mitigation for the remaining take by: 1) minimizing entrainment; 2) improving estuarine processes and flow; 3) improving downstream transport of longfin smelt larvae; and 4) providing more water that is used as habitat (increasing habitat quality and quantity) by longfin smelt than would otherwise be provided by the SWP.

Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1.
This Condition is not likely to occur in many years. To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide Old and Middle River (OMR) flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5,000 cfs and the initial 5-day running average is not more negative than -6,250 cfs. During any time OMR flow restrictions for the USFWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55,000 cfs in

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[8] Pursuant to Fish and Game Code section 86, "'Take' means hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture or kill."

[9] "Candidate species" are species of wildlife that have not yet been placed on the list of endangered species or the list of threatened species, but which are under formal consideration for listing pursuant to Fish and Game Code section 2074.2

the Sacramento River at Rio Vista; or 2) > 8,000 cfs in the San Joaquin River at Vernalis. If flows go below 40,000 cfs in the Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2.
To protect larval and juvenile longfin smelt during January -June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1,250 and -5,000 cfs and be based on review of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period - Jan through Mar OMR range from -1,250 to -5,000 cfs; Medium Entrainment Risk Period - April and May OMR range from -2000 to -5,000 cfs, and Low Entrainment Risk Period - June OMR -5,000 cfs. When river flows are: 1) greater than 55,000 cfs in the Sacramento River at Rio Vista; or 2) greater than 8,000 cfs in the San Joaquin River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40,000 cfs in Sacramento River at Rio Vista or 5,000 cfs in the San Joaquin River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.

3.2.5 Biological Opinions

In 2008 and 2009, the USBR and the DWR concluded consultations regarding the effects of continued long-term operations of the Central CVP and SWP with the USFWS and the NMFS, respectively. Those consultations led to the issuance of biological opinions that require implementation of reasonable and prudent alternatives (RPAs) to avoid jeopardizing the continued existence and potential for recovery of delta smelt (*Hypomesus transpacificus*), Sacramento River winter-run Chinook salmon *(Oncorhynchus tshawytscha)*, Central Valley spring-run Chinook salmon (*O. tshawytscha*), Central Valley steelhead (*O. mykiss*), Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*), and Southern Resident killer whales *(Orcinus orca)*.

Pursuant to Section 7 of the ESA, federal agencies must insure that their actions do not jeopardize the continued existence of threatened or endangered species or adversely modify their designated critical habitat. The regulations (50 CFR 402.02) implementing Section 7 of the ESA define RPAs as alternative actions, identified during formal consultation, that: 1) can be implemented in a manner consistent with the intended purpose of the action; 2) can be implemented consistent with the scope of the action agency’s legal authority and jurisdiction; 3) are economically and technologically feasible; and, 4) would, the USFWS or NMFS believes, avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat. (USFWS 2008, p.279.)

Numerous anthropogenic and other factors (e.g., pollutants and non-native species) that may adversely affect listed fish species in the region are not under the direct control of the CVP or the SWP and as such are not addressed in the biological opinions.

USFWS Biological Opinion

On December 15, 2008, the USFWS issued a biological opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the CVP and SWP (UFWS Opinion). The RPA in the USFWS Opinion, divided into six actions, applies to delta smelt and focuses primarily on managing flow regimes to reduce entrainment of delta smelt and on the extent of suitable water conditions in the Delta, as well as on construction or restoration of habitat. (USFWS 2008, pp.329-381.) Flow related components of the RPA include:

- A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. This action limits exports so that the average daily net OMR flow is no more negative than -2,000 cubic-feet per second (cfs) for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent) (Action 1, p.329).

- An adaptive process to continue to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions after the action identified above. The range of net daily OMR flows will be more no more negative than -1,250 to -5,000 cfs. From the onset of this action through its termination, the Delta Smelt Working Group would provide weekly recommendations for specific net OMR flows based upon review of the sampling data, from real-time salvage data at the CVP and SWP, and utilizing the most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored variables of flow and turbidity. The USFWS will make the final determination (Action 2, p.352).

- Upon completion of Actions 1 and 2 or when Delta water temperatures reach 12°C (based on a 3-station average of daily average water temperature at Mossdale, Antioch, and Rio Vista) or when a spent female delta smelt is detected in the trawls or at the salvage facilities, the projects shall operate to maintain net OMR flows no more negative than -1,250 to -5000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25% of the applicable 14-day OMR flow requirement. Action continues until June 30th or when Delta water temperatures reach 25˚C, whichever comes first (Action 3, p.357).

- Improve fall habitat, both quality and quantity, for delta smelt through increasing Delta outflow during fall (fall X2). Subject to adaptive management, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 km in the fall following wet years and 81km in the fall following above normal years. The monthly average X2 must be maintained at or seaward of these values for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up

- To minimize entrainment of larval and juvenile delta smelt at the State and federal south Delta export facilities or from being transported into the south and central Delta, where they could later become entrained, do not install the Head of Old River Barrier (HORB) if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description of the biological opinion. If installation of the HORB is allowed, the Temporary Barrier Project flap gates would be tied in the open position until May 15 (Action 5, p. 377).

- Implement habitat restoration activities designed to improve habitat conditions for delta smelt by enhancing food production and availability to supplement the benefits resulting from the flow actions described above. DWR shall implement a program to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh. The restoration efforts shall begin within 12 months of signature of this biological opinion and be completed within a 10 year period (Action 6, p. 379).

NMFS Biological Opinion

On June 4, 2009, NMFS issued its Biological and Conference Opinion on the OCAP (NMFS Opinion), which provides RPA actions to protect winter-run and spring-run Chinook salmon, Central Valley steelhead, green sturgeon, and killer whales from project effects in the Delta and upstream areas. (NMFS 3.) The RPA consists of five actions with a total of 72 subsidiary actions. Included within the RPA are actions related to: formation of technical teams, research and adaptive management, monitoring and reporting, flow management, temperature management, gravel augmentation, fish passage and reintroduction, gate operations and installation (Red Bluff Diversion Dam, Delta Cross Channel Gate, South Delta Improvement Program), funding for fish screening, floodplain and other habitat restoration, hatchery management, export restrictions, CVP and SWP fish collection facility modifications, and fish collection and handling. The flow related components of the opinion include:

- In the Sacramento River Basin – flow requirements for Clear Creek; release requirements from Whiskeytown Dam for temperature management; cold water pool management of Shasta Reservoir; development of flow requirements for Wilkins Slough; and restoration of floodplain habitat in the lower Sacramento River basin to better protect Chinook salmon, steelhead, and green sturgeon. (*Id at* pp.587-611.)

- In the American River - flow requirements and cold water pool management requirements to provide protection for steelhead. (*Id at* pp. 611-619.)

- In the San Joaquin River Basin – cold water pool management, floodplain inundation flows, and flow requirements for the Stanislaus River (NMFS 3, pp. 619-628, Appendix 2-E) and an interim minimum flow schedule for the San Joaquin River at Vernalis during April and May effective through 2011 for the protection of steelhead. (*Id at* pp. 641-645.)

- In the Delta – Delta Cross-Channel Gate operational requirements; net negative flow requirements toward the export pumps in Old and Middle rivers; and export limitations based on a ratio of San Joaquin River flows to combined SWP and CVP export during April and May for the protection of Chinook salmon and steelhead. (*Id. at* pp. 628-660.)

It is important to note that the flow protections described in the project description and RPA are the minimum flows necessary to avoid jeopardy. (NMFS written summary, p.3.) In addition, NMFS considered provision of water to senior water rights holders to be non-discretionary for purposes of the ESA as it applies to Section 7 consultation with the USBR, which constrained development of RPA Shasta storage actions and flow schedules. San Joaquin River flows at Vernalis were constrained by the NMFS Opinion's scope extending only to CVP New Melones operations. Operations on other San Joaquin tributaries were not within the scope of the consultation. (*Id.*)

Recent Litigation

Both the USFWS Opinion and the NMFS Opinion are the subject of ongoing litigation in the United States District Court for the Eastern District of California. Plaintiffs challenged the validity of the opinions under various legal theories, including claims under the ESA and the NEPA. Most recently, this year plaintiffs Westlands Water District and San Luis Delta Mendota Water Authority sought preliminary injunctions against the implementation of certain RPAs identified by NMFS and USFWS in their biological opinions for the protection of Delta smelt and Central Valley steelhead and salmonids. In May 2010, Judge Wanger issued a ruling concluding that injunctive relief was appropriate with respect to the NMFS biological opinion PRA Action IV.2.1, which limits pumping based on San Joaquin River inflow from April 1 through May 31, and RPA Action IV.2.3, which imposes restrictions on negative OMR flows in generally between January 1 and June 15. Later that month, he also ruled that injunctive relief was appropriate with respect to RPA Component 2 of Action 3 of the USFWS Opinion, which requires net OMR flows to remain between -1,250 and -5,000 cfs during a certain period for the protection of larval and juvenile delta smelt. The validity of the biological opinions likely will continue to be litigated in the foreseeable future, creating uncertainty about implementation of the RPAs.

3.3 Environmental Setting

Figure 1 is a map of the Bay-Delta Estuary that was included in the 2006 Bay-Delta Plan. The map depicts the location of monitoring stations used to collect baseline water quality data for the Bay-Delta Estuary and stations used to monitor compliance with water quality objectives set forth in the Bay-Delta Plan.

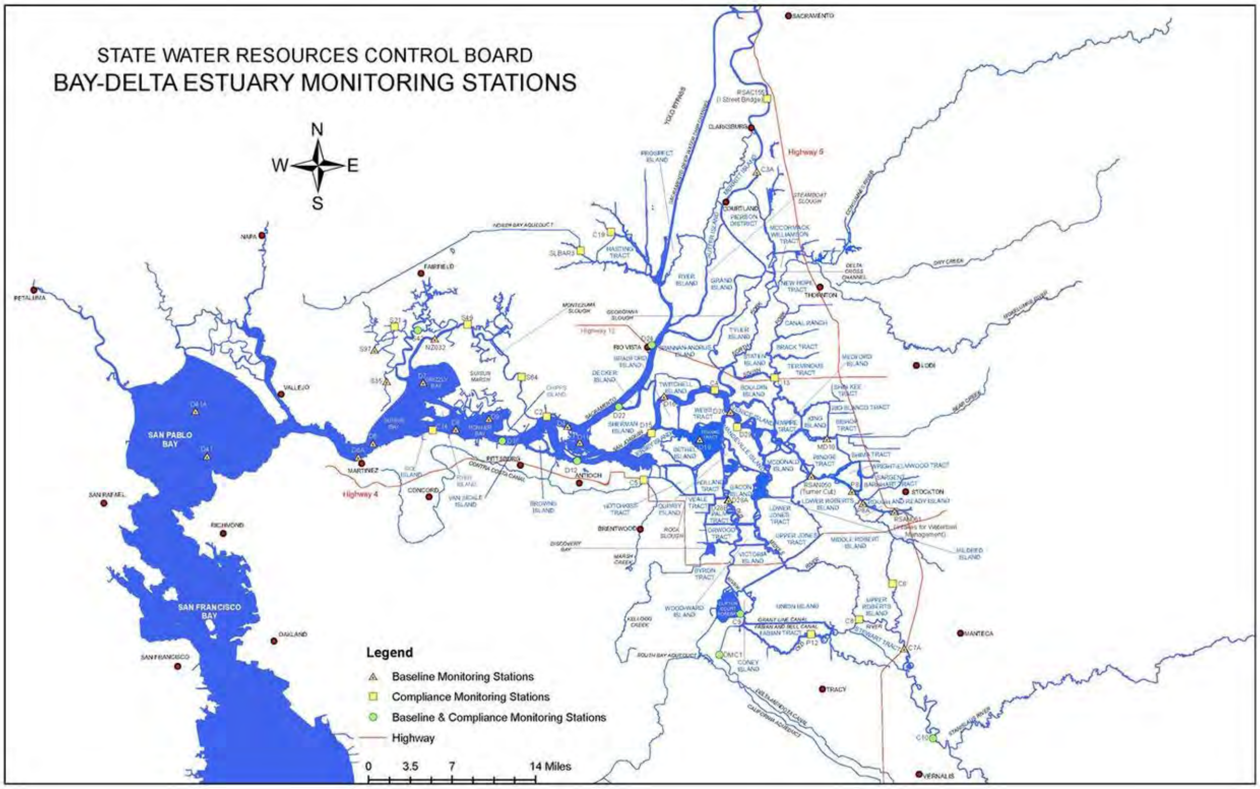


Figure 1. Map of the Bay-Delta Estuary

3.3.1 Physical Setting

The Delta is located where California's two major river systems, the Sacramento and San Joaquin rivers, converge from the north and south and are joined by several tributaries from the Central Sierras to the east, before flowing westward through the San Francisco Bay to the Pacific Ocean. The Sacramento and San Joaquin rivers drain water from the Central Valley Basin, which includes about 40 percent of California's land area.

Outflow from the Delta enters Suisun Bay just west of the confluence of the Sacramento and San Joaquin rivers. Suisun Marsh, which is located along the north shore of Suisun Bay, is one of the few major marshes remaining in California and is the largest remaining brackish wetland in Western North America. The marsh is subject to tidal influence and is directly affected by Delta outflow. Suisun Marsh covers approximately 85,000 acres of marshland and water ways and provides a unique diversity of habitats for fish and wildlife.

The Old Delta
The Delta formed as a freshwater marsh through the interaction of river inflow and the strong tidal influence of the Pacific Ocean and San Francisco Bay. The growth and decay of tules and other marsh plants resulted in the deposition of organic material, creating layers of peat that formed the soils of the marsh. Hydraulic mining during the Gold Rush era washed large amounts of sediment into the rivers, channels and bays, temporarily burying the wetlands. The former wetland areas were reclaimed into more than 60 islands and tracts that are devoted primarily to farming. A network of levees protects the islands and tracts from flooding, because most of the islands lie near or below sea level due to the erosion and oxidation of the peat soils.

As shown in Figure 2 (Courtesy, Chris Enright, DWR, using Atwater data), prior to reclamation, the channels in the Delta were connected in a dendritic, or tree-like, pattern and may have included 5 to 10 times as many miles of interconnected channels as it does today, with largely unidirectional flow.

Figure 2. The Old Delta (*ca.* 1860).

The Recent Delta

Today's Delta covers about 738,000 acres, of which about 48,000 acres are water surface area, and is interlaced with about 700 miles of waterways. As shown in Figure 3 (Courtesy, Chris Enright, DWR, using Atwater data), today's remaining Delta waterways have been greatly modified to facilitate the bi-directional movement of water and the river banks have been armored to protect against erosion, thus changing the geometry of the stream channels and eliminating most of the natural vegetation and habitat of the aquatic and riparian environment. The interconnected geometry and channelized sloughs of the present Delta result in much less variability in water quality than the past dendritic pattern, and today's mostly open ended sloughs results in water quality and habitat being relatively homogenous throughout the system. (Moyle et al. 2010.)

Figure 3. The Recent Delta

The Changing Delta

The Delta Environmental Flows Group (DEFG 2) describes in *Changing Ecosystems: a Brief Ecological History of the Delta* how the Delta has undergone significant physical and biological modification over the past 150 years. Initial development occurred during the Gold Rush when large amounts of sediment washed into the Delta, followed by diking and dredging of rivers. This was followed by increasing diversions and developments, including fixing of levees and channels, and most recently with large-scale dam development and diversions from the Delta. The Moyle et al. history also suggests what is likely to happen in the future:

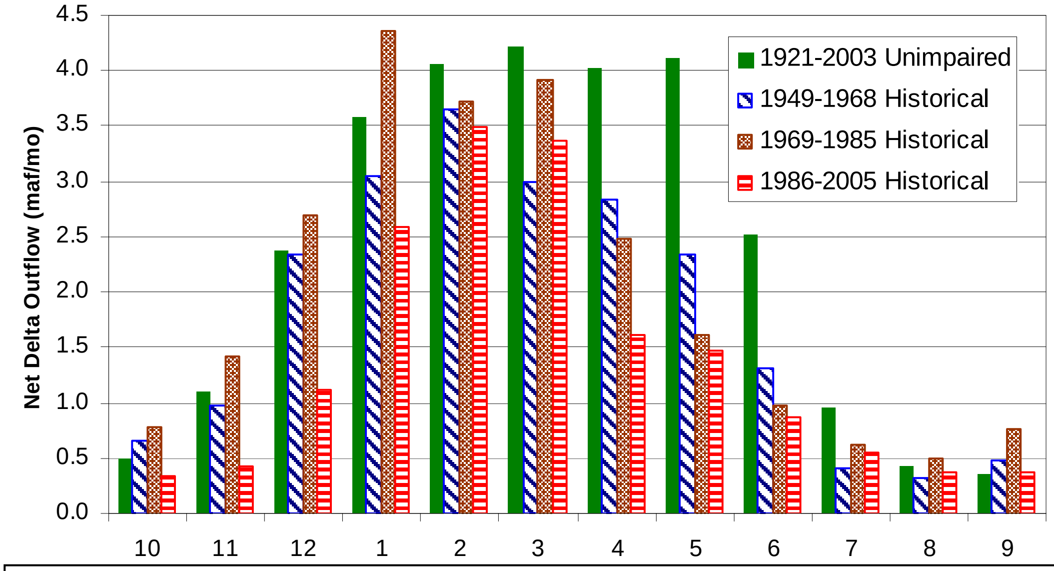
> "The Delta ecosystem is likely to dramatically shift again within 50 years due to large-scale levee collapse in the Delta and Suisun Marsh. Major levee failures are inevitable due to continued subsidence, sea level rise, increasing frequency of large floods, and high probability of earthquakes. These significant changes will create large areas of open water and increased salinity intrusion, as well as new tidal and subtidal marshes. Other likely changes include reduced freshwater inflow during prolonged droughts, altered hydraulics from reduced export pumping, and additional alien invaders (e.g., zebra and quagga mussels). The extent and effects of all these changes are unknown but much will depend on how the estuary is managed in response to change or even before change takes place. Overall, these major changes in the estuary's landscape are likely to promote a more variable, heterogeneous estuary, especially in the Delta and Suisun Marsh. This changed environment is likely to be better for desirable estuarine species; at least it is unlikely to be worse."

3.3.2 Hydrology/Hydrodynamics

California's climate and hydrology are Mediterranean, which is characterized by most precipitation falling during the winter-spring wet season, a dry season extending from late spring through early fall, and high inter-annual variation in total runoff. The life history strategies of all native estuarine Delta fishes are adapted to natural variability. (Moyle and Bennett 2008, as cited in Fleenor et al. 2010.) Although the unimpaired flow record does not indicate precise, or best, flow requirements for fish under current conditions, the general timing (e.g., seasonality), magnitudes, and directions of flows seen in the unimpaired flow record are likely to remain important for native species under contemporary and future conditions. (Fleenor et al. 2010.)

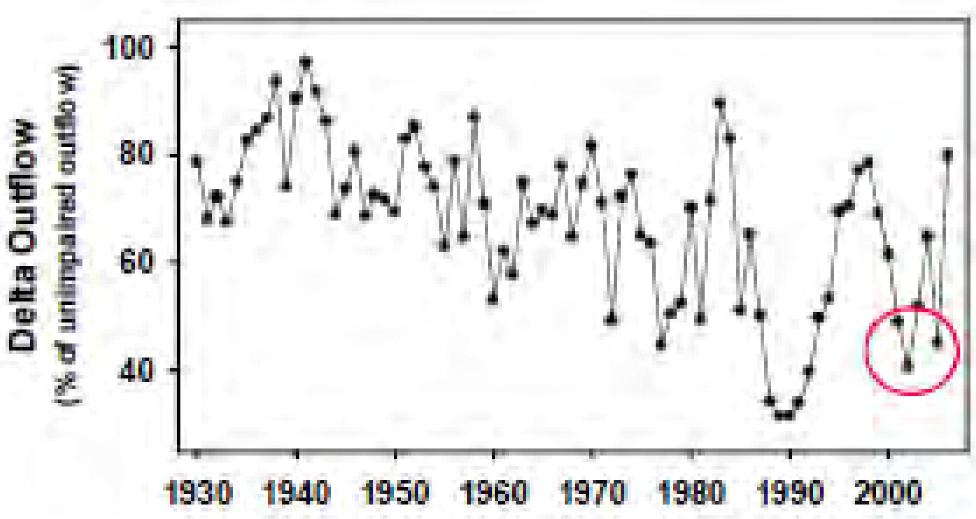
Inflow to the Delta comes primarily from the Central Valley Basin's Sacramento and San Joaquin river systems and is chiefly derived from winter and spring runoff originating in the Cascade and Sierra Nevada mountains, with minor amounts from the Coast Ranges. Precipitation totals vary annually with about 80 percent of the total occurring between the end of October and the beginning of April. Snow storage in the high Sierra delays the runoff from that area until the snow melts in April, May, and June. Normally, about half of the annual runoff from the Central Valley Basin occurs during this period. In recent years, the Sacramento River contributed roughly 75 to 80% of the Delta inflow in most years, while the San Joaquin River contributed about 10 to 15%. The minor flows of the Mokelumne, Cosumnes, and Calaveras rivers, which enter into the eastern side of the Delta, contributed the remainder of the inflow to the Delta.

Net Delta outflow represents the difference between the sum of freshwater inflows from tributaries to the Delta and the sum of exports and net in-Delta consumptive uses. (Kimmerer 2004, DOI 1, p.17.) As noted above, the majority of the freshwater flow into the Delta occurs in winter and spring; however, upstream storage and diversions have reduced the winter-spring flow and increased flow in summer and early fall. (Figure 4, Kimmerer 2002b; Kimmerer 2004; DOI 1, p. 16.) The April-June reductions are largely the result of the San Joaquin River diversions. (Fleenor et al. 2010.) During the summer-fall dry season the Delta channels essentially serve as a conveyance system for moving water from reservoirs in the north to the CVP and SWP export facilities, as well as the smaller Contra Costa Water District facility, for subsequent delivery to farms and cities in the San Joaquin Valley, southern California, and/or other areas outside the watershed. (Kimmerer 2002b.) Figure 5 shows the reduction in annual Delta outflow as a percentage of unimpaired outflow. The combined effects of water exports and upstream diversions reduced average annual net outflow from the Delta from unimpaired conditions by 33% and 48% during the 1948 – 1968 and 1986 – 2005 periods, respectively. (Fleenor et al. 2010.)



This figure shows monthly average net delta outflows (in million acre-feet per month) compared to the unimpaired flows from 1921-2003. Unimpaired flow data is from DWR (2006) and other from Dayflow web site. (Source: Fleenor et al. 2010, Figure 7.)

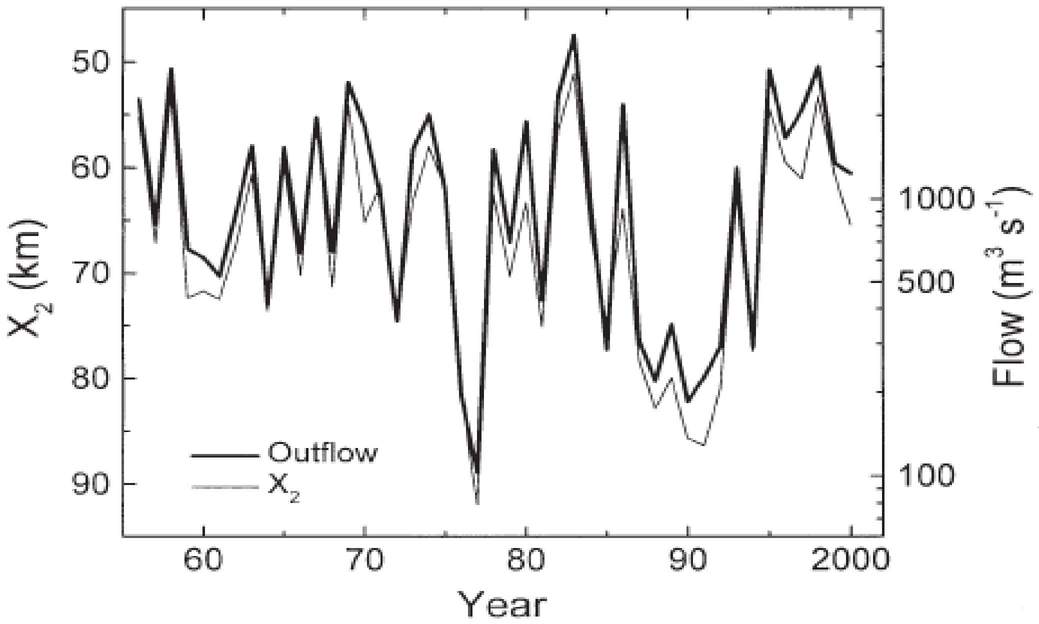
Figure 4. Monthly Average Net Delta Outflows from Fleenor et al. 2010



Delta outflow shown as a percentage of unimpaired outflow (1930-2005); in the last decade annual outflow is reduced by more than 50% in 2001, 2002, and 2005. (Source: TBI 2007, as cited in DOI 1, p. 17.)

Figure 5. Delta Outflow as a Percent of Unimpaired Outflow from TBI 2007

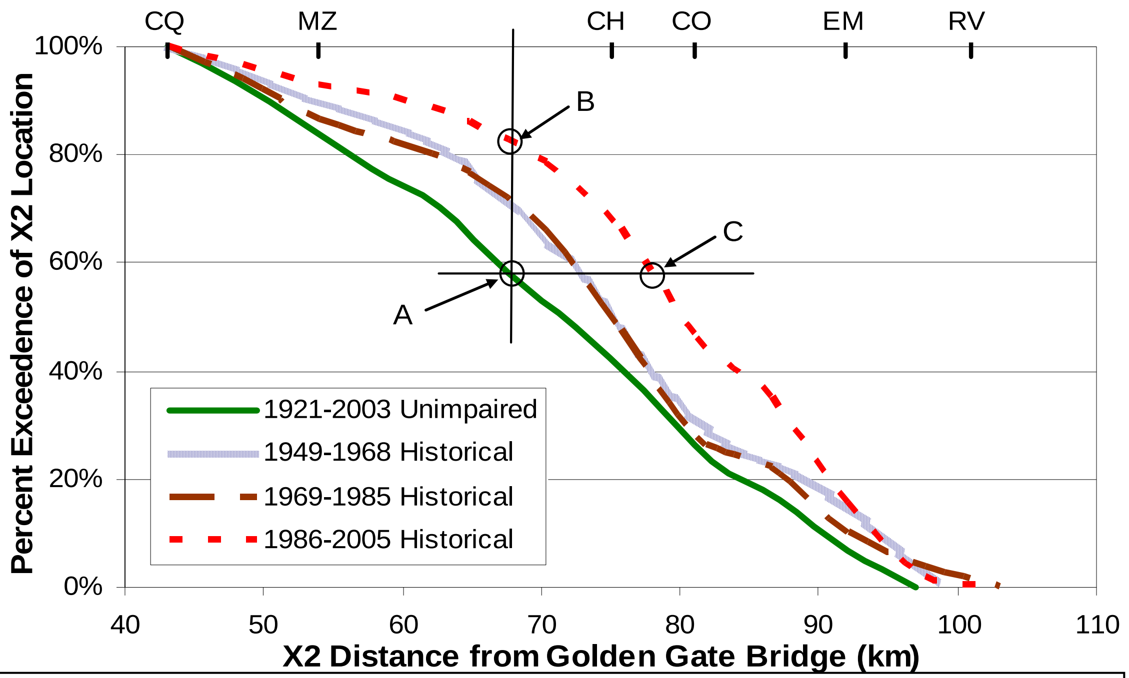
Delta outflows and the position of X2 are closely and inversely related, with a time lag of about two weeks. (Jassby et al. 1995; Kimmerer 2004.) A time series of the annual averages for January to June of X2 and Delta outflow is depicted in Figure 6. X2 is defined as the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units (psu). (Jassby et al. 1995, Kimmerer 2002a.) The position of X2 roughly equates to the center of the low salinity zone (defined as salinity of 0.5 to 6 psu). (Kimmerer 2002a.) The X2 objectives in the 2006 Bay-Delta Plan were designed to restore a more natural hydrograph and salinity pattern by requiring maintenance of the low salinity zone at specified points and durations based on the previous month's Eight River Index. (State Water Board 2006a.) The relationships between outflow and several measures of the health of the Bay-Delta Estuary have been known for some time (Jassby *et al*. 1995) and are the basis for the current X2 objectives.



Time series of X2 (thin line, left axis, scale reversed) and flow (heavy line, right axis, log scale), annual averages for January to June; flow data from DWR; X2 calculated as in Jassby et al. (1995) (Source: Kimmerer 2002a, Figure 3).

Figure 6. X2 and Delta Outflow for January to June from Kimmerer 2002a

Both Delta outflow and the position of X2 have been altered as a result of numerous factors including development and operation of upstream storage and diversions, land use changes, and increasing water demand. Hydrodynamic simulations conducted by Fleenor et al. (2010) indicate that the position of X2 has been skewed eastward in the recent past, as compared to unimpaired conditions and earlier impaired periods, and that the variability of salinity in the western Delta and Suisun Bay has been significantly reduced (Figure 7). The higher X2 values shown in this figure (refer to Point 'B') indicate the low salinity zone is farther upstream for a more prolonged period of time. Point 'B' demonstrates that during the period from 1986 to 2005 the position of X2 was located upstream of 71 km nearly 80% of the time, as opposed to unimpaired flows which were equally likely to place X2 upstream or downstream of the 71 km location (50% probability). (Fleenor *et al*. 2010.) Historically, X2 exhibited a wide seasonal range tracking the unimpaired Delta outflows; however, seasonal variation in X2 range has been reduced by nearly 40%, as compared to pre-dam conditions. (TBI 2003, as cited in DOI 1, pp. 21-22.)



This graph shows the cumulative probability distributions of daily X2 locations showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (light solid blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line), illustrating progressive reduction in salinity variability from unimpaired conditions. Paired letters indicate geographical landmarks: CQ, Carquinez Bridge; MZ, Martinez Bridge; CH, Chipps Island; CO, Collinsville; EM, Emmaton; and RV, Rio Vista (Source: Fleenor et al. 2010, Figure 8).

Figure 7. Cumulative Probability of Daily X2 Locations from Fleenor *et al*. 2010

In their key points on Delta environmental flows for the State Water Board, the DEFG (DEFG 1) noted that the recent flow regimes both harm native species and encourage non-native species and provided the following justification:

> “The major river systems of the arid western United States have highly variable natural flow regimes. The present-day flow regimes of western rivers, including the Sacramento and San Joaquin, are highly managed to increase water supply reliability for agriculture, urban use, and flood protection (Hughes et al. 2005, Lund et al. 2007). Recent Delta inflow and outflow regimes appear to both harm native species and encourage non-native species. Inflow patterns from the Sacramento River may help riverine native species in the north Delta, but inflow patterns from the San Joaquin River encourage non-native species. Ecological theory and observations overwhelmingly support the argument that enhancing variability and complexity across the estuarine landscape will support native species. However, the evidence that flow stabilization reduces native fish abundance in the upper estuary (incl. Delta) is circumstantial:
>
> 1) High winter-spring inflows to the Delta cue native fish spawning migrations (Harrell and Sommer 2003; Grimaldo et al. 2009), improve the reproductive success of resident native fishes (Meng et al. 1994; Sommer et al. 1997; Matern et al. 2002; Feyrer 2004), increase the survival of

juvenile anadromous fishes migrating seaward (Sommer *et al*. 2001; Newman 2003), and disperse native fishes spawned in prior years (Feyrer and Healey 2003; Nobriga et al. 2006).

2) High freshwater outflows (indexed by X2) during winter and spring provide similar benefits to species less tolerant of freshwater including starry flounder, bay shrimp, and longfin smelt (Kimmerer 2002; Kimmerer *et al*. 2009). Freshwater flows provide positive benefits to native fishes across a wide geographic area through various mechanisms including larval-juvenile dispersal, floodplain inundation, reduced entrainment, and increased up-estuary transport flows. Spring Delta inflows and outflow have declined since the early 20th century, but average winter-spring X2 has not had a time trend during the past 4-5 decades (Kimmerer 2004).

3) The estuary's fish assemblages vary along the salinity gradient (Matern et al. 2002; Kimmerer 2004), and along the gradient between predominantly tidal and purely river flow. In tidal freshwater regions, fish assemblages also vary along a gradient in water clarity and submerged vegetation (Nobriga et al. 2005; Brown & Michniuk 2007), and smaller scale, gradients of flow, turbidity, temperature and other habitat features (Matern et al. 2002; Feyrer & Healey 2003). Generally, native fishes have their highest relative abundance in Suisun Marsh and the Sacramento River side of the Delta, which are more spatially and temporally variable in salinity, turbidity, temperature, and nutrient concentration and form than other regions.

4) In both Suisun Marsh and the Delta, native fishes have declined faster than non-native fishes over the past several decades (Matern et al. 2002; Brown and Michniuk 2007). These declines have been linked to persistent low fall outflows (Feyrer et al. 2007) and the proliferation of submerged vegetation in the Delta (Brown and Michniuk 2007). However, many other factors also may be influencing native fish declines including differences in sensitivity to entrainment (sustained or episodic high "fishing pressure" as productivity declines), and greater sensitivity to combinations of food-limitation and contaminants, especially in summer-fall when many native fishes are near their thermal limits.

The weight of the circumstantial evidence summarized above strongly suggests flow stabilization harms native species and encourages non-native species, possibly in synergy with other stressors such as nutrient loading, contaminants, and food limitation."

Diversion and Use

Irrigation is the primary use of water in the Sacramento and San Joaquin river watershed. Water is used to a lesser extent to meet municipal, industrial, environmental, and instream needs. Water is also exported from the Central Valley Basin for many of these same purposes. Local irrigation districts, municipal utility districts, county agencies, private companies and corporations, and State and federal agencies have developed surface water projects throughout the basin to control and conserve the natural runoff and provide a reliable water supply for beneficial uses. Many of these projects are used to produce hydroelectric power and to enhance recreational opportunities. Flood control systems, water storage facilities, and diversion works exist on all major streams in the basin, altering the timing, location, and quantity of water and the habitat associated with the natural flow patterns of the basin. (State Water Board 1999.)

The major surface water supply developments of the Central Valley include the CVP, other federal projects built by the USBR and the U.S. Army Corps of Engineers (USACE), the SWP, and numerous local projects (including several major diversions). The big rim dams, developed mostly since the 1940s, dramatically changed river flow patterns. The dams were built to provide flood protection and a reliable water supply. Collection of water to storage decreased river flows in winter and spring, and changed the timing of high flow periods (except for extreme flood flows). The San Joaquin River has lost most of its natural summer flows because the majority of the water is exported via the Friant project or diverted from the major tributaries for use within the basin. Even though natural flows have been substantially reduced, agricultural return flows during the summer have actually resulted in higher flows than would have occurred under unimpaired conditions at times. Winter and spring flows collected to storage by the State and federal projects in the Sacramento Basin are released in the late spring and throughout the summer and fall, largely to be rediverted from the Delta for export. The federal pumping plants in the southern Delta started operating in the 1950s, exporting water into the Delta-Mendota Canal. The State pumps and the California Aqueduct started operating in the late 1960s, further increasing exports from the Delta. (Moyle, et al. 2010.)

In-Delta Diversions and Old and Middle River Reverse Flows

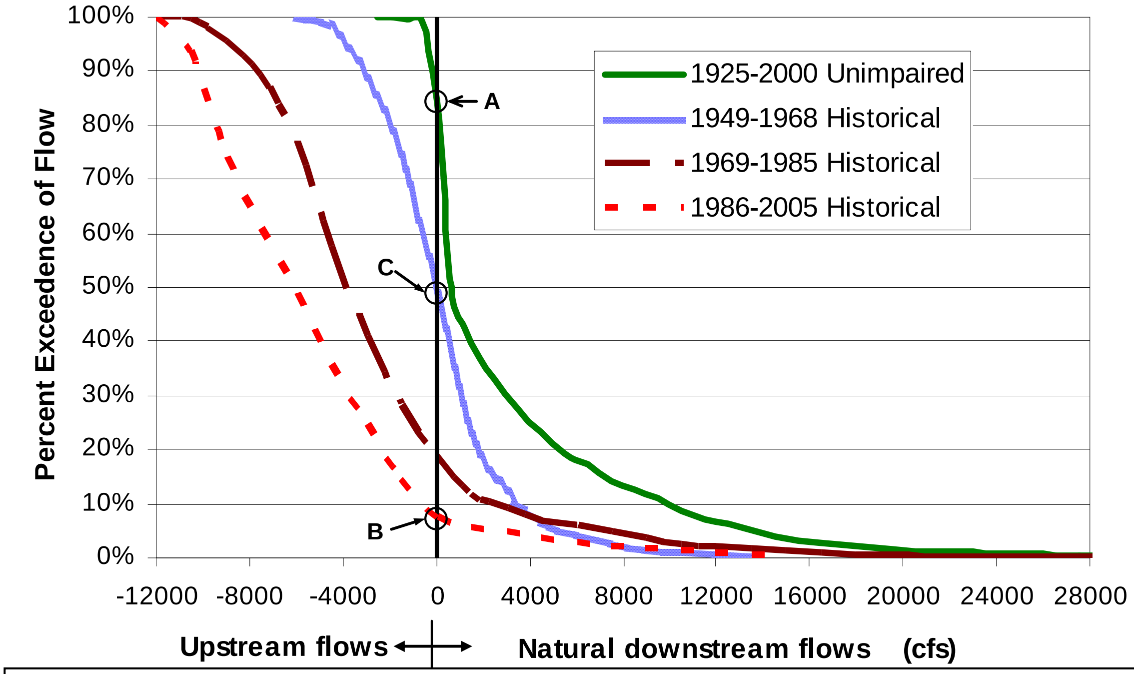
The USBR and the DWR are the major diverters in the Delta. The USBR exports water from the Delta at the Tracy Pumping Plant and the Contra Costa Water District diverts CVP water at Rock Slough and Old River under a water supply contract with the USBR. The DWR exports from the Delta at the Banks Delta Pumping Plant and Barker Slough to serve the SWP contractors. Operation of the CVP and SWP Delta export facilities are coordinated to meet water quality and flow standards set by the Board, the USACE, and by fisheries agencies. In addition, there are approximately 1,800 local diversions within the Delta that amount to a combined potential instantaneous flow rate of more than 4,000 cfs. (State Water Board 1999.)

Net OMR reverse flows are now a regular occurrence in the Delta (Figure 8). Net OMR reverse flows are caused by the fact that the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping facilites, the SWP and CVP, are located in the south (Figure 1). This results in a net water movement across the Delta in a north-south direction along a web of channels including Old and Middle rivers instead of the more natural pattern from east to west or from land to sea. Net OMR is calculated as half the flow of the San Joaquin River at Vernalis minus the combined SWP and CVP pumping rate. (CCWD closing comments, p. 2.) A negative value, or a reverse flow, indicates a net water movement across the Delta along Old and Middle river channels to the State and Federal pumping facilities. Fleenor *et al* (2010) has documented the change in both the magnitude and frequency of net OMR reverse flows as water development occurred in the Delta (Figure 8). The 1925-2000 unimpaired line in Figure 8 represents the best estimate of “quasi-natural” or net OMR values before most modern water development. (Fleenor et al. 2010.) The other three lines represent changes in the frequency and magnitude of net OMR flows with increasing development. Net OMR reverse flows are estimated to have occurred naturally about 15% of the time before most modern water development, including construction of the major pumping facilities in the South Delta (point A, Figure 8). The magnitude of net OMR reverse flows was seldom more negative than a couple of thousand cfs. In contrast, between1986-2005 net OMR reverse flows had become more frequent than 90 percent of the time (Point B). The magnitude of net OMR reverse flows may now be as much as -12,000 cfs. High net OMR reverse flows have several negative ecological consequences. First, net reverse OMR flows draw fish, especially the weaker swimming larval and juvenile forms, into the SWP and CVP export facilities. The export facilities have been documented to entrain most species of fish present in the upper estuary. (Brown *et al*. 1996,.) Approximately 110 million fish were salvaged at the SWP pumping facilities and returned to the Delta over a 15 year period, (Brown et al. 1996.) However, this number underestimates the actual number of fish entrained, as it does not include losses at the CVP nor does it account for fish less than 20 mm in length which are not collected and counted at the fish collection facilities. Second, net OMR reverse flows reduce spawning and rearing habitat for native species, like delta smelt. Any fish that enters the Central or Southern Delta has a high probability of being entrained and lost at the pumps. (Kimmerer and Nobriga, 2008.) This has restricted their habitat to the western Delta and Suisun and Grizzly bays. Third, net OMR reverse flows have led to a confusing environment for migrating juvenile salmon leaving the San Joaquin Basin. Through-Delta exports reduce salinity in the central and southern Delta and as a result juvenile salmon migrate from higher salinity in the San Joaquin River to lower salinity in the southern Delta, contrary to the natural historical conditions and their inherited migratory cues. Finally, net OMR reverse flows reduce the natural variability in the Delta by drawing Sacramento River water across and into the Central Delta. The UC Davis Delta Solutions Group recommends:

> “Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables…These goals in turn encourage policies which… establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality… and … restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species.”
> (Moyle et al., 2010.)

Net OMR reverse flow restrictions are included in the USFWS Opinion (Actions 1 through 3), the NMFS Opinion (Action IV.2.3), and the DFG Incidental Take Permit (Conditions 5.1 and 5.2) for the protection of delta smelt, salmonids, and longfin smelt, respectively. (NMFS 3. p. 648; USFWS 2008, DFG 2009.) Additional net OMR reverse flow restrictions are recommended in this report for protection of longfin and delta smelt and Chinook salmon.

Further north in the Delta, the Delta Cross Channel is used to divert a portion of the Sacramento River flow into the interior Delta channels. The purpose of the Delta Cross Channel is to preserve the quality of water diverted from the Sacramento River by conveying it to southern Delta pumping plants through eastern Delta channels rather than allowing it to flow through more saline western Delta channels. The Delta Cross Channel is also operated to protect fish and wildlife beneficial uses (specifically Chinook salmon), while recognizing the need for fresh water to be moved through the system. With a capacity of 3,500 cfs, the Delta Cross Channel can divert a significant portion of the Sacramento River flows into the eastern Delta, particularly in the fall.



Cumulative probability distribution of sum of Old and Middle River flows (cfs) resulting from through Delta conveyance showing unimpaired flows (green solid line) and three historical periods, 1949-1968 (solid light blue line), 1969-1985 (long-dashed brown line) and 1986-2005 (short-dashed red line) (Source: Fleenor et al. 2010, Figure 9).

Figure 8. OMR Cumulative Probability Flows from Fleenor et al. 2010

3.3.3 Water Quality

Water quality in the Delta may be negatively impacted by contaminants in sediments and water, low DO levels, and blue green algal blooms. Additionally, changes in hydrology and hydrodynamics affect water quality. The conversion of tidal wetlands to leveed Delta islands has altered the tidal exchange and prism. These changes can contribute to spatial and temporal shifts in salinity and other physical and chemical water quality parameters (temperature, DO, contaminants, etc.).

Contaminants

The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include: organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low DO levels periodically develop in the San Joaquin River in the Stockton Deep Water Ship Channel (DWSC) and in Old and Middle rivers. The low DO levels in the DWSC inhibit the upstream migration of adult fall-run Chinook salmon and adversely impact other resident aquatic organisms. The Central Valley and San Francisco Regional Boards are systematically developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds and blue-green algal blooms could also limit biological productivity and impair beneficial uses. More work is needed to determine their impact on the aquatic community. Sources of these contaminants include: agricultural, municipal, and industrial wastewater; urban storm water discharges; discharges from wetlands; and channel dredging activities.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causing toxicity to delta smelt, other local fish, and zooplankton, and is reducing primary production rates in the Sacramento River below the Sacramento Regional Wastewater Treatment Plant (SRWTP) and in Suisun Bay. A third, newer, hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition, and these changes have had a detrimental effect on zooplankton and fish population abundance. (Glibert, 2010.)

The SRWTP is the primary source of ammonia to the Delta. (Jassby 2008.) The SRWTP has converted the Delta from a nitrate to an ammonia dominated nitrogen system. (Foe et al. 2010.) Seven-day flow-through bioassays by Werner et al. (2008, 2009) have demonstrated that ammonia concentrations in the Delta are not acutely toxic to delta smelt. Monthly nutrient monitoring by Foe *et al*. (2010) has demonstrated that ammonia concentrations are below the recommended USEPA (1999) chronic criterion for the protection of juvenile fish. Results from the nutrient monitoring suggest that ammonia-induced toxicity to fish is not regularly occurring in the Delta.

Elevated ammonia concentrations inhibit nitrate uptake and that appears to be one factor preventing spring diatom blooms from developing in Suisun Bay. (Dugdale et al. 2007; Wilkerson et al. 2006.) One of the primary hypotheses for the POD is a decrease in the availability of food at the base of the food web. (Sommer et al. 2007.) Staff from the San Francisco Regional Board has informed the Central Valley Regional Board that ammonia may be impairing aquatic life beneficial uses in Suisun Bay (letter to Kathy Harder with the Central Valley Regional Board from Bruce Wolfe of the San Francisco Regional Board dated June 4, 2010).

Ammonia concentrations are higher in the Sacramento River below the SRWTP than in Suisun Bay. This led to a hypothesis that ammonia might be inhibiting nitrate uptake and reducing primary production rates in the Sacramento River and downstream Delta, as occurs in Suisun Bay. Experimental results for the Sacramento River are more ambiguous than for Suisun Bay. (Parker *et al*., 2010.) Five-day cubitainer grow out experiments conducted using water collected above and below the SRWTP usually demonstrated more chlorophyll in water collected below the SRWTP. Short-term bottle primary production rate measurements conducted using water collected above and below the SRWTP also demonstrate no decrease in the rate when normalized by the amount of chlorophyll in the bottle. However, effluent dosed into upstream Sacramento River water at environmentally realistic concentrations does show a decrease in primary production. Elevated ammonia concentrations consistently decrease nitrate uptake. Whether the shift in nitrogen utilization indicates that different algal species are beginning to grow in the ammonia rich water is not known. A recent paper by Glibert (2010) demonstrates significant correlations between the form and concentration of nutrients discharged by the SRWTP, and changes in phytoplankton, zooplankton, and fish abundance in the Delta.

Salinity

Elevated salinity can impair the uses of water by municipal, industrial, and agricultural users and by organisms that require lower salinity levels. There are at least three factors that may cause salinity levels to exceed water quality objectives in the Delta: saltwater intrusion from the Pacific

Ocean and San Francisco Bay moving into the Delta on high tides during periods of relatively low flows of fresh water through the Delta; salts from agricultural return flows, municipalities, and other sources carried into the southern and eastern Delta with the waters of the San Joaquin River; and localized increases in salinity due to irrigation return flows into dead-end sloughs and low-capacity channels (null zones). The effects of saltwater intrusion are seen primarily in the western Delta. Due to the operation of the State and federal export pumping plants near Tracy, the higher salinity areas caused by salts in the San Joaquin River tend to be restricted to the southeast corner of the Delta. Null zones, and the localized areas of increased salinity associated with them, exist predominantly in three areas of the Delta: Old River between Sugar Cut and the CVP intake; Middle River between Victoria canal and Old River; and the San Joaquin River between the head of Old River and the City of Stockton.

Suspended Sediments and Turbidity

Turbidity in the Delta is caused by factors that include suspended material such as silts, clays, and organic matter coming from the major tributary rivers; planktonic algal populations; and sediments stirred up during dredging operations to maintain deep channels for shipping. Turbidity affects large river and estuarine fish assemblages because some fishes survive best in turbid (muddy) water, while other species do best in clear water. Studies suggest that changes in specific conductance and turbidity are associated with declines in upper estuary habitat for delta smelt, striped bass, and threadfin shad. Laboratory studies have shown that delta smelt require turbidity for successful feeding.

Turbidity in the Delta has decreased through time. The primary hypotheses to explain the turbidity decrease are: (1) reduced sediment supply; (2) sediment washout from very high inflows during the 1982 to 1983 El Nino; and (3) trapping of sediment by submerged aquatic vegetation. (Wright and Schoellhamer 2004, Jassby et al. 2005, Nobriga et al. 2005, and Brown and Michniuk 2007 as cited in Nobriga et al. 2008.)

Dissolved Oxygen

Low DO levels are found along the lower San Joaquin River and in certain localized areas of the Delta. Dissolved oxygen impairment is caused, in part, by loads of oxygen demanding substances such as dead algae or waste discharges. Low DO in the Delta occurs mainly in the late summer and coincides with low river flows and high temperatures. Fish vary greatly in their ability to tolerate low DO concentrations, based on the environmental conditions the species has evolved to inhabit. Salmonids are relatively intolerant of low DO concentrations. Within the lower San Joaquin River, DO concentrations can become sufficiently low to impair the passage and/or cause mortality of migratory salmonids. (DFG 3, p. 3; DOI 1, p. 25; TBI/NRDC 3, p. 26.)

The DWSC is a portion of the lower San Joaquin River between the City of Stockton and the San Francisco Bay that has been dredged to allow for the navigation of ocean-going vessels to the Port of Stockton. A 14-mile stretch of the DWSC, from the City of Stockton to Disappointment Slough, is listed as impaired for DO and, at times, does not meet the objectives set forth in the San Joaquin Riverwater quality control plan. Studies have identified three main contributing factors to the problem: loads of oxygen demanding substances that exert an oxygen demand (particularly the death and decay of algae); DWSC geometry, which reduces the assimilative capacity for loads of oxygen demanding substances by reducing the efficiency of natural re-aeration mechanisms and by magnifying the effect of oxygen demanding reactions; and, reduced flow through the DWSC, which reduces the assimilative capacity by reducing upstream inputs of oxygen and increasing the residence time for oxygen demanding reactions. (Central Valley Regional Board 2003.)

3.3.4 Biological Setting

The Bay-Delta Estuary is one of the largest, most important estuarine systems for fish and waterfowl production on the Pacific Coast of the United States. The Delta provides habitat for a wide variety of freshwater, estuarine, and marine fish species. Channels in the Delta range from dead-end sloughs to deep, open water areas that include several flooded islands that provide submerged vegetative shelter. The complex interface between land and water in the Delta provides rich and varied habitat for wildlife, especially birds. The Delta is particularly important to waterfowl migrating via the Pacific Flyway as these birds are attracted to the winter-flooded fields and seasonal wetlands. (State Water Board 1999.)

Existing Setting

A wide variety of fish are found throughout the waterways of the Central Valley and the Bay-Delta Estuary. About 90 species of fish are found in the Delta. Some species, such as the anadromous fish, are found in particular parts of the Bay-Delta Estuary and the tributary rivers and streams only during certain stages of their life cycle. The Delta's channels serve as a migratory route and nursery area for Chinook salmon, striped bass, white and green sturgeon, American shad, and steelhead trout. These anadromous fishes spend most of their adult lives either in the lower bays of the estuary or in the ocean, moving inland to spawn. Resident fishes in the Bay-Delta Estuary include delta smelt, longfin smelt, threadfin shad, Sacramento splittail, catfish, largemouth and other bass, crappie, and bluegill.

Food supplies for Delta fish communities consist of phytoplankton, zooplankton, benthic invertebrates, insects, and forage fish. The entrapment zone, where freshwater outflow meets and mixes with the more saline water of the Bay, concentrates sediments, nutrients, phytoplankton, some fish larvae, and other fish food organisms. Biological standing crop (biomass) of phytoplankton and zooplankton in the estuary has generally been highest in this zone. However, the overall productivity at the lower trophic levels has decreased over time. (State Water Board 1999.)

Non-Native and Invasive Species

Invasive aquatic organisms are known to have deleterious effects on the Delta ecosystem. These effects include reductions in habitat suitability, reductions in food supply, alteration of the aquatic food-web, and predation on or competition with native species. There are many notable examples of exotic species invasions in the Bay-Delta, so much so, that the Delta has been labeled “the most invaded estuary on earth.”

Of particular importance potentially in the recent decline in pelagic organisms is the introduction of the Asian clam, *Corbula amurensis*. The introduction of the clam has lead to substantial declines in the lower trophic production of the Bay-Delta Estuary. In addition to reductions in planktonic production caused by *Corbula*, the planktonic food web composition has changed dramatically over the past decade or so. Once dominant copepods in the food web have declined leading to speculation that estuarine conditions have changed to favor alien species. The decrease in these desirable copepods may further increase the likelihood of larval fish starvation or result in decreased growth rates. (State Water Board 2008.)

The proliferation of invasive, aquatic weeds, such as *Egeria densa*, which filter out particulate materials and further reduce planktonic growth, are also having a impact on the Bay-Delta. Areas with low or no flow, such as warm, shallow, dead-end sloughs in the eastern Delta also support objectionable populations of plants during summer months including planktonic blue-green algae and floating and semi-attached aquatic plants such as water primrose, water hyacinth, and *Egeria densa*. All of these plants contribute organic matter that reduces DO levels in the fall, and the floating and semi-attached plants interfere with the passage of small boat traffic. In addition, native fishes in the Bay-Delta face growing challenges associated with competition and predation by non-native fish. (State Water Board 1999; State Water Board 2008.)

Recent Species Declines

Historical fisheries within the Central Valley and the Bay-Delta Estuary were considerably different than the fisheries present today. Many native species have declined in abundance and distribution, while several introduced species have become well established. The Sacramento perch is believed to have been extirpated from the Delta; however, striped bass and American shad are introduced species that, until recently, have been relatively abundant and have contributed substantially to California's recreational fishery. (State Water Board 1999.)

In 2005, scientists with the Interagency Ecological Program (IEP) announced observations of a precipitous decline in several pelagic organisms in the Delta, beginning in 2002, in addition to declining levels of zooplankton. Zooplankton are the primary food source for older life stages of species such as delta smelt. The decline in pelagic organisms included delta smelt, striped bass, longfin smelt, and threadfin shad. Scientists hypothesized that at least three general factors may be acting individually, or in concert, to cause this recent decline in pelagic productivity: 1) toxic effects; 2) exotic species effects; and 3) water project effects. Scientists and resources agencies have continued to investigate the causes of the decline, and have prepared plans that identify actions designed to help stabilize the Delta ecosystem and improve conditions for pelagic fish species. (State Water Board 2008.)

In January of 2008, the Pacific Fisheries Management Council reported unexpectedly low Chinook salmon returns to California, particularly to the Central Valley, for 2007. Adult returns to the Sacramento River, the largest of Central Valley Chinook salmon runs, failed to meet resource management goals (122,000-180,000 spawners) for the first time in 15 years. (State Water Board 2008.) The Sacramento River fall Chinook salmon escapement to the Central Valley was estimated to be 88,000 adults in 2007; 66,000 in 2008; and 39,530 – the lowest on record -- in 2009. (PCFFA 2.) The NMFS concluded that poor ocean conditions were a major factor contributing to the low fall-run abundance; however, other conditions may exacerbate these effects. (State Water Board 2008.)

In April 2008, the Pacific Fisheries Management Council and the Commission adopted the most restrictive ocean and coastal salmon seasons ever for California by closing the ocean and coastal fishery to commercial and recreation fishing for the 2008 fishing season. The Commission further banned salmon fishing in all Central Valley rivers, with the exception of limited fishing on a stretch of the Sacramento River. (State Water Board 2008.) The ban on all salmon fishing was extended through the 2009 season, but the restrictions were eased somewhat for 2010.

3.3.5 How Flow-Related Factors Affect Public Trust Resources

Flow is important to sustaining the ecological integrity of aquatic ecosystems, including the public trust resources that are the subject of this proceeding. Flow affects water quality, food resources, physical habitat, and biotic interactions. Alterations in the natural flow regime affect aquatic biodiversity and the structure and function of aquatic ecosystems.

In its key points on Delta environmental flows for the State Water Board, the DEFG (DEFG 1) noted that:

- Flow related factors that affect public trust resources include more than just volumes of inflow and outflow and no single rate of flow can protect all public trust resources at all times. The frequency, timing, duration, and rate of change of flows, the tides, and the occurrence of overbank flows, all are important. Seasonal, interannual, and spatial variability in flows, to which native species are adapted, are as important as the quantity of flow. Biological responses to flows rest on combinations of quantity, timing, duration, frequency and how these inputs vary spatially in the context of a Delta that is geometrically complex, highly altered by humans, and fundamentally tidally driven.

- Recent flow regimes in the Delta have contributed to the decline of native species and encouraged non-native species. Flows into and within the estuary affect turbidity, salinity, aquatic plant communities, and nutrients that are important to both native and non-native species. However, flows and habitat structure are often mismatched and now favor non-native species.

- Flow is a major determinant of habitat and transport. The effects of flow on transport and habitat are controlled by the geometry of the waterways. Further, because the geometry of the waterways will change through time, flow regimes needed to maintain desired habitat conditions will also change through time. Delta inflow is an important factor affecting the biological resources of the Delta because inflow has a direct effect on flood plain inundation, in-Delta net channel flows, and net Delta outflows.

- Flow modification is one of the few immediate actions available to improve conditions to benefit native species. However, habitat restoration, contaminant and nutrient reduction, changes in diversions, control of invasive species, as well as flood plain inundation and island flooding all interact with flow to affect aquatic habitats.

4. Methods and Data

The notice for the informational proceeding requested scientific information on the volume, quality, and timing of water needed for the Delta ecosystem under different hydrologic conditions to protect public trust resources pursuant to the State Water Board's public trust obligations and the requirements of SB 1. Specifically, the notice focused on Delta outflows, but also requested information concerning the importance of the source of those flows and information concerning adaptive management, monitoring, and special study programs. In addition to the requested information concerning Delta outflows, the State Water Board also received information on Sacramento River inflows, San Joaquin River inflows, hydrodynamics including Old and Middle River flows, and other information that is relevant to protection of public trust resources in the Delta ecosystem. This section presents the recommendations received by the State Water Board and discusses approaches used to evaluate the recommendations and develop flow criteria responsive to SB1.

4.1 *Summary of Participants' Submittals*

Information submitted by interested parties over the course of this proceeding has resulted in the development of a substantive record; submittals are available on the State Water Board's website at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/entity_index.shtml

The exhibits include discussions pertaining to: the State Water Board's public trust obligations; methodologies that should be used to develop flow criteria; the importance of the source of flows when determining outflows; means by which uncertainty should be addressed; and specific recommendations concerning Delta outflows, Sacramento and San Joaquin river inflows, hydrodynamics, operation of the Delta Cross Channel Gates, and floodplain activation.

The State Water Board received a wide range of recommendations for the volume, quantity and timing of flow necessary to protect public trust resources. Delta outflow recommendations ranged from statements that the current state of scientific understanding does not support development of numeric Delta flow criteria that differ from the current outflow objectives included in D-1641 (DWR closing comments; SFWC closing comments) to flow volumes during above normal and wet water year types that are two to four times greater than currently required under D-1641 (TBI/NRDC closing comments; AR/NHI closing comments; EDF closing comments, CSPA closing comments; CWIN closing comments). Appendix A: Summary of Participant Recommendations, provides summary tables of the recommendations received for Delta outflows, Sacramento River inflows, San Joaquin River inflows, hydrodynamics, floodplain inundation, and Delta Cross Channel Gate closures.

4.2 *Approach to Developing Flow Criteria*

Fleenor et al. (2010) examined the following four approaches for prescribing environmental flows for the Delta:

- Unimpaired (quasi-natural) inflows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- The appropriate accumulation of flows estimated to provide specific ecological functions for desirable species and ecosystem attributes based on available literature.

Fleenor *et al*. (2010) concludes:

> "Generally, approaches that rely on data from the past will become more risky as the underlying changes in the Delta accumulate. However, since the objective is to provide flows for species which evolved under past conditions, information on past flows and life history strategies of fish provide considerable insight and context. Aggregate statistical approaches, which essentially establish correlations between past conditions and past species abundance, are likely to be less directly useful as the Delta changes. However, statistical approaches will continue to be useful, especially if developed for causal insights. More focused statistical relationships can be of more enduring value in the context of more causal models, even given underlying changes. In the absence of more process-based science, empirical relationships might be required for some locations and functions on an interim basis. Insights and information can be gained from each approach. Given the importance of the problem and the uncertainties involved,

> the strengths of each approach should be employed to provide greater certainty or improve definition of uncertainties."

Among other things, the Fleenor report recommends:

1. Flow prescriptions should be supported preferably by causally or process-based science, rather than correlative empirical relationships or other statistical relationships without supporting ecological basis. Having a greater causal basis for flow prescriptions should make them more effective and readily adapted to improvements in knowledge and changing conditions in the Delta. A more explicit causal basis for flow prescriptions will also create incentives for improved scientific understanding of this system and its management as well as better integration of physical, chemical, and biological aspects of the problem.
2. Ongoing managed and unmanaged changes in the Delta will make any static set of flow standards increasingly irrelevant and obsolete for improving conditions for native fishes. Flows should be tied to habitat, fish, hydrologic, and other management conditions, as well as our knowledge of the system. Flows needed for fish native to the Delta will change.

Information received during this proceeding supports these conclusions and recommendations. The record for this proceeding contains a mix of data and analyses that uses the four approaches identified by Fleenor et al. (2010):

- Unimpaired flows
- Historical impaired inflows that supported more desirable ecological conditions
- Statistical relationships between flow and native species abundance
- Ecological functions-based analysis for desirable species and ecosystem attributes

All four types of information are relied upon to develop the flow criteria in this report. Emphasis, however, is placed on ecological function-based information, followed by information on statistical relationships between flow and native species abundance. In all cases, the criteria are supported by the best available scientific information submitted into the record for this proceeding. The species and ecosystem function-based needs assessments and criteria in this report are supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles. Criteria based upon statistical relationships between flow and native species abundance are also supported by references to specific scientific and empirical evidence, and cite to exhibits and testimony in the record or conclusions in published and peer reviewed articles.

Furthermore, the conceptual bases for all of the criteria in this report are supported by scientific information on function-based species or ecosystem needs. In other words, there is sufficiently strong scientific evidence to support the need for functional flows. This does not necessarily mean that there is scientific evidence to support *specific* numeric criteria. Recommendations are therefore divided into two categories: Category "A" criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category "B" criteria. In all cases, the assumptions upon which the criteria are based are identified and discussed. The following steps were followed to develop flow criteria and other recommendations:

1. Establish general goals and objectives for protection of public trust resources in the Delta
2. Identify species to include based on ecological, recreational, or commercial importance
3. Review and summarize species life history requirements, including description of:
    - general life history and species needs
    - population distribution and abundance
    - population abundance and relationship to flow
    - specific population goals
    - species-specific basis for flow criteria
4. Summarize numeric and other criteria for each of: Delta outflows, Sacramento River inflows, San Joaquin River inflows, and hydrodynamics
5. Review other flow-related and non-flow measures that should be considered
6. Provide summary determinations for flow criteria and other measures

The following information was assembled and considered for each species, if available in the record for this proceeding:

- Life history information including timing of migrations
- Seasons or time periods when flow characteristics are most important
- Relationships of species abundance or habitat to Delta outflows, Delta inflows, hydrodynamics, or water quality parameters linked to flow, etc.
- Species environmental requirements (e.g., DO, temperature preferences, salinity, X2 location, turbidity, toxicity to specific pollutants, etc.)
- Relationship of species abundance to invasive species, to the extent possible
- Key quantifiable population responses or habitat characteristics linked to flow
- Mechanisms or hypotheses about mechanisms that link species abundance, habitat, and other metrics to flow or other variables

4.2.1 Biological and Management Goals

The goal of this report is discussed in Section 3.1.4 (Scope of this Report). The following biological and management goals are used to guide the development of criteria that support species life history requirements.

Biological Goals

- Depending on water year type or hydrologic condition, provide sufficient flow to increase abundance of desirable species that depend on the Delta (longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton).

- Create shallow brackish water habitat for longfin smelt, delta smelt, starry flounder, bay shrimp, American shad, and zooplankton in Suisun Bay (and farther downstream).

- Provide floodplain inundation of appropriate timing and sufficient duration to enhance spawning and rearing opportunities to support Sacramento splittail, Chinook salmon, and other native species.

- Manage net OMR reverse flows and other hydrodynamic conditions to protect sensitive life stages of desirable species.

- Provide sufficient flow in the San Joaquin River to transport salmon smolts through the Delta during spring in order to contribute to attainment of the State Water Board's salmon protection water quality objective. (2009 Bay-Delta Plan, p. 14.)

- Provide sufficient flow in the Sacramento River to transport salmon smolts through the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective. (*Id.*)

- Provide sufficient flow in eastside streams that flow to the Delta, including the Mokelumne and Consumes rivers, to transport salmon smolts to the Delta during the spring in order to contribute to the attainment of the salmon protection water quality objective.

- Maintain water temperatures and DO in mainstem rivers that flow into the Delta and their tributaries at levels that will support adult Chinook salmon migration, egg incubation, smolting, and early-year and late-year juvenile rearing.

Management Goals

- Combine freshwater flows needed to protect species and ecosystem functions in a manner that is comprehensive, does not double count flows, uses an appropriate time step, and is well-documented

- Establish mechanisms to evaluate Delta environmental conditions, periodically review underpinnings of the biological objectives and flow criteria, and change biological objectives and flow criteria when warranted

- Periodically review new research and monitoring to evaluate the need to modify biological objectives and flow criteria

- Do not recommend overly complex flow criteria so as not to infer a greater understanding of specific numeric flow criteria than the available science supports

4.2.2 Selection of Species[10]

Information received during the informational proceeding links the abundance and habitat of several key species that live in, move through, or otherwise depend upon for their survival, the Delta and its ecosystem. DFG Exhibits 1 through 4 present information on the relationship between abundance and the quantity, quality, and timing of flow for the following species: (1) Chinook salmon, (2) Pacific herring, (3) longfin smelt, (4) prickly sculpin, (5) Sacramento splittail, (6) delta smelt, (7) starry flounder, (8) white sturgeon, (9) green sturgeon, (10) Pacific lamprey, (11) river lamprey, (12) bay shrimp, (13) mysid shrimp and a copepod, *Eurytemora affinis*, and (14) American shad. In general, the available data and information indicates:

- For many species, abundance is related to timing and quantity of flow (or the placement of X2).
- For many species, more flow translates into greater species production or abundance.
- Species are adapted to use the water resources of the Delta during all seasons of the year, yet for many species, important life history stages or processes consistently

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[10] This section is largely drawn from DFG exhibits 1 through 4.

coincide with the winter-spring seasons and its associated increased flows because this is the reproductive season for most native fishes, and the time that most salmonid fishes are emigrating.

- The source, quantity, quality, and timing of Central Valley tributary outflow affects the same characteristics of mainstem river flow into and through the Delta. Flows in all three of these areas, Delta outflows, tributary inflows, and hydrodynamics, influence production and survival of Chinook salmon in both the San Joaquin River and Sacramento River basins.
- Some invasive species negatively influence native species abundance.

This report is consistent with DFG's recommendation to establish flow criteria for species of priority concern that will benefit most by improving flow conditions. (DFG closing comments, p. 3.) Table 2 (from DFG closing comments p.4) identifies select species that have the greatest ecological, commercial, or recreational importance and are influenced by Delta inflows (including mainstem river tributaries) or Delta outflows. The table identifies the species life stage most affected by flows, the mechanism most affected by flows, and the time when flows are most important to the species.

Table 2. Species of Importance (from DFG closing comments p.4)

Priority Species	Life Stage	Mechanism	Time When Water Flows are Most Important	Reference
Chinook salmon (San Joaquin River basin)	Smolt	Outmigration	March – June	DFG Exhibit 1 – page 2; DFG Exhibit 3 – pages 7-10, 21-35.
Chinook salmon (Sacramento River basin)	Juvenile	Outmigration	November – June	DFG Exhibit 1 – page 1-2, 6-8
Chinook salmon (San Joaquin River tributaries)	Egg/fry	Temperature, DO, upstream barrier avoidance	October – March	DFG Exhibit 3, pages 2-4; DFG Exhibit 4
Longfin smelt	Egg	Freshwater-brackish habitat	December – April	DFG Exhibit 1 – page 2, 9-12
Longfin smelt	Larvae	Freshwater-brackish habitat; transport; turbidity	December – May	DFG Exhibit 1 – page 2, 9-12
Sacramento Splittail	Adults	Floodplain inundating flows	January – April	DFG Exhibit 1 – page 2, 13-14
Sacramento Splittail	Eggs and larvae	Floodplain habitat persistence	January – May	DFG Exhibit 1 – page 3, 13-14

Priority Species	**Life Stage**	**Mechanism**	**Time When Water Flows are Most Important**	**Reference**
Delta smelt	Larvae and Pre-adult	Transport; habitat	March – November September – November	DFG Exhibit 1 – page 2,14-15
Starry flounder	Settled juvenile; Juvenile-2 yr old	Estuary attraction; habitat	February – May	DFG Exhibit 1 – page 3, 15-16
Bay shrimp	Late-stage larvae and small juveniles	Transport	February – June	DFG Exhibit 1 – page 4; 22-25
Bay shrimp	Juveniles	Nursery habitat	April – June	DFG Exhibit 1 – page 4; 22-25
Mysid shrimp (zooplankton)	All	Habitat	March – November	DFG Exhibit 1 – page 5; 25-26
Eurytemora affinis (zooplankton)	All	Habitat	March – May	DFG Exhibit 1 – page 5; 25-26
American shad	Egg/larvae	Transport; dispersal; habitat	March – June	DFG Exhibit 1 – page 5; 26-28

While many species found in the Delta are of ecological, commercial, and/or recreational interest, specific flow needs for some of those species may not be directly addressed in this report because: they overlap with the needs of more sensitive species otherwise addressed in the report; the relationships between flow and abundance of those species are not well understood; or the needs of those species may be outside the scope of this report. For example, placement of X2 at certain locations in the Delta to protect longfin smelt or starry flounder will also protect striped bass (*Morone saxatilis*). Striped bass survival from egg to 38 mm is significantly increased as X2 shifts downstream in the estuary. (Kimmerer 2002a.) Kimmerer et al. (2009) showed that as X2 location moved downstream, several measures of striped bass survival and abundance significantly increased, as did several measures of striped bass habitat. Similarly, it is assumed that improved stream flow conditions for Chinook salmon will benefit steelhead, but additional work is needed to assure that these flow criteria are adequate for the protection of steelhead. Adult steelhead in the Central Valley migrate upstream beginning in June, peaking in September, and continuing through February or March. (Hallock *et al*. 1961, Bailey 1954, McEwan and Jackson 1996, as cited in SJRRP FMWG 2009.) Spawning occurs primarily from January through March, but may begin as early as December and may extend through April. (Hallock et al. 1961, as cited in McEwan and Jackson 1996.) Steelhead also rear in tributaries to the Delta throughout the year. Consequently, additional inflow criteria may be needed to protect steelhead at times when flows are not specifically recommended to protect Chinook salmon. As will be discussed in the species needs section for Chinook salmon, additional flow criteria may also be needed to protect various runs and life-stages of Chinook salmon. Adequate information is not currently available, however, upon which to base criteria.

Other species are influenced by very high and infrequent flows, far in excess of what could be provided by the State and federal water projects because they occur only during very wet years when project operations are not controlling. For example, white sturgeon are influenced by high winter and spring Delta and river flows (March-June Delta outflow greater than 60,000 cfs) that attract migrating adults, cue spawning, transport larvae, and enhance nursery habitat. These types of flows occur episodically in very wet years. Historical flow patterns combined with the unique life history (long-lived, late maturing, long intervals between spawning, high fecundity) result in infrequent strong recruitment.

There is adequate information in the record, and adequate time to evaluate life history requirements and develop species-specific flow criteria for the following species:

- Chinook Salmon (various runs) (primarily mirgration flows)
- American Shad
- Longfin Smelt
- Delta Smelt
- Sacramento Splittail
- Starry Flounder
- Bay Shrimp
- Zooplankton

4.2.3 Life History Requirements – Anadromous Species

Following are life history and species-specific requirements for Chinook Salmon (including Sacramento River winter-run, Central Valley spring-run, Central Valley fall-run, and Central Valley late fall-run) and American shad.

Chinook Salmon (Sacramento River Winter-Run, Central Valley Spring-Run, Central Valley Fall-Run, and Central Valley Late Fall-Run)

Status

Sacramento River winter-run Chinook salmon is listed as endangered pursuant to the ESA and the CESA. Central Valley spring-run Chinook salmon is listed as threatened pursuant to both the ESA and the CESA. Central Valley fall/late fall-run Chinook salmon are classified as species of special concern pursuant to the ESA.[11]

Life History[12]

Chinook salmon exhibit two generalized freshwater life history types (Healey 1991). Adult "stream-type" Chinook salmon enter freshwater up to several months before spawning, and juveniles reside in freshwater for a year or more, whereas "ocean-type" Chinook salmon spawn soon after entering freshwater and migrate to the ocean as fry or parr within their first year. Adequate instream flows and cool water temperatures are more critical for the survival of Chinook salmon exhibiting a stream-type life history due to over-summering by adults and/or juveniles.

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[11] Source: http://www.dfg.ca.gov/fish/Resources/Chinook/index.asp

[12] This section was largely extracted from NMFS 3, pages 76 through 79.

Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998). Freshwater entry and spawning timing generally are thought to be related to local water temperature and flow regimes. Runs are designated on the basis of adult migration timing. However, distinct runs also differ in the degree of maturation of the fish at the time of river entry, thermal regime, and flow characteristics of their spawning sites, and the actual time of spawning (Myers et al. 1998). Both winter-run and spring-run tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months. Fall-run enter freshwater at an advanced stage of maturity, move rapidly to their spawning areas on the mainstem or lower tributaries of the rivers, and spawn within a few days or weeks of freshwater entry (Healey 1991).

During their upstream migration, adult Chinook salmon require streamflows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate streamflows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38ºF to 56ºF (Bell 1991, DFG 1998). Boles (1988) recommends water temperatures below 65ºF for adult Chinook salmon migration, and Lindley et al. (2004) report that adult migration is blocked when temperatures reach 70ºF, and that fish can become stressed as temperatures approach 70ºF.

Information on the migration rates of adult Chinook salmon in freshwater is scant and primarily comes from the Columbia River basin (Matter and Sanford 2003). Keefer et al. (2004) found migration rates of Chinook salmon ranging from approximately 10 kilometers (km) per day to greater than 35 km per day and to be primarily correlated with date, and secondarily with discharge, year, and reach, in the Columbia River basin. Matter and Sanford (2003) documented migration rates of adult Chinook salmon ranging from 29 to 32 km per day in the Snake River.

Adult Chinook salmon inserted with sonic tags and tracked throughout the Delta and lower Sacramento and San Joaquin rivers were observed exhibiting substantial upstream and downstream movement in a random fashion, for several days at a time, while migrating upstream (CALFED 2001). Adult salmonids migrating upstream are assumed to make greater use of pool and mid-channel habitat than channel margins (Stillwater Sciences 2004), particularly larger salmon such as Chinook salmon, as described by Hughes (2004). During their upstream migration, adults are thought to be primarily active during twilight hours.

Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995). The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. The upper preferred water temperature for spawning Chinook salmon is 55ºF to 57ºF (Chambers 1956, Smith 1973, Bjornn and Reiser 1991, and Snider 2001).

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel percolation, and poor water quality. Studies of Chinook salmon egg survival to hatching conducted by Shelton (1995) indicated 87% of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41ºF to 56ºF [44ºF to 54ºF (Rich 1997), 46ºF to 56ºF (NMFS 1997), and 41ºF to 55.4ºF (Moyle 2002)]. A significant reduction in egg viability occurs at water temperatures above 57.5ºF and total embryo mortality can occur at temperatures above 62ºF (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50% pre-hatch mortality were 61ºF and 37ºF, respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases, as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the egg pocket in the redd. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the yolk-sac fry remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4 to 6 week period when alevins remain in the gravel, they utilize their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. Fry typically range from 25 mm to 40 mm at this stage. Upon emergence, fry swim or are displaced downstream (Healey 1991). The post-emergent fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and other microcrustaceans. Some fry may take up residence in their natal stream for several weeks to a year or more, while others are displaced downstream by the stream's current. Once started downstream, fry may continue downstream to the estuary and rear there, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

Fry then seek nearshore habitats containing riparian vegetation and associated substrates important for providing aquatic and terrestrial invertebrates, predator avoidance, and slower velocities for resting (NMFS 1996). The benefits of shallow water habitats for salmonid rearing have been found to be more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures (Healey 1991). Catches of juvenile salmon in the Sacramento River near West Sacramento exhibited larger-sized juveniles captured in the main channel and smaller-sized fry along the margins (USFWS 1997). When the channel of the river is greater than 9 to 10 feet in depth, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams, may spur outmigration of juveniles from the upper Sacramento River basin when they have reached the appropriate stage of maturation (Kjelson et al. 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is crepuscular. Juvenile Chinook salmon migration rates vary considerably presumably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson *et al*. (1982) found Chinook salmon fry to travel as fast as 30 km per day in the Sacramento River, and Sommer et *al.* (2001) found travel rates ranging from approximately 0.5 miles up to more than 6 miles per day in the Yolo Bypass. As Chinook salmon begin the smoltification stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (ppt, Healey 1980, Levy and Northcote 1981).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries (Maslin et al. 1997, Snider 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover, such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975, Meyer 1979, Healey 1980). Cladocerans, copepods, amphipods, and larvae of diptera, as well as small arachnids and ants are common prey items (Kjelson et al. 1982, Sommer et al. 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates, as well as favorable environmental temperatures (Sommer et al. 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54ºF to 57ºF (Brett 1952). In Suisun and San Pablo bays, water temperatures reach 54ºF by February in a typical year. Other portions of the Delta (*i.e*., South Delta and Central Delta) can reach 70ºF by February in a dry year. However, cooler temperatures are usually the norm until after the spring runoff has ended.

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels, and returning to the main channels when the tide recedes (Levings 1982, Levy and Northcote 1982, Levings et al. 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean. Juvenile Chinook salmon were found to spend about 40 days migrating through the Delta to the mouth of San Francisco Bay and grew little in length or weight until they reached the Gulf of the Farallones (MacFarlane and Norton 2002). Based on the mainly oceantype life history observed (*i.e.*, fall-run), MacFarlane and Norton (2002) concluded that unlike other salmonid populations in the Pacific Northwest, Central Valley Chinook salmon show little estuarine dependence and may benefit from expedited ocean entry.

Population Distribution and Abundance

Four seasonal runs of Chinook salmon occur in the Central Valley, with each run defined by a combination of adult migration timing, spawning period, and juvenile residency and smolt migration periods. (Fisher 1994 as cited in Yoshiyama et al. 2001 p. 73.) The runs are named after the season when adults move upstream to migrate-- winter, spring, fall, and late-fall. The Sacramento River basin supports all four runs resulting in adult salmon being present in the basin throughout the year. (Stone 1883a; Rutter 1904; Healey 1991; Vogel and Marine 1991 as cited in Yoshiyama *et. al,* 2001 p. 73.) Historically, different runs occurred in the same streams staggered in time to correspond to the appropriate stream flow regime for which that species evolved, but overlapping. (Vogel and Marine 1991; Fisher 1994 as cited in Yoshiyama et al*.,* 2001, p. 73.) Typically, fall and late-fall runs spawn soon after entering natal streams and spring and winter runs typically “hold” for up to several months before spawning. (Rutter 1904; Reynolds and others 1993 as cited in Yoshiyama *et. al,* 2001, p. 73.) These runs and their life-cycle timing are summarized in Table 3 and described in more detail below.

Winter-Run - Due to a need for cool summer flows, Sacramento River winter-run originally likely only spawned in the upper Sacramento River tributaries, including the McCloud, Pit, Fall, and Little Sacramento rivers and Battle Creek. (NMFS 5, p. 16.) As a result of construction of

Shasta and Keswick Dams, today all spawning habitat above Keswick Dam has been eliminated and approximately 47 of the 53 miles of habitat in Battle Creek has been eliminated. (Yoshiyama et al. 1996, as cited in NMFS 5, p. 16.) Currently, winter-run habitat is likely limited to the Sacramento River reach between Keswick Dam downstream of the Red Bluff Diversion Dam. (NMFS 5, p. 16.)

The winter-run population is currently very vulnerable due to its low population numbers and the fact that only one population exists. (Good et al. 2005, as cited in NMFS 5, p. 16.) In the late 1960s escapement was near 100,000 fish declining to fewer than 200 fish in the 1990s. (*Id*.) Recent escapement estimates from 2004 to 2006 averaged 13,700 fish. (DFG Website 2007, as cited in NMFS 5, p. 16.) However, in 2007 and 2008 escapements were less than 3,000 fish. Since 1998, hatchery produced winter-run have been released likely contributing to the observed increased escapement numbers. (Brown and Nichols 2003 as cited in NNFS 5, p. 16.) In addition, a temperature control device was installed on Shasta Dam in 1997 likely improving conditions for winter-run. (NMFS 5, p. 18.)

<u>Spring-Run</u> - Historically, spring-run were likely the most abundant salmonid in the Central Valley inhabiting headwater reaches of all major river systems in the Central Valley in the absence of natural migration barriers. (NMFS 5, p. 28.) Since the 1880s, construction of dams and other factors have significantly reduced the numbers and range of spring-run in the Central Valley. (*Id*.) Currently, the only viable populations occur on Mill, Deer, and Butte creeks, but those populations are small and isolated. (DFG 1998, as cited in NMFS 5, p. 28.) In addition, the Feather River Fish Hatchery which opened in 1967 produces spring-run salmon. However, significant hybridization of these hatchery fish with fall-run has occurred. (NMFS 5, p. 28-31.)

Historically, Central Valley spring-run numbers were estimated to be as large as 600,000 fish. (DFG 1998 as cited in NMFS 5, p. 28.) Nearly 50,000 spring-run adults were counted on the San Joaquin River prior to construction of Friant Dam. (Fry 1961 as cited in NMFS 5, p. 28.) Shortly after construction of Friant Dam, spring-run were extirpated on the San Joaquin River. (Yoshiyama et al. 1998 as cited in NMFS 5, p. 28.) Since 1970, estimates of spring-run populations in the Sacramento River have been as high as 30,000 fish and as low as 3,000 fish. (NMFS 5, p. 28.)

<u>Fall-Run</u> - Historically, fall run likely occurred in all Central Valley streams that had adequate flows during the fall months, even if the streams were intermittent during other parts of the year. (Yoshiyama *et. al* 2001, p. 74.) Due to their egg-laden and deteriorating physical condition, fall-run likely historically spawned in the valley floor and lower foothill reaches and probably were limited in their upstream migration. (Rutter 1904 as cited in Yoshiyama *et. al* 2001, p. 74.)

Currently, fall-run Chinook inhabit both the Sacramento and San Joaquin river basins and are currently the most abundant of the Central Valley races, contributing to large commercial and recreational fisheries in the ocean and popular sportfisheries in the freshwater streams. Fall-run Chinook are raised at five major Central Valley hatcheries which release more than 32 million smolts each year. In the past few years, there have been large declines in fall-run populations with escapements of 88,0000 and 66,000 fish in 2007 and 2008. (NMFS 2009, p. 4.) NMFS concluded that the recent declines were likely primarily due to poor ocean conditions in 2005 and 2006. (*Id*.) Other factors contributing to the decline of fall-run include: loss of spawning grounds due to dams and other factors, degradation of spawning habitat from water diversions, introduced species, altered sediment dynamics, hatchery practices, degraded water quality, and loss of riparian and estuarine habitat. (*Id*.)

Late-Fall Run - Historically, late fall-run probably spawned in the mainstem Sacramento River and major tributary reaches and possibly in the San Joaquin River upstream of its tributaries. (Hatton and Clark 1942; Van Cleve 1945; Fisher 1994 as cited in Yoshiyama *et. al* 2001.) Today, late-fall run are mostly found in the upper Sacramento River where the river remains deep and cool enough in the summer for juvenile rearing. (Moyle 2002, p. 254.) The late fall-run has continued low, but potentially stable abundance. (NMFS 2009, p. 4.) Estimates from 1992 ranged from 6,700 to 9,700 fish and in 1998 were 9,717 fish. However, changes in estimation methods, lack of data, and hatchery influences make it difficult to accurately estimate abundance trends for this run. (*Id.*)

Table 3. Generalized Life History Timing of Central Valley Chinook Salmon Runs

	Migration Period	**Peak Migration**	**Spawning Period**	**Peak Spawning**	**Juvenile Emergence Period**	**Juvenile Stream Residency**
Sacramento River Basin Late Fall-Run	October–April	December	Early January–April	February–March	April-June	7-13 months
Winter-Run	December-July	March	Late April-early August	May-June	July-October	5-10 months
Spring-Run	March-September	May- June	Late August-October	Mid-September	November-March	3-15 months
Fall Run	June-December	September-October	Late September-December	October-November	December-March	1-7 months
San Joaquin (Tuolumne River) Fall-Run	October-early January	November	Late October-January	November	December-April	1-5 months

Source: Yoshiyama *et al*. (1998) as cited in Moyle 2002, p. 255.

Population Abundance and Relationship to Flow

Delta outflows and inflows affect rearing conditions and migration patterns for Chinook salmon in the Delta watershed. Freshwater flow serves as an important cue for upstream adult migration and directly affects juvenile survival and abundance as they move downstream through the Delta. (DOI 1, p. 23.) Decreased flows may decrease migration rates and increase exposure to unsuitable water quality and temperature conditions, predators, and entrainment at water diversion facilities. (DFG 1, p. 1.) For the most part, relationships between salmon survival and abundance have been developed using tributary inflows rather than Delta outflows, however, the Delta is an extension of the riverine environment until salmon reach the salt water interface. (DOI 1, p. 29.) Prior to development and channelization, the Delta provided hospitable habitat for salmon. With channelization and other development, the environment is no longer hospitable for salmon. As a result, the most beneficial Delta outflow pattern for salmon may currently be one that moves salmon through the Delta faster. (*d.*)

Salmon respond behaviorally to variations in flows. Monitoring shows that juvenile and adult salmon begin migrating during the rising limb of the hydrograph. (DOI 1, p. 30.) For juveniles, pulse flows appear to be more important than for adults. (*Id.*) For adults, continuous flows through the Delta and up to each of the natal tributaries appears to be more important. (*Id.*) Flows and water temperatures are also important to maintain populations with varied life history strategies in different year types to insure continuation of the species over different hydrologic and other conditions. For salmon migrating as fry within a few days of emigration from redds, increased flows provide improved transport downstream and improved rearing habitat, and for salmon that stay in the rivers to rear, increased flows provide for increased habitat and food production. (DOI 1, 30.)

Population Abundance Goal

The immediate goal is to significantly improve survival of all existing runs of Chinook salmon that migrate through the Delta in order to facilitate positive population growth in the short term and subsequently achieve the narrative salmon protection objective identified in the 2006 Bay-Delta Plan to double the natural production of Chinook salmon from the average production from 1967 to 1991 consistent with the provisions of State and federal law. (State Water Board 2006a, p. 14.)

Species- Specific Recommendations

Delta Outflow

No specific Delta outflow criteria are recommended for Chinook salmon. Any flow needs would generally be met by the following inflow criteria and by the Delta outflow criteria determined for estuarine dependant species discussed elsewhere in this report.

Sacramento River Inflows

The 2006 Bay-Delta Plan includes flow objectives for the Sacramento River at Rio Vista for the protection of fish and wildlife beneficial uses from September through December ranging from 3,000 to 4,500 cfs. (State Water Board 2006a, p. 15.) These flow objectives are in part intended to provide attraction and transport flows and suitable habitat conditions for Chinook salmon. (State Water Board 2006b, p. 49.) The 2006 Bay-Delta Plan includes Delta outflow objectives for the remainder of the year, which effectively provide Sacramento River inflows. However, the Bay-Delta Plan does not include any specific Sacramento River flow requirements for the remainder of the year, including the critical spring period.

Habitat alterations in the Delta limit Sacramento River salmon production primarily through reduced survival during the outmigrant (smolt) stage. Decreases in flow through the estuary, increased temperatures, and the proportion of flow diverted through the Delta Cross Channel and Georgiana Slough on the Sacramento River are associated with lower survival in the Delta of marked juvenile fall-run Sacramento River salmon. (DOI 1, p. 24.) In 1981 (p. 17-18) and 1982 (p. 404), Kjelson et al. reported that flow was positively correlated with juvenile fall-run Chinook salmon survival through the Delta and that temperature was negatively correlated with survival. In testimony before the State Water Board in 1987 Kjelson presented additional analyses that again showed that survival of fall-run Chinook salmon smolts through the Delta between Sacramento and Suisun Bay was found to be positively correlated to flow and negatively correlated to water temperature. (p. 36.) Smolt survival increased with increasing Sacramento River flow at Rio Vista, with maximum survival observed at or above about 20,000 and 30,000 cfs from April through June (p. 36), while no apparent relationship was found at flows between 7,000 and 19,000 cfs (p. 27), suggesting a potential threshold response to flow. Smolt survival was also found to be highest when water temperatures were below 66ºF. (p. 61.) In addition to increased survival, juvenile abundance has also been found to be higher with greater Sacramento River flow. (DFG 3, pp. 1 and 6.) The abundance of juvenile Chinook salmon leaving the Delta at Chipps Island was found to be highest when Rio Vista flows averaged above 20,000 cfs from April through June. (*Id*.)

Dettman et al. (1987) reanalyzed data from the 1987 Kjelson experiments and found a positive correlation between an index of spawning returns, based on coded-wire tagged fish, and both

June and July outflow from the Delta. (p. 1.) In 1989, Kjelson and Brandes updated and confirmed Kjelson's 1987 findings again reporting that survival of smolts through the Delta from Sacramento to Suisun Bay was highly correlated to mean daily Sacramento River flow at Rio Vista. (p. 113.) In the State Water Board's 1992 hearings, USFWS (1992) presented additional evidence, based on data collected from 1988 to 1991, that increased flow in the Delta may increase migration rates of both wild and hatchery fish migrating from the North Delta (Sacramento and Courtland) to Chipps Island. (DOI 1, p. 26.)

In 2001, Brandes and McLain confirmed the relationships between water temperature, flow, and juvenile salmonid survival. (p. 95.) In 2006, Brandes et al. updated findings regarding the relationship between Sacramento River flows and survival and found that the catch of Chinook salmon smolts surveyed at Chipps Island between April and June of 1978 to 2005 was positively correlated with mean daily Sacramento River flow at Rio Vista between April and June. (p. 41-46.)

In addition to the flow versus juvenile fall-run Chinook salmon survival relationships discussed above, several studies show that loss of migrating salmonids within Georgiana Slough and the interior Delta is approximately twice that of fish remaining in the mainstem Sacramento River. (Kjelson and Brandes 1989; Brandes and McLain 2001; Vogel 2004, 2008; and Newman 2008 as cited in NMFS 3, p. 640). Recent studies and modeling efforts have found that increasing Sacramento River flow such that tidal reversal does not occur in the vicinity of Georgiana Slough and at the Cross Channel Gates would lessen the proportion of fish diverted into channels off the mainstem Sacramento River. (Perry et al. 2008, 2009.) Thus, closing the Delta Cross Channel and increasing the flow on the Sacramento River to levels where there is no upstream flow from the Sacramento River entering Georgiana Slough on the flood tide during the juvenile salmon migration period (November to June) will likely reduce the number of fish that enter the interior Delta and improve survival. (DOI 1, p. 24.) To achieve no bidirectional flow in the mainstem Sacramento River near Georgiana Slough, flow levels of 13,000 (personal communication Del Rosario) to 17,000 cfs at Freeport are needed. (DOI 1, p. 24.)

Monitoring of emigration of juvenile Chinook salmon on the lower Sacramento River near Knights Landing also indicates a relationship between timing and magnitude of flow in the Sacramento River and the migration timing and survival of Chinook salmon approaching the Delta from the upper Sacramento River basin. (Snider and Titus 1998, 2000a, 2000b, 2000c, and subsequent draft reports and data as cited in DFG 1, p. 7.) The emigration timing of juvenile late fall, winter, and spring-run Chinook salmon from the upper Sacramento River basin depends on increases in river flow through the lower Sacramento River in fall, with significant precipitation in the basin by November to sustain downstream migration of juvenile Chinook salmon approaching the Delta. (Titus 2004 as cited in DFG 1, p. 7.) Sacramento River flows at Wilkins Slough of 15,000 to 20,000 cfs following major precipitation events are associated with increased emigration. (DFG 1, p. 7 and NMFS 7, p. 2-4.)

Delays in precipitation producing flows result in delayed emigration which may result in increased susceptibility to in-river mortality from predation and poor water quality conditions. (DFG 1, p. 7.) Allen and Titus (2004) suggest that the longer the delay in migration, the lower the survival of juvenile salmon to the Delta. (as cited in DFG 1, p. 7.) DFG indicates that juvenile Chinook salmon appear to need increases in Sacramento River flow that correspond to flows in excess of 20,000 cfs at Wilkins Slough by November with similar peaks continuing past the first of the year. (DFG 1, p. 7.) Pulse flows in excess of 15,000 to 20,000 cfs may also be necessary to erode sediment in the upper Sacramento River downstream of Shasta to create turbid inflow pulses to the Delta. (AR/NHI 1, p. 32.)

Salmon are the only species considered for the Sacramento River inflow criteria; discussion of the flow criteria for Sacramento River inflows is therefore continued in Section 5.2, Sacramento River Inflow criteria.

San Joaquin River Inflows

Currently the Merced, Tuolumne, and Stanislaus river tributaries to the San Joaquin River support fall-run Chinook salmon. Historically spring-run also inhabited the basin. Pursuant to the San Joaquin River Restoration effort, there are plans to reintroduce spring-run Chinook salmon to the main-stem river beginning in 2012. Since the 1980s (1980-1989), San Joaquin basin fall-run Chinook salmon escapement numbers have declined from approximately 26,000 fish to 13,000 fish in the 2000s (2000-2008). (TBI/NRDC 3, p. 22.) Flow related conditions are believed to be a significant cause of this decline.

The 2006 Bay-Delta Plan includes flow objectives for the San Joaquin River at Vernalis, largely for the protection of fall-run Chinook salmon. The plan includes base flows during the spring (February through June with the exception of mid-April through mid-May) that vary between 700 and 3,420 cfs based on water year type and required location of X2. To improve juvenile fall-run Chinook salmon outmigration, the Plan also includes spring pulse flows (mid-April through mid-May) that vary between 3,110 and 8,620 cfs, however, those flows have never been implemented and have instead been replaced with the Vernalis Adaptive Management Plan (VAMP) flow targets for the past 10 years. The VAMP flows are lower than the pulse flow objectives and vary between 2,000 and 7,000 cfs based on existing flows and other conditions. (State Water Board 2006a, p. 24-26.) The 2006 Bay-Delta Plan also includes a flow objective of 1,000 to 2,000 cfs during October to support adult fall-run Chinook salmon migration. (State Water Board 2006b, p. 15-16.) The 2006 Bay-Delta Plan does not include any specific flow requirements during the remainder of the year. (State Water Board 2006b, pg. 50.)

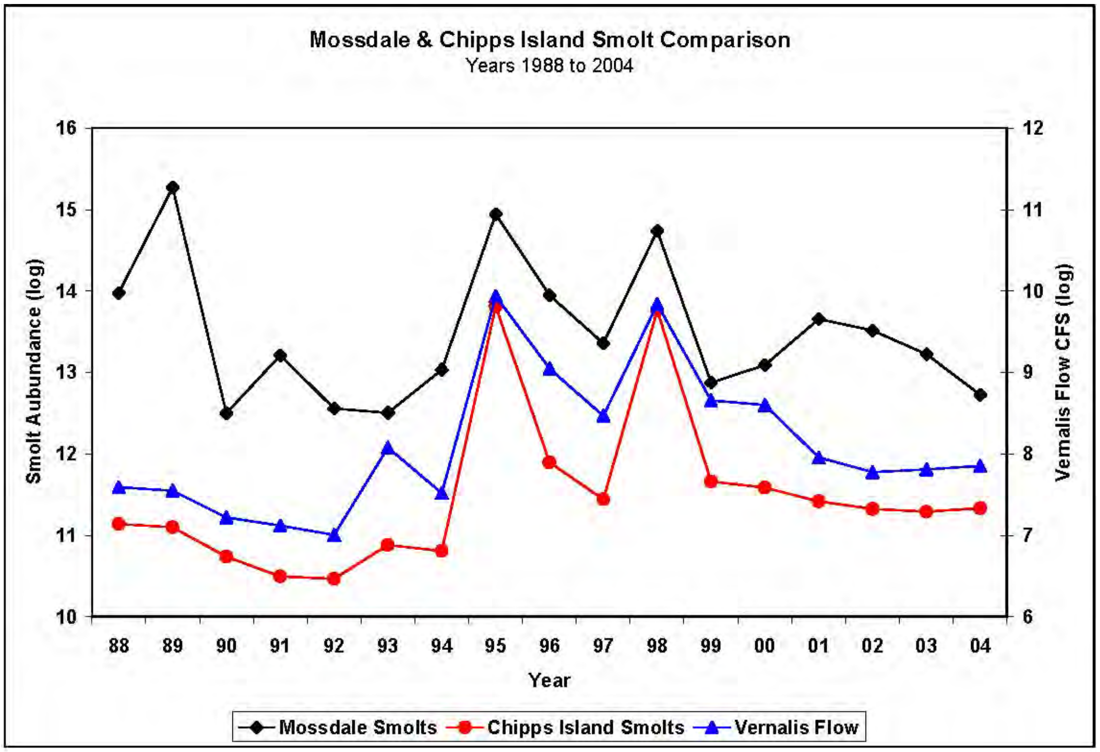
Inflows from the San Joaquin River affect various life stages of Chinook salmon including adult migration, spawning, egg incubation, juvenile rearing, and juvenile emigration to the ocean. Evidence indicates that to maintain a viable Chinook salmon population, escapements should not decline below approximately 833 adult salmon per year (a total of 2,500 salmon in 3 years), and fluctuations in escapement between wet and dry years should be reduced by increasing dry year escapements and the percentages of hatchery fish should be reduced to no more than 10%. (Lindley and others 2007, as cited in CSPA 14, p. 3-4.) Mesick estimates that the Tuolumne River population is currently at a high risk of extinction (Mesick 2009); and that the Stanislaus and Merced river populations are also likely soon to be at a high risk of extinction due to high percentages of hatchery fish. (CSPA 7, p.4.)

Mesick estimates that the decline in escapement on the Tuolumne River from 130,000 salmon in the 1940s to less than 500 in recent years is primarily due to inadequate minimum instream flow releases from La Grange Dam in late winter and spring during non-flood years. (CSPA 14, p. 1.) Mesick suggests that escapement has been primarily determined by the rate of juvenile survival, which is primarily determined by the magnitude and duration of late winter and spring flows since the 1940s. (CSPA 14, p. 2.) Mesick indicates that other analyses show that spawner abundance, spawning habitat degradation, and the harvest of adult salmon in the ocean have not caused the decline in escapement. (CSPA 14, p. 1.)

Successful adult Chinook salmon migration depends on environmental conditions that cue the response to return to natal streams. Optimal conditions help to reduce straying and maintain egg viability and fecundity rates. (DFG 3, p. 2 and CSPA 7, p. 1.) Analyses of flow needs for the protection of adult fall-run migration conducted by Hallock and others from 1964 to 1967 indicate that the presence of Sacramento River water in the central and south Delta channels results in migration delays for both San Joaquin River and Sacramento River basin salmon. (Hallock et al*.,* 1970 as cited in DOI 1, p. 25.) These analyses also show that reverse flows on the San Joaquin River delay and potentially hamper migration. (*Id.*) In addition, analyses by Hallock show that water temperatures in excess of 65˚ F and low DO conditions of less than 5 mg/l in the San Joaquin River near Stockton act as a barrier to adult migration. (as cited in AFRP 2005, p. 11.) Delayed migration may result in reduced gamete viability under elevated temperatures and mortality to adults prior to spawning. (AFRP 2005, p. 12.)

Mesick found that up to 58% of Merced River Hatchery Chinook salmon strayed to the Sacramento River Basin when flows in the San Joaquin River were less than 3,500 cfs for ten days in late October, but stray rates were less than 6% when flows were at least 3,500 cfs. (CSPA 14, p. 15 and CSPA 7, p. 1.) Mesick indicates that providing 1,200 cfs flows from the tributaries to the San Joaquin River (Merced, Tuolumne, and Stanislaus) for ten days in late October increases escapement by an average of 10%. (Mesick 2009 as cited in CSPA 7, p. 1.) The 2005 AFRP includes similar recommendations for flows of 1,000 cfs from each of the San Joaquin River tributaries. (AFRP, p. 12.) Such flows would likely improve DO conditions, temperatures, and olfactory homing fidelity for San Joaquin basin salmon. (Harden Jones 1968, Quinn et al. 1989, Quinn 1990 as cited in EDF 1, p. 48.) To achieve olfactory homing fidelity and continuous flows for adult migration, the physical source of this water is at least as important as the volume or rate of flow, especially given that the entire volume of the San Joaquin River during the fall period is typically diverted at the southern Delta export facilities. (EDF 1. p. 48.) Even in the absence of exports, it is necessary for the scent of the San Joaquin basin watershed to enter the Bay in order for adult salmonids to find their way back to their natal rivers. (NMFS 2009, p.407 as cited in EDF 1, p. 48.)

Outmigration success of juvenile Chinook salmon is affected by multiple factors, including water diversions and conditions related to flow. Data show that smolt survival and resulting adult production is better in wet years. (Kjelson and Brandes, 1989, SJRGA, 2007 as cited in DOI 1, p. 24.) VAMP analyses indicate that San Joaquin River flow at Vernalis is positively associated with the probability of survival for outmigrating smolts from Dos Reis (downstream of the Old River bifurcation) to the Delta (Jersey Point). (Newman, 2008 as cited in DOI 1, p. 24.) A positive relationship has also been shown between salmon survival indices and flow at Jersey Point for fish released at Jersey Point. (USFWS 1992, p. 21 as cited in DOI 1, p. 24.) Data indicate that maximum San Joaquin basin adult fall-run chinook salmon escapement may be achieved with flows exceeding 20,000 cfs at Vernalis during the smolt emigration period of April 15 through June 15. (2006 VAMP report page 65; DOI 1, p. 25.) As indicated below in Figure 9, DFG found that more spring flow from the San Joaquin River tributaries results in more juvenile salmon leaving the tributaries, more salmon successfully migrating to the South Delta, and more juvenile salmon surviving through the Delta. (DFG 3, p. 17.) DFG concludes that the primary mechanism needed to substantially produce more smolts at Jersey Point is to substantially increase the spring Vernalis flow level (magnitude, duration, and frequency) which will produce more smolts leaving the San Joaquin River tributaries, and produce more smolts surviving to, and through, the South Delta. (DFG 3, p. 17-18.) DFG indicates that random rare and unpredictable poor ocean conditions may cause stochastic high mortality of juvenile salmon entering the ocean, but that the overwhelming evidence is that more spring flow results in higher smolt abundance, and higher smolt abundance equates to higher adult production. (DFG 3, p.17.)



Note: This figure shows the relationship of smolt abundance (log transformed) at Mossdale to estimate smolt abundance at Chipps Island by average spring (3/15 to 6/15) Vernalis flow level (log transformed). To estimate the number of smolts at Chipps Island the smolt survival vs. flow level relationship developed by Dr. Hubbard was applied on a daily basis to the Mossdale smolt abundance and out-migration pattern. Smolt abundance at Chipps Island (or stated differently smolt survival through the Delta on an annual basis) can change by an order of magnitude pending Vernalis flow rate. (DFG 3, p. 16.)

Figure 9. Salmon Smolt Survival and San Joaquin River Vernalis Flows

Elevated flows during the smolt outmigration period function as an environmental cue to trigger migration, facilitate transport of juveniles downstream, improve migration corridor conditions to inundate floodplains, reduce predation and improve temperature and other water quality conditions; these are all functions that are currently extremely impaired on the San Joaquin River. (e.g., “Steelhead stressor matrix,” NMFS 2009 as cited in TBI/NRDC 3, p. 7.) Under the 2006 Bay-Delta Plan, elevated flows are limited to approximately the mid-April to mid-May period. However, outmigration timing in the San Joaquin River basin occurs over a prolonged time frame from mid-March through June. (TBI/NRDC 3, p. 12-13.) This restricted window may impair population viability by limiting survival of fish that migrate outside of this time period, thus reducing the life history diversity and the genetic diversity of the population. (TBI/NRDC 3, p. 11-12.) Diverse migration timing increases population viability by making it more likely that at least some portion of the population is exposed to favorable ecological conditions in the Delta and into the ocean. (Smith et al. 1995 as cited in TBI/NRDC 3, p. 12.)

Temperature conditions in the San Joaquin River basin may limit smolt outmigration and survival. Lethal temperature thresholds for Pacific salmon depend, to some extent, on acclimation temperatures. (Myrick and Cech 2004 as cited in TBI/NRDC 3, p. 18.) Central Valley salmonids are generally temperature-stressed through at least some portion of their freshwater life-cycle. (e.g. Myrick and Cech 2004, 2005 as cited in TBI/NRDC 3, p. 18.) Lethal temperature effects commence in a range between 71.6° and 75.2° F (Baker et al.1995 as cited in TBI/NRDC 3, p. 18), with sub-lethal effects occurring at lower temperatures. Access to food also affects temperature responses. When fish have adequate access to food, growth increases with increasing temperature, but when food is limited (which is typical), optimal growth occurs at lower temperatures. (TBI/NRDC 3, p 18.) Marine and Cech (2004) observed decreased growth, smoltification success, and predator avoidance at temperatures above 68˚ F and that fish reared at temperatures between 62.6˚ and 68˚ F experienced increased predation compared to fish reared at between 55.4˚ and 60.8˚ F. (as cited in TBI/NRDC 3, p. 18.) Several studies indicate that optimal rearing temperatures for Chinook salmon range from 53.6˚ to 62.6F (Richter and Kolmes 2005 as cited in TBI/NRDC 3, p. 18.) Mesick found that Tuolumne River smolt outmigration rates and adult recruitment were highest when water temperatures were at or below 59˚F when smolts were migrating in the lower river. (Mesick 2009, p. 25.) Elevated temperatures may also affect competition between different species. (Reese and Harvey 2002 as cited in TBI/NRDC 3, p. 18.)

Temperature is determined by a number of factors including reservoir releases, channel geometry, and ambient air temperatures. As a result, a given flow may achieve different water temperatures depending on the other conditions listed above. Cain estimates that flows over 5,000 cfs in late spring (April to May) generally provide water temperatures (below 65˚ F) suitable for Chinook salmon, but that flows less than 5,000 cfs may be adequate to provide sufficient temperature conditions. (Cain 2003 as cited in TBI/NRDC 3, p 13-14.) Mesick indicates that salmon smolt survival can be improved by maintaining water temperatures near 59˚F from March 15 to May 15 and as low as practical from May 16 to June 15. (CSPA 7, p. 2-3.) To maintain mean water temperatures near 59˚F and maximum temperatures below 65˚F from March 15 to May 15 in the tributaries downstream to the confluence with the San Joaquin River, Mesick indicates that flows need to be increased in response to average air temperature. (CSPA 7, p. 3.)

There are several different estimates for flow needs on the San Joaquin River during the spring period to improve or double salmon populations on the San Joaquin River. The USFWS's 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* (2005 AFRP) concludes that the declines in salmon in the San Joaquin River basin primarily resulted from reductions in the frequency and magnitude of spring flooding in the basin from 1992-2004 compared to the baseline period of 1967-1991. (2005 AFRP, p. 1.) The AFRP states that the most likely method to increase production of fall-run Chinook salmon is to increase flows from February to March to increase survival of juveniles in the tributaries and smolts in the mainstem and then to increase flows from April to mid-June to increase smolt survival through the Delta. (*Id.*) Using salmon production models for the San Joaquin River Basin, the AFRP provides recommendations for the amount of flow at Vernalis that would be needed to double salmon production in the San Joaquin River basin. On average, over the four month period of February to May, the AFRP recommends that flows range from less than 4,000 cfs in critical years to a little more than 10,000 cfs in wet years. From March through June, AFRP recommends that flows average between about 4,500 cfs in critical years to more than 12,000 cfs in wet years. (2005 AFRP, p. 8-10.)

Using a non-linear regression empirical data driven fall-run Chinook salmon production model, DFG developed flow recommendations for the San Joaquin River from March 15 through June 15 to double Chinook salmon smolt production. DFG developed a variety of modeling scenarios to evaluate the effects of various combinations of flow magnitudes and durations in order to identify the combination of flow levels varied by water year type to achieve doubling of juveniles. Base flows for the March 15 through June 15 period vary between 1,500 cfs in critical years to

6,315 cfs in wet years. Pulse flow recommendations vary between 7,000 cfs and 15,000 cfs for durations of 31 to 70 days depending on water year type. (DFG 3, p. 34.)

In analyzing the relationship between Vernalis flow and cohort return ratios of San Joaquin River Chinook salmon, TBI/NRDC found that Vernalis average March through June flows of approximately 4,600 cfs corresponded to an equal probability for positive population growth or negative population growth. (TBI/NRDC 3, p. 24.) TBI/NRDC found that average March through June flows exceeding 5,000 cfs resulted in positive population growth in 84% of years with only 66% growth in years with flows less than 5,000 cfs. (*Id.)* TBI/NRDC found that flows of 6,000 cfs produced a similar response as the 5,000 cfs flows and flows of 4,000 cfs or lower resulted in significantly reduced population growth of only 37% of years. (*Id*.) The TBI/NRDC analysis suggests that 5,000 cfs may represent an important minimum flow threshold for salmon survival on the San Joaquin River. (*Id*.) Based on abundance to prior flow relationships, TBI/NRDC estimates that average March through June inflows of 10,000 cfs are likely to achieve the salmon doubling goal. (TBI/NRDC 3, p. 16-17.)

In addition to fall pulse flows for adult migration and spring flows to support juvenile emigration, additional flows on the San Joaquin River may be needed at other times of year to support Chinook salmon and their habitat. The 2006 Bay-Delta Plan does not include base flow objectives for the San Joaquin River. However, the Central Valley Regional Board's Water Quality Control Plan for the Sacramento and San Joaquin River Basins does include a year round DO objective of 5.0 mg/l at all times on the San Joaquin River within the Delta. (Central Valley Regional Board 2009,. III-5.0). The 2006 Bay-Delta Plan and the Central Valley Basin Plan also include a DO objective of 6.0 mg/L between Turner Cut and Stockton from September 1 through November 30. (*Id*.)

Current flow conditions on the San Joaquin River result in DO conditions below the existing DO objectives in the fall and winter in lower flow years. These conditions may result in delayed migration and mortality to San Joaquin River Chinook salmon, steelhead and other species. Increased flows would improve DO levels in the lower San Joaquin River. Additional flows at other times of year in the tributaries to the San Joaquin River would also provide improved conditions for steelhead inhabiting tributaries to the San Joaquin River (NMFS 3, p. 105) and would have additional benefits by reducing nutrients pollution and biological oxygen demand. (TBI/NRDC 3, p. 27.)

To reduce crowding of spawning adults during the fall, increased flows in the tributaries may also be needed from November through January to ensure protection of Chinook salmon. (AFRP, p. 12.) However, there is no evidence that increased flows would reduce spawner crowding or improve juvenile production. (*Id*.) Habitat modeling indicates that flows of up to 300 cfs on the San Joaquin River tributaries may provide optimum physical habitat during the fall. (AFRP 2005, p. 14.)

To maintain the ecosystem benefits of a healthy riparian forest, minimum flows and ramping rates for riparian recruitment may also be needed during late spring and early summer. (AFRP 2005, p. 14.) To protect over-summering steelhead and salmon, flows in the tributaries during the summer and fall are needed. To maintain minimal habitat of a suitable temperature (less than 65° F), flows between 150 and 325 cfs may be needed on each of the tributaries to the San Joaquin River. (AFRP 2005, pp. 14-15.)

The magnitude, duration, timing, and source of San Joaquin River inflows are important to San Joaquin River Chinook salmon migrating through the Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important during the fall to provide attraction flows and are especially important during juvenile emigration periods. Flows on tributaries to the San Joaquin River are also important for egg incubation and rearing, in addition to migration.

As with the Sacramento River inflows, Chinook salmon are the only species considered for the San Joaquin River inflow criteria; discussion of flow criteria for San Joaquin River inflows is therefore continued in Section 5.3, San Joaquin River inflow criteria.

Hydrodynamics

All Central Valley Chinook salmon must migrate out of the Delta as juveniles and back through the Delta as adults returning to spawn. In addition, many Central Valley Chinook salmon also rear in the Delta for a period of time. (DOI 1, p. 53.) Delta exports affect salmon migrating through and rearing in the Delta by modifying tidally dominated flows in the channels. It is, however, difficult to quantitatively evaluate the direct and indirect effects of these hydrodynamic changes. Delta exports can cause a false attraction flow drawing fish to the export facilities where direct mortality from entrainment may occur. (DOI 1, p. 29.) More important than direct entrainment effects, however, may be the indirect effects caused by export operations increasing the amount of time salmon spend in channelized habitats where predation is high. (*Id*.) Steady flows during drier periods (as opposed to pulse flows that occur during wetter periods) may increase these residence time effects. (DOI 1.)

Direct mortality from entrainment at the south Delta export facilities is most important for San Joaquin River and eastside tributary salmon (and steelhead). (DOI 1, p. 29.) Juvenile salmonids emigrate downstream on the San Joaquin River during the winter and spring. Salmonids from the Calaveras River basin and the Mokelumne River basin also use the lower San Joaquin River as a migration corridor. This lower reach of the San Joaquin River between the Port of Stockton and Jersey Point has many side channels leading toward the export facilities that draw water through the channels to the export pumps. (NMFS 3, p. 651.) Particle tracking model (PTM) simulations and acoustic tagging studies indicate that migrating fish may be diverted into these channels and may be affected by flow in these channels. (Vogel 2004, SJRGA 2006, p. 68, SJRGA 2007, pp. 76-77, and NMFS 3, p. 651.) Analyses indicate that tagged fish may be more likely to choose to migrate south toward the export facilities during periods of elevated diversions than when exports are reduced. (Vogel 2004.)

Similarly, salmon that enter the San Joaquin River through Georgiana Slough from the Sacramento River may also be vulnerable to export effects. (NMFS 3, p. 652.) While fish may eventually find their way out of the Central Delta channels after entering them, migratory paths through the Central Delta channels increase the length and time that fish take to migrate to the ocean increasing their exposure to predation, increased temperatures, contaminants, and unscreened diversions. (NMFS 3, p. 651-652.)

PTM analyses indicate that as net reverse flows in Old and Middle rivers increase from -2,500 cfs to -3,500 cfs, particle entrainment changes from 10% to 20% and then again to 40% when flows are -5,000 cfs and 90% when flows are -7,000 cfs. (*Id*.) Based on these findings, NMFS's Opinion includes requirements that exports be reduced to limit negative net Old and Middle river flows to -2,500 cfs to -5,000 cfs depending on the presence of salmonids from January 1 through June 15. (NMFS 3, p. 648.)

In addition to effects of net reverse flows in Old and Middle rivers, analyses concerning the effects of net reverse flows in the San Joaquin River at Jersey Point were also conducted and documented in the USFWS, 1995 *Working Paper on Restoration Needs, Habitat Restoration Actions to Double the Natural Production of Anadromous Fish in the Central Valley California* (1995Working Paper). These analyses show that net reverse flows at Jersey Point decrease the survival of smolts migrating through the lower San Joaquin River. (USFWS 1992b as cited in USFWS 1995b, p. 3Xe-19.) Net reverse flows on the lower San Joaquin River and diversions into the central Delta may also result in reduced survival for Sacramento River fall-run Chinook salmon. (USFWS 1995b, p. 3Xe-19) Based on these factors, the 1995 Working Paper includes a recommendation to maintain positive flows at Jersey Point of 1,000 cfs in critical and dry years, 2,000 cfs in below- and above-normal years, and 3,000 cfs in wet years from October 1 through June 30 to improve survival for all races and stocks of juvenile salmon and steelhead migrating through and rearing in the Delta. (*Id*.)

In addition to relationships between reverse flows and entrainment effects, flows on the San Joaquin River versus exports also appear to be an important factor in protecting San Joaquin River Chinook salmon. Various studies show that, in general, juvenile salmon released downstream of the effects of the export facilities (Jersey Point) have higher survival out of the Delta than those released closer to the export facilities. (NMFS 3-Appendix 3, p. 74.) Studies also indicate that San Joaquin basin Chinook salmon production increases when the ratio of spring flows to exports increases. (DFG 2005, SJRGA 2007 as cited in NMFS 3-Appendix 3, p. 74.) However, it should be noted that flow at Vernalis appears to be the controlling factor. Increased flows in the San Joaquin River in the Delta may also benefit Sacramento basin salmon by reducing the amount of Sacramento River water that is pulled into the central Delta and increasing the amount of Sacramento River water that flows out to the Bay. (NMFS 3, Appendix 3, p. 74-75.) Based on these findings, the NMFS Opinion calls for export restrictions from April 1 through May 31 with Vernalis flows to export ratios ranging from 1.0 to 4.0 based on water year type, with unrestricted exports above flows of 21,750 cfs at Vernalis, in addition to other provisions for health and safety requirements. (NMFS 3, Appendix 3, p.73-74.)

Analyses by TBI/NRDC indicate that Vernalis flow to export ratios above 1.0 during the San Joaquin basin juvenile salmon outmigration period in the spring consistently correspond to higher escapement estimates two and half years later, with more than 10,000 fish in 76% of years. (TBI/NRDC 4, p. 11.) Vernalis flows to export ratios of less than 1.0 correspond to lower escapement estimates two and half years later, with more than 10,000 fish in only 33% of years. (*Id*.) TBI/NRDC estimates that Vernalis flows to export ratios of greater than 4.0 would reach population abundance goals. (TBI/NRDC 4, pp. 11-12.)

Vernalis flows to export ratios also appear to be important during the fall period to provide improved migration conditions for adult fall-run San Joaquin basin Chinook salmon. Adult fall-run San Joaquin basin Chinook salmon migrate upstream through the Delta primarily during October when San Joaquin River flows are typically low. (AFRP 2005, p. 12.) As a result, when exports are high, little if any flow from the San Joaquin basin may make it out to the ocean to help guide San Joaquin basin salmon back to the basin to spawn. (*Id*.) Analyses indicate that increased straying occurs when more than 400% of the flow at Vernalis is exported at the Delta pumping facilities (equivalent to a Vernalis flow to export ratio of 0.25). (*Id*.) Straying rates decreased substantially when export rates were less than 300% of Vernalis flow. (*Id.*)

Export related criteria for salmon are provided in section 5.4, Hydrodynamic Recommendations.

Floodplain Flows

Juvenile salmon will rear on seasonally inundated floodplains when available. Such rearing in the Central Valley, in the Yolo Bypass and the Cosumnes River floodplain, has been found to have a positive effect on growth and apparent survival of juvenile Central Valley salmon through the Delta. (Sommer *et al*. 2001 and Jeffres *et al*. 2005 as cited in DOI 1, p. 27 and Sommer *et al*. 2005 and Jeffres *et al*. 2008 as cited in NMFS 3, p. 609.) The increased growth rates may be due to increased temperatures and increased food supplies. (DOI 1, p. 27, DFG 3, p. 3.) Floodplain rearing provides conditions that promote larger and faster growth which improves outmigration, predator avoidance, and ultimately survival. (Stillwater Science 2003 as cited in DFG 3, p. 6.) Increased survival may also be related to the fact that ephemeral floodplain habitat and other side-channels provide better habitat conditions for juvenile salmon than intertidal river channels during high flow events when, in the absence of such habitat, juvenile salmon may be displaced to these intertidal areas. (Grosholz and Gallo 2006 as cited in DOI 1, p. 27 and Stillwater Science as cited in DFG 3, p. 6.) The improved growing conditions provided by floodplain habitat are also believed to improve ocean survival resulting in higher adult return rates. (Healy 1982, Parker 1971 as cited in DOI 1, p. 28.)

While floodplain habitat is generally beneficial to salmon, it may also be detrimental under certain conditions. Areas with engineered water control structures have comparatively higher rates of stranding. (Sommer *et al*. 2005 as cited in DOI 1, p. 28.) In addition, high temperatures, low DO, and other water quality conditions that may occur on floodplains may adversely affect salmon. (DFG 3, p. 6.) Reduced depth may also make salmon more susceptible to predation. (*Id*.) Water depths of 30 cm or more are believed to reduce the risk of avian predation. (Gawlik 2002 as cited in DFG 3, p. 6.) Further, the most successful native fish are those that use the floodplain for rearing, but leave before the floodplain becomes disconnected to the river. (Moyle *et al*. 2007, DFG 3, p. 6.) From a restoration perspective, projects should be designed to drain completely to minimize formation of ponds in order to avoid stranding. (Jones and Stokes, 1999 as cited in DOI 1, p. 28.) Bioenergetic modeling indicates that with regard to increased temperatures, increased food availability may be sufficient to offset increased metabolic demands from higher water temperatures. (DFG 3, p. 6.) However, as temperatures increase, juveniles may be unable to migrate to areas of lower temperatures due to reduced swimming ability. (DFG 3, p. 7.) As a result, as summer temperatures increase, floodplain habitat should also decrease. (*Id*.)

The timing of floodplain inundation for the protection of Central Valley Chinook salmon should generally occur from winter to mid-spring to coincide with the peak juvenile Chinook salmon outmigration period (which itself generally coincides with peak flows) and to avoid non-native access to the floodplain (which would generally occur in late-spring). (AR/NHI 1, p. 25.) The benefits of floodplain inundation generally increase with increasing duration, with even relatively short periods of two-weeks providing potential benefits to salmon. (Jeffres *et al*., 2008 as cited in AR/NHI 1, p. 25.) Benefits to salmon may also increase with increasing inter-annual frequency of flooding. Repeated pulse flows and associated increased residence times may be associated with increased productivity which would benefit salmon growth rates and potentially reduce stranding. (*Id*.)

Table 4, developed by AR/NHI, provides estimated thresholds for inundating floodplain habitat under existing and potentially modified conditions. Inundation threshold refers to the discharge when floodwaters begin to inundate the floodplain. Target discharge is the amount of water necessary to produce substantial inundation and flow across the floodplain. (Source: AR/NHI 1, p. 30.)

Floodplain inundation criteria for protection of salmon are provided in section 5.6.2, Floodplain Activation, under Other Measures.

Table 4. Inundation Thresholds for Floodplains and Side Channels at Various Locations Along the Sacramento River

Location	Stage (in feet)	Inundation Threshold (cfs)	Target Discharge (avg. cfs)	Gauge Location	Source
Freemont Weir					
Existing crest	33.5	56,000	63,000	Verona	USGS
Proposed notch	17.5	23,100	35,000	Verona	USGS
Sutter Bypass					
Tisdale weir	45.5	21,000		Colusa	NOAA; Feyrer
Tisdail with notch					
Lower Sutter Bypass	25	30,000	30,000	Verona	USGS
Upper Sacramento Meander belt side channels	Various	10,000	12,000	Red Bluff	USGS

American Shad (*Alosa sapidissima*)

Status

This species is not listed pursuant to either the ESA or CESA.

Life History[13]

The American shad (*Alosa sapidissima*) is an anadromous fish, introduced into California in the late 1880s, that has become an important sport fish within the San Francisco Estuary. American shad range from Alaska to Mexico and use major rivers between British Columbia and the Sacramento watershed for spawning. (Moyle 2002.)

American shad adults, at 3 to 5 years of age, return from the ocean and migrate into the freshwater reaches of the Sacramento and San Joaquin rivers during March through May, with peak migration occurring in May (Stevens *et al*. 1987). Within California, the major spawning run occurs in the Sacramento River up to Red Bluff and in the adjoining American, Feather, and Yuba rivers with lesser use of the Mokelumne, Cosumnes, and Stanislaus rivers and the Delta (Moyle 2002). Spawning takes place from May through early July (Stevens *et al*. 1987). Following their first spawning event, American shad will return annually to spawn up to seven years of age (Stevens *et al*. 1987). It is believed that river flow will affect the distribution of first time spawners, with numbers of newly mature adults spawning in rivers proportional to flows at the time of arrival (Stevens *et al*. 1987). Spawning takes place in the main channels of the rivers with flows washing negatively buoyant eggs downstream. Depending upon temperature, larvae hatch from eggs in 3 to 12 days and will remain planktonic for 4 weeks (Moyle 2002).

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[13] This section was largely extracted from DFG Exhibit 1, pages 26-27.

The lower Feather River and the Sacramento River from Colusa to the northern Delta provide the major summer nursery for larvae and juveniles. Flows drive the transport of young downstream, with wet years changing the location of the concentration of young and their nursery area further downstream into the northern Delta (Stevens *et al*. 1987). Out migration of young American shad through the Delta occurs from June through November (Stevens 1966). American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and federal pumping facilities; catches at the facilities in some years have numbered in the millions (Stevens and Miller 1983). During migration to the ocean, young fish feed upon zooplankton, including copepods, mysids, and cladocerans, as well as amphipods (Stevens 1966, Moyle 2002). Most American shad migrate to the ocean by the end of their first year, but some remain in the estuary (Stevens *et al*. 1987).

Population Abundance and its Relationship to Flow

Year class strength correlates positively with river flow during the spawning and nursery period (April-June). (Stevens and Miller 1983.) American shad exhibit a weak but significant relationship to X2, (Kimmerer 2002a). After 1987, the relationship changed such that abundance increased per unit flow. (Kimmerer 2002a, Kimmerer 2009.) The X2 versus abundance relationship has remained intact into recent years. (Kimmerer *et al*. 2009.) In addition, Kimmerer *et al*. (2009) found that American shad had a habitat relationship (defined by salinity and Secchi depth) to X2 that appeared consistent with its relationship of abundance to X2 (i.e., slopes for abundance versus X2 and habitat versus X2 were similar), which provides some support for the idea that increasing quantity of habitat could explain the X2 relationship for this species (a possible causal mechanism for the abundance versus X2 relationship). Stevens and Miller (1983) determined that the apparent general effect of high flow on all of the species they examined, including American shad, is to increase the quality and quantity of nursery habitat and more widely disperse the young fish, thus reducing density-dependent mortality.

Population Goal

The immediate goal is to maintain viable populations of this species by providing sufficient flows to facilitate attraction of spawners, survival of eggs and larvae, and dispersal of young fish to suitable nursery habitats.

Species-Specific Recommendations

Delta Outflow

The DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. As noted by DFG, X2, in this instance, is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. The species specific flow criteria to protect American shad shown in Table 5 are consistent with those submitted by DFG. (closing comments, p. 7.)

Inflows

No explicit recommendations for inflows to support American shad were identified in the record. The DFG provided outflow criteria for this species based on positioning X2 in Suisun Bay (DFG closing comments, p. 7); noting that in this instance X2 is a surrogate for tributary and mainstem river inflows. As noted above, year class strength correlates positively with river flow during the spawning and nursery period (April to June). (Steven and Miller 1983.) Flows must be sufficient to attract American shad spawners into Sacramento River tributaries, transport and disperse the young fish to suitable nursery habitat, and reduce the probability of entrainment of young fish and their food organisms in water diversions. (DFG 1987 [Exh 23, p. 23].) Water development has reduced flows during the spring and early summer periods which are most critical in this respect. (*Id.*) The spawning and nursery period, during which inflows appear to be most critical for this species, generally correspond to important periods for other more sensitive species (e.g., salmon outmigration, longfin smelt spawning and rearing). It is anticipated that by providing sufficient flows to meet the outflow criteria recommended above, favorable river conditions will be provided to support American shad spawning and rearing.

Old and Middle River Flows

American shad spawned and rearing in the Delta and those that travel through the Delta during out migration are vulnerable to entrainment at the State and Federal export facilities; in some years catches at the facilities have numbered in the millions. (Stevens and Miller 1983.) Although evaluations of screening efficiency comparable to studies for striped bass and salmon had not been completed for American shad, DFG believed in 1987 that larger fish in the fall were screened fairly efficiently, while screening efficiencies for newly metamorphosed juveniles in the late spring and early summer were quite low. (DFG 1987 [Exh 23, p. 20].) American shad are notoriously intolerant of handling. Tests have shown that losses of American shad that were successfully screened exceeded 50%during the summer months, with slightly lower mortalities during the cooler fall months. (DFG 1987 [Exh 23, p. 22].) These high handling mortalities suggest the only practical strategy for reducing losses may be pumping schedules that minimize shad entrainment. (*Id.*). However, no recommendations specific to American shad for net OMR flows or pumping restrictions were identified in the record. Net OMR flow criteria are intended to protect salmon, delta smelt, and longfin smelt populations and are also likely to reduce the number of American shad entrained at the export facilities. In addition, restrictions stipulated in the OCAP Biological Opinions (NMFS 3, pp. 648-653; USFWS 2008) will also reduce entrainment of American shad.

Table 5. Delta Outflows to Protect American Shad

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning; Nursery	All	--	--	--	X2[1] – 75 to 64 km (~11400 – 29200 cfs)			--	--	--	--	--	--

[1] For this species, X2 is a surrogate for tributary and mainstem river inflows to the Delta that support egg and larval survival. Source: DFG 1, p. 26; DFG 2, p. 6, DFG closing comments, p. 7.

4.2.4 Life History Requirements – Pelagic Species

Following are life history and species-specific requirements for longfin smelt, Delta smelt, Sacramento splittail, starry flounder, Bay shrimp, and zooplankton

Longfin Smelt (*Spirinchus thaleichthys*)

Status

Longfin smelt is listed as a candidate for threatened status under the CESA. (DFG 2010.)

Life History

Longfin smelt are a native species that live two years with females reproducing in their second year. Both juveniles and adults feed on zooplankton. Longfin smelt is an anadromous, open water species moving between fresh and salt water. Adults spend time in San Francisco Bay and may go outside the Golden Gate for short periods. Adults aggregate in Suisun Bay and the western Delta in late fall and migrate upstream to spawn in freshwater as water temperatures drop below 18˚C. (Baxter *et al*. 2009.) The spawning habitat is between the confluence of the Sacramento and San Joaquin rivers (around Point Sacramento) to Rio Vista on the Sacramento side and Medford Island on the San Joaquin River. Spawning activity appears to decrease with distance from the low salinity zone, so the location of X2 influences how far spawning migrations extend into the Delta. (Baxter *et al*. 2009.) Spawning takes place between November and April with peak reproduction in January. Eggs are deposited on the bottom and hatch between December and May into buoyant larvae. Peak hatch is in February. Net Delta outflow transports the larvae and juvenile fish to higher salinity water.

Population Abundance and its Relationship to Flow

The population abundance of longfin smelt is positively correlated with spring Delta outflow and inversely related to net OMR spring reverse flows. The correlations are interpreted to mean that net Delta outflow and net reverse OMR flows are, at least partially, responsible for controlling the abundance of longfin smelt. Modifications in the two flow regimes are intended to begin to stabilize and increase the population abundance of longfin smelt. Each correlation is discussed below.

The population abundance of longfin smelt is positively related to Delta outflow during winter and spring. (Jassby *et al*. 1995; Rosenfield and Baxter 2007; Kimmerer 2002a; Kimmerer *et al*. 2009.) The statistically strongest outflow averaging period is January-June. The abundance relationships are from the fall mid-water trawl (FMWT) survey, the bay study mid-water trawl, and the bay study otter trawl. All three surveys show statistically significant positive relationships between the abundance of juveniles/adults and Delta outflow. There has been a decrease in the carrying capacity of the estuary since 1988, presumably because of the invasion of the clam *Corbula*, but the overall winter spring relationship is still statistically significant. More spring outflow results in more smelt as measured by all three indices. The biological basis for the spring outflow relationship is not known. Baxter et al. (2009) speculate that the larvae may benefit from increased downstream transport, increased food production, and a reduction in entrainment losses at the SWP and CVP pumps.

The population abundance of juvenile and adult longfin smelt, as measured by the FMWT index, is also inversely related to the number of fish salvaged at the SWP and CVP pumping facilities. (TBI/NRDC 4, pp. 19-20.) High pumping rates at the two facilities cause net OMR reverse flows which passively move all age groups of longfin smelt toward entrainment at the pumps. A subset of the juvenile and adult populations are counted at the pumping facilities. Larval longfin smelt (<20 mm) pass through the louvers and are not counted. Peak adult and juvenile longfin smelt salvage occurs in January and April to May, respectively. (Baxter *et al*. 2009.) Entrainment of larval smelt, although not counted, are likely greatest between March and April. (TBI/NRDC 4, p.16.) Adult and juvenile longfin smelt salvage is an inverse logarithmic function of net OMR flows. (Grimaldo *et al*. 2009.) Increasing OMR reverse flows results in an exponential increase in salvage loss. Juvenile longfin smelt salvage is a negative function of Delta outflow between March and May. (TBI/NRDC 4, p.17.) Higher outflow in these three months results in lower entrainment loss. This may result from the fact that during low outflow years spawning occurs higher in the system, placing adults and subsequent larvae and juveniles closer to the pumps. Also, negative net OMR flows can either passively draw fish to the pumps or at high levels mis-cue them as to the direction of higher salinity. A consequence is that juvenile longfin smelt are most in danger of entrainment at the CVP and SWP pumping facilities during low outflow years with high net negative OMR flows.

The OMR flow results discussed above are consistent with the findings of Baxter *et al* (2009). The authors used the Delta Simulation Model (DSM2, PTM subroutine) to predict the fate of larval longfin smelt. The PTM predicted that larval entrainment at the SWP might be substantial (2 to10%), particularly during the relatively low outflow conditions modeled. Baxter *et al*. (2009) also identified a significant negative relationship between spring (April to June) net negative OMR flows and the sum of combined SWP and CVP juvenile longfin smelt salvage. Juvenile longfin smelt salvage increased rapidly as OMR became more negative than -2,000 cfs. However, as winter-spring or just spring outflows increased, shifting the position of X2 downstream, the salvage of juvenile longfin smelt decreased significantly. Also, particle entrapment decreased, even with a high negative net OMR, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

TBI/NRDC (TBI/NRDC 2, pp. 15-19) conducted a generation to generation population abundance analysis for longfin smelt versus Delta outflow. The authors found that the probability of an increase in the FMWT longfin smelt index was greater than 50% in years when Delta outflow averaged 51,000 and 35,000-cfs between January to March and March to May, respectively. The analysis is important because it suggests a potential outflow trigger for growing the population.

There is also evidence that longfin smelt is food limited. (SFWC 1, p.59.) The FMWT index for longfin smelt is positively correlated in a multiple linear regression with the previous spring's *Eurytemora affinis* abundance (an important prey organism) after weighting the data by the proportion of smelt at each *Eurytemora* sampling station and normalizing by the previous years FMWT index. The spring population abundance of *Eurytemora* has itself been positively correlated with outflow between March and May since the introduction of *Corbula.* (Kimmerer, 2002a.) The positive correlation between *Eurytemora* abundance and spring outflow provides further support for a spring outflow criterion.

Longfin smelt populations are at an all time low. The average FMWT index for years 2001-2009 are only 3 percent of the average value for 1967 to 1987, a time period when pelagic fish did better in the estuary. The FMWT index for two of the last three years is the lowest on record.

Delta outflow recommendations to protect longfin smelt received from participants are summarized in Table 6. The DFG (DFG closing comments, p.7) recommended a Delta outflow between 12,400 and 28,000 cfs from January to June of all water year types to help transport larval/juvenile longfin smelt seaward in the estuary. TBI/NRDC (TBI/NRDC 2, pp. 19-26; TBI/NRDC Closing Comments, pp. 6-7) also made spring Delta outflow recommendations based on five sets of hydrologic conditions for the Central Valley. The TBI/NRDC recommendations range between 14,000 and 140,000 cfs for January through March and 10,000 to 110,000 cfs between April and May. The TBI/NRDC recommendations are based on their longfin smelt population abundance analysis which demonstrated positive growth in years with high spring outflow.

The four sets of OMR recommendations to protect longfin smelt received from participants are summarized in Table 7. TBI/NRDC (TBI/NRDC 4, pp. 21 and 30; TBI/NRDC closing comments, p. 11) recommended reducing entrainment losses of longfin smelt in dry years (March to May when outflow is less than 18,000 cfs) and population abundance is low (FMWT index less than 500) by maintaining positive net OMR flows in April and May. Alternatively, if the index is greater than 500 and Delta outflow is low, then net OMR flows should not be more negative than -1,500 cfs. The DOI (DOI 1, p.53) made a non-species specific recommendation that OMR flows should be positive in all months between January and June. CSPA/CWIN made a non-species specific recommendations that combined export rates equal zero from mid-March through June. (CSPA 1, p.8; CWIN 2, p. 26.) Finally, the DFG has issued an Incidental Take Permit for longfin smelt (2081-2009-001-03) that restricts net OMR flows in some years based on the recommendations of the Delta Smelt Workgroup. (Baxter *et al*. 2009.)

Table 6. Participant Recommendations for Delta Outflow to Protect Longfin Smelt

Organization	**Water Year**	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**
TBI/NRDC	81-100% (driest years)	14,000 – 21,000			10,000 – 17,500		3000 – 4200
	61-80%	21,000 – 35,200			17,500 – 29,000		4200 – 5000
	41-60%	35,200 – 55,000			29,000 – 42,000		5000 – 8500
	21-40%	55,000 – 87,500			42,000 – 62,500		8500 – 25000
	0-20% (wettest years)	87,500 – 140,000			62,500 – 110,000		25000 – 50000
DFG	all	12,400 to 28,000					

Population Goal

The immediate goal is to stabilize the longfin smelt population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996). The plan states that longfin smelt will be considered recovered when its abundance is similar to the 1967 to 1984 period.

Species- Specific Recommendations

Table 8 contains the species-specific flow criteria to protect longfin smelt. The purpose of the Delta outflow criteria is to stabilize and begin to grow the longfin smelt population; positive population growth is expected in half of all years with these flows. The net OMR flow criteria are intended to protect the longfin smelt population from entrainment in the CVP and SWP pumping facilities during years with limited Delta outflow (dry and critically dry years). As noted above, longfin smelt spawn in the Delta on both the Sacramento and San Joaquin rivers. Longfin smelt optimally need positive flow on both river systems to move buoyant larvae downstream and away from the influence of the pumps.

Table 7. Participant Recommendations for Net OMR Reverse Flows to Protect Longfin Smelt

Organization	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of E/I ratios											
DFG Take Permit	all	-1,250 to -5,000[1]											
TBI/NRDC	C/D				>0[2] or -1,500[3]								
DOI	all	>0											
CSPA/CWIN	all			Combined export rates = 0									

[1] This condition is not likely to occur in many years and is based on requirements in the DFG Incidental Take Permit 2081-2009-001-03 and the advice of the Smelt Working Team. The condition is most likely to occur in dry or critical years when longfin smelt spawn higher in the Delta and hydrology does not rapidly transport hatched larvae from the central and south Delta.

[2] If FMWT index is less than 500

[3] If FMWT index is greater than 500

Table 8. Delta Outflows to Protect Longfin Smelt

Flow Type	Water Year Type	Jan	Feb	Mar	April	May	Jun
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		3,000 – 4,200
	D	21,000 – 35,200			17,500 – 29,000		4,200 – 5,000
	BN	35,200 – >50,000			29,000 – 42,000		5,000 – 8,500
	AN	>50,000			>42,000		8,500 – 25,000
	W	>50,000			>42,000		25,000 – 50,000
OMR	C/D				>0[1] or -1,500[2]		

[1] If FMWT index is less than 500

[2] If FMWT index is greater than 500

Delta Smelt (*Hypomesus transpacificus*)

Status

Delta smelt is listed as endangered under the CESA and threatened under the ESA. (DFG 2010.)

Life History

Delta smelt are endemic to the Delta. Delta smelt have an annual, one-year life cycle although some females may live and reproduce in their second year. (Bennett 2005.) Delta smelt complete their entire life cycle in the Delta and upper estuary. Delta smelt feed primarily on planktonic copepods, cladocerans, and amphipods. (Baxter *et al*. 2008.) In September or October delta smelt begin a slow upstream migration toward their freshwater spawning areas in the upper Delta, a process that may take several months. (Moyle 2002.) The upstream migration may be triggered by Sacramento River flows in excess of 25,000 cfs. (DSWG 2006.) Spawning can occur from late February to July, although most reproduction appears to take place between early April and mid-May. (Moyle 2002.) Spawning areas include the lower Sacramento, Mokelumne, and San Joaquin rivers, the west and south Delta, Suisun Bay, Suisun Marsh, and occasionally in wet years, the Napa River. (Wang 2007.) Eggs are negatively buoyant and adhesive with larvae hatching in about 13 days. (Wang, 1986; Mager 1996.) Upon hatching, the larvae are semi-buoyant staying near the bottom. Within a few weeks, larvae develop an air bladder and become pelagic, utilizing vertical water column movement to maintain their longitudinal position in the estuary. (Moyle 2002.)

Freshwater outflow during spring (March to June) affects the distribution of larvae by transporting them seaward toward the low salinity zone. (Dege and Brown 2004.) High Delta outflow during spring can carry some smelt downstream of their traditional rearing areas in the west Delta and Suisun Bay and into San Pablo Bay where long-term growth and survival may not be optimal. Conversely, periods of low outflow increase residence time in the Delta. Increasing residence time in the Delta probably prolongs the exposure of delta smelt to higher water temperatures and increased risk of entrainment at the State and Federal pumping facilities. (Moyle 2002.) Ideal rearing habitat conditions are believed to be shallow water areas most commonly found in Suisun Bay. (Bennett 2005.) When the mixing zone was located in Suisun Bay, it may in the past have provided optimal conditions for algal and zooplankton growth, an important food source for delta smelt. (Moyle 2002.) However, the quality of habitat in Suisun Bay appears to have deteriorated with the introduction of the clam *Corbula* which now consumes much of the phytoplankton that previously supported large populations of zooplankton. Since 2005, approximately 40% of the delta smelt population now remains in the Cache Slough complex north of the Delta. This may represent an alternative life history strategy in which the fish stay upstream of the low salinity zone (LSZ) through maturity. (Sommer et al., 2009.)

Population Abundance and Relationship to Flow

Delta smelt population abundance is measured in the summer tow net survey, the FMWT survey and the 20-mm spring-summer survey of juvenile fish. (Kimmerer et al. 2009.) All three indices indicate that delta smelt populations are at an all time low and may be in danger of extinction. The average FMWT index for 2001-2009 is only 20% of the value measured between 1967 and 1987, a time period when pelagic fish did better in the estuary. FMWT indices for the last six years (2004 to 2009) include all of the lowest values on record. The cause of the decline is unclear but likely includes some combination of flow, export pumping, food limitation, and introduced species.

Three types of flow have been hypothesized to affect delta smelt abundance. These are spring and fall Delta outflow and net OMR reverse flow. Testimony was received at the public proceeding recommending management changes to all three types of flow (Table 9 and Table 10). In the past, there has been a weak negative relationship between spring Delta outflow and delta smelt abundance as measured by the FMWT, however, the relationship has now disappeared. (Kimmerer *et al*. 2009.) The cause for the disappearance of the spring outflow-abundance relationship is not known but may result from the deterioration of rearing habitat in Suisun Bay because of colonization by the clam *Corbula.*

Several organizations recommend fall Delta outflow criteria for protection of delta smelt (Table 9). The primary purpose of a fall Delta outflow criterion is to increase the quality and quantity of rearing habitat for Delta smelt. (Nobriga et al. 2008; Feyrer et al. 2007; Feyrer et al., in review.) Rearing habitat is hypothesized to increase when the fall LSZ is downstream of the confluence of the Sacramento and San Joaquin rivers. This corresponds to Delta outflows greater than about 7,500 cfs between September and November, which would have to be achieved by release of water from upstream reservoirs in most years. Grimaldo et al. (2009) found that X2 was a predictor for salvage of adult delta smelt at the intra-annual scale when net OMR flows were negative. Moving X2 westward in the fall serves to increase the geographic and hydrologic distance of delta smelt from the influence of the export facilities and therefore likely reduces the risk of entrainment. (DOI 1, p. 34.) The USFWS (2008) recommended in their Opinion that the LSZ be maintained in the fall of above normal and wet water year types in Suisun Bay (Action 4). The action was restricted to above average water years to insure that sufficient cold water pool resources remained for steelhead and salmon and because these are the years in which SWP and CVP operations have most significantly affected fall conditions. (USFWS 2008.) The National Academy of Sciences (NAS) (2010) commented on this action in their review:

> ”The statistical relationship is complex. When the area of highly suitable habitat …is low, either high or low FMWT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse… The … action is conceptually sound … to the degree that the amount of habitat available for smelt limits their abundance… however…the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand.” The National Academy of Sciences noted approvingly that the U.S. Fish and Wildlife Service (2008) required “additional studies addressing elements of the habitat conceptual model to be formulated … and … implemented promptly.”

Table 9. Participant Recommendations for Delta Outflows to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan [1]	C	4500 [2]	7100 – 29200 [3]					4000	3000	3000	3000	3500	
	D	4500	7100 - 29200					5000	3500	3000	4000	4500	
	BN	4500	7100 - 29200					6500	4000	3000	4000	4500	
	AN	4500	7100 - 29200					8000	4000	3000	4000	4500	
	W	4500	7100 - 29200					8000	4000	3000	4000	4500	
USFWS Opinion[1]	AN									7000 [4]			
	W									12400			
EDF/Stillwater Sciences	C			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	D			26800	17500	17500	7500	4800	4800	4800	4800	4800	
	BN			26800	26800	26800	11500	7500	7500	7500	7500	7500	
	AN			26800	26800	26800	11500	11500	11500	11500	11500	11500	
	W			26800	26800	26800	17500	17500	17500	17500	17500	17500	
TBI/NRDC	81-100%									5750 - 7500			
	61-80%									7500 - 9000			
	41-60%									9700 - 12400			
	21-40%									12400 - 16100			
	0-20%									16100 - 19000			

[1] 2006 Bay-Delta Plan and USFWS Opinion flows shown for comparative purposes.

[2] All water year types - Increase to 6000 if the December Eight River Index is > than 800 thousand acre-feet (TAF).

[3] Minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of the 2006 Bay-Delta Plan.

[4] USFWS Opinion (RPA concerning Fall X2 requirements [pp282-283] - improve fall habitat [quality and quantity] for delta smelt) (references USFWS 2008, Feyrer *et al* 2007, Feyrer *et al* in revision) - September-October in years when the preceding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal years, respectively. During any November when the preceding water year was wet or above normal, as defined by Sacramento Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sacramento Basin shall be added to reservoir releases in November to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for wet and above normal water years, respectively. In the event there is an increase in storage during any November this action applies, the increase in reservoir storage shall be released in December to augment the December outflow requirements in the 2006 Bay-Delta Plan.

Table 10. Participant Recommendations for Net OMR Flows to Protect Delta Smelt

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2006 Bay-Delta Plan	all	Some restrictions, given in terms of exports to inflow ratios											
USFWS - Opinion	all	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met; Action 2: range btw -1250 and -5000 cfs [1]			Range between -1,250 and -5,000 [2]								See Jan-Mar
USFWS	all	>0 [3]											
CSPA/ CWIN				Combined Export Rates = 0[3]									
TBI/ NRDC	all	>-1,500 cfs											>-1500 cfs

[1] USFWS Opinion - RPA re: net OMR flows. Component 1 - Adults (December - March) - Action 1 (protect upmigrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR flow for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) – Net OMR flow range between -1250 and -5000 cfs determined using adaptive process until spawning detected. (pp.280-282.)

[2] USFWS Opinion - RPA re: net OMR flows. Component 2 - Larvae/juveniles - action starts once temperatures hit 12° C at three Delta monitoring stations or when spent female is caught. Net OMR flow range between -1250 and -5000 cfs determined using adaptive process. OMR flow restrictions continue until June 30 or when Delta water temperatures reach 25° C, whichever comes first. (pp. 280-282.)

[3] Recommendations by the USFWS and CSPA/CWIN were not species specific.

It should be reiterated that this measure should be implemented within an adaptive framework, including completing studies designed to clarify the mechanism(s) underlying the effects of fall habitat on the delta smelt population, and a comprehensive review of the outcomes of the action and its effectiveness. Until additional studies are conducted demonstrating the importance of fall X2 to the survival of delta smelt, additional fall flows, beyond those stipulated in the fall X2criteria, for the protection of delta smelt are not recommended if it will compete with preservation of cold water pool resources needed for the protection of salmonids.

Net negative OMR flows can affect delta smelt by pulling them into the central Delta where they are at risk of entrainment in the SWP and CVP pumps. Recent studies have shown that entrainment of delta smelt and other pelagic species increases as net OMR flows become more negative. (Grimaldo et al. 2009; Kimmerer 2008.) Delta smelt are at risk as juveniles in the spring during downstream migration to their rearing area, and as adults between the fall and early spring as they move upstream to spawn. Salvage of age-0 delta smelt at the SWP /CVP fish collection facilities at the intra-annual scale has been found to be related to the abundance of these fish in the Delta, while net OMR flows and turbidity were also strong predictors. (Grimaldo et al. 2009.) This suggests that within a given year, the mechanism influencing entrainment is probably a measure of the degree to which their habitat overlaps with the hydrodynamic “footprint” of net negative OMR flows. (Grimaldo et al. 2009.) PTM results suggest that entrainment is a function of both net OMR flows and river outflows. (Kimmerer and Nobriga 2008.) PTM results may be more applicable to neutrally buoyant larvae and poorly swimming juveniles than adult delta smelt. Particle entrainment increased as a logarithmic function of increasing net negative OMR flows and decreases in river outflows. The highest entrainment was observed at high net negative OMR flows and low outflows. PTM results suggest that entrainment losses might be as high as 40% of the total delta smelt population in some years. (Kimmerer 2008.) Similar results were obtained by Baxter et al. (2009) when evaluating entrainment of longfin smelt using PTM. Juvenile longfin smelt salvage increased rapidly as net OMR flows became more negative than -2,000 cfs. Also, particle entrapment decreased, even with high net negative OMR flows, when the flow of the Sacramento River at Rio Vista increased above 40,000 cfs. Entrainment of particles almost ceased at flows of 55,000 cfs.

Field population investigations support some of the spring PTM results. Gravid females and larvae are present in the Delta as early as March and April. (Bennett 2005.) However, analysis of otolith data on individuals collected later in the year by Bennett *et al*. (unpublished data) show that few of the early progeny survived if spawned prior to the VAMP time period (typically April 15 to May 15). The hydrodynamic data showed high net negative OMR flows in the months preceding and after the VAMP, leading the researchers to conclude that high winter and early spring net negative OMR flows were selectively entraining the early spawning and/or early hatching cohort of the delta smelt population. However, Baxter *et al*. (2008) stated that “under this hypothesis, the most important result of the loss of early spawning females would manifest itself in the year following the loss, and would therefore not necessarily be detected by analyses relating fall abundance indices to same-year predictors.” No statistical relationships have been found between either OMR flows or CVP and SWP pumping rates and Delta smelt population abundance. (Bennett 2005.)

Entrainment of adult delta smelt occurs following the first substantial precipitation event (“first flush”), characterized by sudden increases in river inflows and turbidity, in the estuary as they begin their migration into the tidal freshwater areas of the Delta. (Grimaldo *et al*. 2009.) Patterns of adult entrainment are distinctly unimodal, suggesting that migration is a large population-level event, as opposed to being intermittent or random. (DOI 1, p. 36.) Grimaldo *et al*. (2009) provided evidence suggesting that entrainment during these "first flush" periods could be reduced if export reductions were made at the onset of such periods.

The USFWS Opinion identifies turbidity criteria for which to trigger first flush export reductions, but total Delta outflow greater than 25,000 cfs could serve as an alternate or additional trigger since such flows are highly correlated with turbidity. (Grimaldo *et al*. 2009, DOI 1, p. 36.) Managing OMR flows to thresholds at which entrainment or populations losses increase rapidly, represents a strategy for providing additional protection for adult delta smelt in the winter period (Dec-Mar). (DOI 1, p.36.). The USFWS Opinion identified the lower net OMR flow threshold as - 5000 cfs based on observed OMR flow versus salvage relationships from a longer data period (USFWS 2008) and additional data summarized over a more recent period. (Grimaldo et al. 2009.) The -5000 cfs OMR flow threshold is appropriate because it is the level where population losses consistently exceed 10%. (USFWS 2008, DOI 1, p. 36.) Adult delta smelt entrainment varies according to their distribution in the Delta following their upstream migration. The population is at higher entrainment risk if the majority of the population migrates into the south Delta, which may require net OMR flows to be more positive than -5000 cfs to reduce high entrainment. Conversely, if the majority of the population migrates up the lower Sacramento River or north Delta, a smaller entrainment risk is presumed, which would allow for OMR flows to be more negative than -5000 cfs for an extended period of time, or until conditions warrant a more protective OMR flow. (DOI 1, p.36.)

The USFWS Opinion for delta smelt includes net negative OMR flow restrictions to protect both spawning adult and out-migrating young. Component 1 of the USFWS Opinion has two action items; both are to protect adult delta smelt. Action 1 restricts OMR flow in fall to -2,000 cfs for 14 days when a turbidity or salvage trigger has been met. Both triggers have previously been correlated with the upstream movement of spawning adult smelt. Action 2 commences immediately after Action 1. Action 2 is to protect adult delta smelt after migration, but prior to spawning, by restricting net OMR flows to between -1250 and -5,000 cfs based on the recommendations of the Delta Smelt Workgroup. Component 2 of the USFWS Opinion is to protect larval and juvenile fish. Component 2 actions start once water temperatures hit 12°C at three monitoring stations in the Delta or when a spent female is caught. OMR flows during this phase are to be maintained more positive than -1,250 to -5000 cfs based on a 14-day running average. Component 2 actions are to continue until June 30 or when the 3-day-mean water temperature at Clifton Court Forebay is 25°C. The Delta Smelt Working Group is to make recommendations on the specific OMR flow restrictions between -1250 and -5000 cfs.

The NAS (2010) reviewed the USFWS Opinion OMR flow restrictions and concluded:

> "…it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP and CVP facilities is scientifically justified … but the data do not permit a confident identification of the threshold values to use … and … do not

> permit a confident assessment of the benefits to the population…As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves."

The negative impact of negative OMR flows on delta smelt, like on longfin smelt, is likely to be greatest during time periods with high negative OMR flows and low Sacramento River outflow. (Baxter *et al*. 2009; Kimmerer and Nobriga 2008.) The work of Grimaldo *et al*, (2009) suggests that impacts associated with the export facilities can be mitigated on a larger scale by altering the timing and magnitude of exports based on the biology of the fishes and changes in key physical and biological variables.

For the protection of longfin smelt, Delta outflow criteria between January and March range from 35,000 cfs in below normal water years to greater than 50,000 cfs in wet water years (Table 8). For the protection of longfin smelt, flow criteria between April and May range from 29,000 cfs to more than 42,000 cfs. These flows should also afford protection for larval delta smelt from excessive negative OMR flows and entrainment at the CVP and SWP pumping facilities. Under this criterion, lower outflows will still likely occur during critically dry and dry water year types (Table 6). These outflows may not be sufficient to prevent longfin and delta smelt entrainment at the pumping facilities. Therefore, the recommended criterion for longfin smelt specifies that net OMR flows should not be more negative than -1500 cfs in April and May of dry and critically dry water years to protect longfin smelt. The State Water Board determines that this criterion should be extended to include March and June of dry and critically dry water years to protect early and late spawning delta smelt (Table 11).

Minimizing net negative OMR flows during periods when adult delta smelt are migrating into the Delta could also substantially reduce mortality of the critical life stage. For example, one potential strategy is to reduce exports during the period immediately following the "first flush", based on a turbidity or flow trigger. (Grimaldo et al. 2009.) This supports a recommendation that net OMR flows be more positive than -5000 cfs during the period between December and March. Additional OMR flow restrictions may be warranted during periods when a significant portion of the adult delta smelt population migrates into the south or central Delta. In such instances, the determination of specific thresholds should be made through an adaptive approach that takes into account a variety of factors including relative risk (e.g., biology, distribution and abundance of fishes), hydrodynamics, water quality, and key physical and biological variables. The State Water Board agrees with the NAS (2010) that the data, as currently available, do not permit a confident assessment of the threshold OMR flow values nor of the overall benefit to the delta smelt population. Development of a comprehensive life-cycle model for delta smelt would be valuable in that it would allow for an assessment of population level impacts associated with entrainment. Such life-cycle models for delta smelt are currently under development. Therefore, net OMR flow criteria need to be accompanied by a strong monitoring program and adaptive management to adjust OMR flow criteria as more knowledge becomes available.

Delta smelt are food limited. Delta smelt survival is positively correlated with zooplankton abundance. (Feyrer et al., 2007; Kimmerer 2008; Grimaldo et al., 2009.) A new analysis by the SFWC (SFWC 1, p.60) also demonstrates a positive relationship between FMWT delta smelt indices and the previous spring and summer abundance of

Eurytemora and *Psuedodiaptomus.* There are several hypotheses for the cause of the decline in zooplankton abundance. First, zooplankton abundance in Suisun and Grizzly bays, prime habitat for delta smelt, declined after the introduction of the invasive clam *Corbula. Corbula* is thought to compete directly with zooplankton for phytoplankton food and lower phytoplankton levels may limit zooplankton abundance. A second hypothesis is that changes in nutrient loading and nutrient form in the Delta that result from the SRWTP discharge can have major impacts on food webs, from primary producers through secondary producers to fish. (Glibert, 2010.) Changes in nutrient concentrations and their ratios may have caused the documented shift in phytoplankton species composition from large diatoms to smaller, less nutritious algal forms for filter feeding organisms like zooplankton. If true, both of the above hypotheses could indirectly result in lower densities of delta smelt. Therefore, all recommended flow modifications should be accompanied by a strong monitoring and adaptive management process to determine whether changes in OMR flows result in an improvement in delta smelt population levels.

Population Abundance Goal

The immediate goal is to stabilize delta smelt populations, as measured by the FMWT index, and begin to grow the population. The long term goal should be to achieve the objective of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996.)

Species-Specific Recommendations

Although a positive correlation between Delta outflows and delta smelt is lacking, Delta outflows do have significant positive effects on several measures of delta smelt habitat. (Kimmerer *et al*. 2009), and spring outflow is positively correlated with spring abundance of *Eurytemora affinis* (Kimmerer 2002a), an important delta smelt prey item. No specific spring Delta outflow criteria are therefore recommended for delta smelt. Flow criteria to protect longfin smelt in the spring of wetter years (Table 8) may, however, afford some additional protection for the Delta smelt population.

The State Water Board advances the OMR flow criteria in Table 11 for dry and critically dry years to protect the delta smelt population from entrainment in the CVP and SWP pumping facilities during years with limited Delta outflow. The OMR flow restrictions are an extension of the criteria for longfin smelt. In addition, the State Water Board includes criteria for OMR flows to be more positive than -5,000 cfs between December and February of all water year types to protect upstream migrating adult delta smelt. The -5,000 cfs criteria may need to be made more protective in years when delta smelt move into the central Delta to spawn. The more restrictive OMR flows would be recommended after consultation with the USFWS's Delta Smelt Working Group. In the absence of any other specific information, the State Water Board determines that the existing 2006 Bay-Delta Plan Delta outflow objectives for July through December are needed to protect delta smelt.

Table 11. Net OMR Flows for the Protection of Delta Smelt

Flow Type	Water Year Type	Dec	Jan	Feb	Mar - June
Net OMR flows	C/D				> -1,500 cfs
Net OMR flows	All	> - 5000 cfs (thresholds determined through adaptive management)			

Sacramento Splittail (*Pogonichthys macrolepidotus*)

Status

Sacramento splittail is currently recognized by the DFG as a species of special concern. Splittail was listed as a threatened species pursuant to the ESA in 1999; however, its status was remanded in 2003 on the premise of recent increases in abundance and population stability. This decision was subsequently challenged and the USFWS is revisiting the status of splittail and will make a new 12-month finding on whether listing is warranted by September 30, 2010.

Life History

Sacramento splittail (*Pogonichthys macrolepidotus*) is a cyprinid native to California that can live seven to nine years and has a high tolerance to a wide variety of water quality parameters including moderate salinity levels. (Moyle 2002, Moyle et al. 2004.)

Adult splittail are found predominantly in Suisun Marsh, Suisun Bay, and the western Delta, but are also found in other brackish water marshes in the San Francisco Estuary as well as the fresher Delta. Splittail feed on detritus and a wide variety of invertebrates; non-detrital food starts with cladocerans and aquatic fly larvae on the floodplains, progresses to insects and copepods in the rivers, and to mysid shrimps, amphipods and clams for older juveniles and adults. (Daniels and Moyle 1983, Feyrer et al. 2003, Feyrer et al. 2007a, as cited in DFG 1, p. 13.) In winter and spring when California's Central Valley experiences increased runoff from rainfall and snowmelt, adult splittail move onto inundated floodplains to forage and spawn. (Meng and Moyle 1995; Sommer et al. 1997, Moyle et al. 2004, as cited in DFG 1, p. 13.) Spawning takes place primarily between late February and early July, and most frequently during March and April (Wang 1986, Moyle 2002) and occasionally as early as January. (Feyrer et al. 2006a.) Splittail eggs, laid on submerged vegetation, begin to hatch in a few days and the larval fish grow fast in the warm and food rich environment. (e.g., Moyle et al. 2004, Ribeiro et al. 2004.) After spawning, the adult fish move back downstream.

Once they have grown a few centimeters, the juvenile splittail begin moving off of the floodplain and downstream into similar habitats as the adults. These juveniles become mature in two to three years. In the Yolo Bypass, two flow components appear necessary for substantial splittail production (Feyrer et al. 2006a): (1) inundating flows in winter (January to February) to stimulate and attract migrating adults; and (2) sustained floodplain inundation for 30 or more days from March through May or June to allow successful incubation through hatching (3 to 7 days, see Moyle 2002), and extended rearing until larvae are competent swimmers (10 to 14 days; Sommer et al. 1997) and beyond to maximize recruitment. (DFG 1, p. 13.)

Large-scale spawning and juvenile recruitment occurs only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the

Sutter and Yolo bypasses. (Meng and Moyle 1995, Sommer et al. 1997, Feyrer et al. 2006a, as cited in DFG 1, p. 13.) Some spawning also occurs in perennial marshes and along the vegetated edges of the Sacramento and San Joaquin rivers. (Moyle et al. 2004.) During periods of low outflow, splittail appear to migrate farther upstream to find suitable spawning and rearing habitats. (Feyrer et al. 2005.) Moyle et al. (2004) noted that though modeling shows splittail to be resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant.

Population Abundance and its Relationship to Flow

Age-0 splittail abundance has been significantly correlated to mean February through May Delta outflow and days of Yolo Bypass floodplain inundation, representing flow/inundation during the incubation and early rearing periods. (Meng and Moyle 1995, Sommer et al. 1997.) The flow-abundance relationship is characterized by increased abundance (measured by the FMWT) as mean February–May X2 decreases, indicating a significant positive relationship between FMWT abundance and flow entering the estuary during February–May. (Kimmerer 2002a.)

Feyrer et al. (2006a) proposed the following lines of evidence to suggest the mechanism supporting this relationship for splittail lies within the covarying relationship between X2 and flow patterns upstream entering the estuary: the vast majority of splittail spawning occurs upstream of the estuary in freshwater rivers and floodplains (Moyle et al. 2004); the averaging time frame (February–May) for X2 coincides with the primary spawning and upstream rearing period for splittail; the availability of floodplain habitat, as indexed by Yolo Bypass stage, is directly related to X2 during February–May ($y = 4.38 - 2.21x$; $p<0.001$; $r^2 = 0.97$); the center of age-0 splittail distribution does not reach the estuary until summer (Feyrer et al. 2005); and the splittail X2-abundance relationship has not been affected by dramatic food web changes (Kimmerer 2002a) that have significantly altered the diet of young splittail in the estuary. (Feyrer et al. 2003.)

Population Abundance Goal

The immediate goal is to stabilize the Sacramento Splittail population, as measured by the FMWT index, and to begin to grow the population. The long-term goal is to maintain population abundance index as measured by FMWT in half of all years above the long term population index value.

Species- Specific Recommendations

Delta Outflow - Upstream covariates of X2, such as the availability of suitable floodplain and off-channel spawning and nursery habitat, appear to be the attributes supporting the flow-abundance relationship for splittail. Therefore, the flow needs of this species, with respect to spawning and rearing habitat, are most effectively dealt with through establishment of flow criteria that address the timing, duration, and magnitude of floodplain inundation from a river inflow standpoint.

Delta Inflow - Information in the record on conditions conducive to successful spawning and recruitment of splittail shows that the species depends on inundation of off-channel areas. Sufficient flows are therefore needed to maintain continuous inundation for at least 30 consecutive days in the Yolo Bypass, once floodplain inundation has been achieved based on runoff and discharge for ten days between late-February and May, during above normal and wet years (Table 12). (DFG closing comments, p. 7.)

Opportunities to provide floodplain inundation in other locations (e.g., the San Joaquin River) warrant further examination.

Feyrer *et al* (2006a) noted that manipulating flows entering Yolo Bypass such that floodplain inundation is maximized during January through June will likely provide the greatest overall benefit for splittail, especially in relatively dry years when overall production is lowest. Within the Yolo Bypass, floodplain inundation of at least a month appears to be necessary for a strong year class of splittail (Sommer *et al*. 1997); however, abundance was highest when the period of inundation extended 50 days or more. (Meng and Moyle 1995.) Floodplain inundation during the months of March, April, and May appears to be most important. (Wang 1986, Moyle 2002.) Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives. (Moyle et al. 2007, Grimaldo et al. 2004.) Duration and timing of inundation are important factors that influence ecological benefits of floodplains.

<u>Yolo Bypass Inundation</u> – The Fremont Weir is a passive facility that begins to spill into the Yolo Bypass when the Sacramento River flow at Verona exceeds 55,000 to 56,000 cfs. (AR/NHI 1, p. 21; EDF 1, p. 50; TBI/NRDC 3, p. 35; Sommer et al. 2001b.) Water also enters the bypass at the Sacramento Weir and from the west via high flow events in small west-side tributaries. (Feyrer et al. 2006b.) Each of these sources joins the Toe Drain, a perennial channel along the east side of the Yolo Bypass floodplain, and water spills onto the floodplain when the Toe Drain flow exceeds approximately 3,500 cfs. (Feyrer et al. 2006b.) The Yolo Bypass typically floods in winter and spring in about 60% of years (DOI 1, p. 54; Sommer et al. 2001a; Feyrer et al. 2006a), with inundation occurring as early as October and as late as June, with typical peak period of inundation during January-March. (Sommer et al. 2001b.) In addition, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary. (Jassby and Cloern 2000; Mueller-Solger et al. 2002; Sommer et al. 2004.) Much of the water diverted into the bypass drains back into the north Delta near Rio Vista. Besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed. (Sommer et al. 2001b.)

Multiple participants provided recommendations concerning the magnitude and duration of floodplain inundation along the Sacramento River, lower San Joaquin River, and within the Yolo and Sutter bypasses. (AR/NHI 1, p. 32; DFG closing comments; DOI 1, p. 54, EDF 1, pp. 50-52, 53-55; SFWC closing comments; TBI/NRDC 3, p. 36.) In addition, the draft recovery plan for the Sacramento River winter-run Chinook salmon, Central Valley spring-run Chinook salmon, and Central Valley Steelhead (NMFS 2009) calls for the creation of annual spring inundation of at least 8,000 cfs to fully activate the Yolo Bypass floodplain. (NMFS 5, p.157.)

Overtopping the existing weirs and flooding the bypasses (e.g., Yolo and Sutter) to achieve prolonged periods (30 to 60 days) of floodplain inundation in below normal and dry water years would require excessive amounts flows given the typical runoff patterns during those year types. (AR/NHI 1, p. 29.) From a practical standpoint, it is probably only realistic to achieve prolonged inundation during drier water year types by notching the upstream weirs and possibly implementing other modifications to the existing system. (AR/NHI 1, p. 29.)

The BDCP is currently evaluating structural modifications to the Fremont Weir (e.g., notch the weir and install operable “inundation gates”), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass. (BDCP 2009.) TBI/NRDC (TBI/NRDC 3, p. 36) and AR/NHI (AR/NHI 1, p. 32) provided floodplain inundation recommendations for the Yolo Bypass assuming structural modifications to the Fremont Weir were implemented. A potential negative impact of notching the Fremont Weir is that it will affect stage height and Sutter Bypass flooding, and the resulting spawning and rearing of splittail and spring-run Chinook salmon. (personal communication R. Baxter.)

The NMFS Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. (NMFS 3, p.608.) USBR and DWR are to submit a plan to implement this action to NMFS by December 31, 2011. (NMFS 3, p. 608.) This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat. (NMFS 3, p. 608.) The NMFS Opinion specifies that in the event that this action conflicts with Shasta Operations Actions I.2.1 to I.2.3 (e.g., carryover storage requirements), the Shasta Operations Actions shall prevail. (NMFS 3, p. 608.)

<u>OMR Flows</u> - Entrainment of splittail at the SWP and CVP export facilities is highest during adult spawning migrations and periods of peak juvenile abundance in the Delta. (Meng and Moyle 1995, Sommer et al. 1997.) The incidence of age-0 splittail entrainment increased during wet years when abundance was also high (Sommer et al. 1997.) However, analyses conducted by Sommer et al. (1997) suggested that entrainment at the export facilities did not have an important population-level effect. However, Sommer et al. (1997) noted that their evidence does not demonstrate that entrainment never affects the species. For example, if the core of the population’s distribution were to shift toward the south Delta export facilities during a dry year, there could be substantial entrainment effects to a year-class. (Sommer et al. 1997.) Criteria for net OMR flows intended to protect salmon, delta smelt, and longfin smelt populations, as well as restrictions stipulated in the Opinions (NMFS 3, pp. 648-653; USFWS 2008) are likely to reduce the number of splittail entrained at the export facilities.

Table 12. Floodplain Inundation Criteria for Sacramento Splittail

Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spawning and Rearing Habitat	AN / W	--	≥ 30 day floodplain inundation				--	--	--	--	--	--	--

Starry Flounder (*Platichthys stellatus*)

Status

Starry flounder is not listed pursuant to either the ESA or CESA.

Life History

Starry flounder is a native to the Bay-Delta Estuary. The geographic distribution of flounder is from Santa Barbara, California, to Alaska and in the western Pacific as far south as the Sea of Japan. (Miller and Lea 1972.) Starry flounder are important in both the recreational and commercial catch in both central and northern California. (Haugen 1992; Karpov et al. 1995.)

Starry flounder is an estuarine dependent species. (Emmett et al. 1991.) Spawning occurs in the Pacific Ocean near the entrance to estuaries and other freshwater sources between November and February. (Orcutt 1950.) Juveniles migrate from marine to fresh water between March and June and remain through at least their second year of life before returning to the ocean. (Baxter 1999.) Young individuals are found in Suisun Bay and Marsh and in the Delta. Older individuals range from Suisun to San Pablo bays. Maturity is reached by males at the end of their second year and by females in their third or fourth years. (Orcott 1950.)

Population abundance of young of the year and one year old starry flounder have been measured by the San Francisco Otter Trawl Study since 1980 and reported as an annual index. (Kimmerer et al. 2009.) The index declined between 2000 and 2002 but has since recovered to values in the 300 to 500 range. The median index value for the 29 years of record is 293.

Population Abundance Relationship to Flow

Starry flounder age-1 abundance in the San Francisco Bay otter trawl study is positively correlated with the March through June outflow of the previous year. (Kimmerer et al. 2009.) The mechanism underlying the abundance outflow relationship is not known but may be increased passive transport of juvenile flounder by strong bottom currents during high outflow years. (Moyle 2002.) There has been a decline in the abundance of flounder for any given outflow volume since 1987, presumably because of the invasion by the clam Corbula, however, the overall abundance-flow relationship is still statistically significant. (Kimmerer 2002a.)

Population Abundance Goal

The goal is to maintain the starry flounder population abundance index, as measured by the San Francisco Otter Trawl Study, in half of all years above the long term population median index value of 293.

Species-Specific Recommendations

Outflow recommendations were only received from the DFG. (DFG 1, p. 16.) DFG recommends maintaining X2 between 65 and 74 km between February and June. This corresponds to an average outflow of 11,400 to 26,815 cfs. Table 13 contains the criteria needed for protection of starry flounder. The purpose of this outflow criteria is to maintain population abundance near the long term median index value of 293. This net Delta outflow criteria is similar to those proposed for the protection of longfin smelt, delta smelt, and *Crangon sp*. The State Water Board's criteria for Delta outflow for the protection of both longfin and delta smelt and *Crangon* will also protect starry flounder. The proposed outflow is consistent with DFG's recommendation for starry flounder. There is no information in the record to support criteria for inflows or hydrodynamics to protect starry flounder.

Table 13. Criteria for Delta Outflow to Protect Starry Flounder

Flow Type	**Water Year Type**	**Jan**	**Feb**	**Mar**	**April**	**May**	**Jun**
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500		
	D	21,000 – 35,200			17,500 – 29,000		
	BN	35,200 – >50,000			29,000 – 42,000		
	AN	>50,000			>42,000		
	W	>50,000			>42,000		

California Bay Shrimp (*Crangon franciscorum*)

Status

The California bay shrimp is not listed pursuant to either ESA or CESA.

Life History

There are three native species of Crangon, collectively known as bay shrimp or grass shrimp, common to the San Francisco Estuary: *Crangon franciscorum, C. nigricauda*, and *C. nigromaculata.* (Hieb 1999.) Bay shrimp are fished commercially in the lower estuary and sold as bait. (Reilly et al. 2001.) *C. franciscorum* species is targeted by the commercial fishery because of its larger size. Bay shrimp are also important prey organisms for many fish in the estuary. (Hatfield, 1995.)

The California bay shrimp (*Crangon franciscorum*) is an estuary dependent species that is distributed along the west coast of North America from Alaska to San Diego. Larvae hatch from eggs carried by females in winter in the lower estuary or offshore in the Pacific Ocean. Most late-stage larvae and juvenile *C. franciscorum* migrate into the estuary and upstream to nursery areas between April and June. Juvenile shrimp are common in San Pablo and Suisun bays in high outflow years. Their center of distribution moves upstream to Honker Bay and the lower Sacramento and San Joaquin rivers during low flow years. (Hieb 1999.) Mature shrimp migrate back down to higher salinity waters after a four to six month residence in the upper estuary. (Hatfield 1985.) *C. franciscornum* mature at one year and may live up to two years. Some females hatch more than one brood of eggs during a breeding season.

Population abundance of juvenile *C. franiscorum* is measured by DFG's San Francisco Bay Study and is reported as an annual index. (Jassby et al. 1995, Hieb 1999.) Indices over the 29 years of record have varied from 31 to 588 with a median value of about 103.

Population Abundance and Relationship to Flow

There is a positive correlation between the abundance of *C. franciscorum* and net Delta outflow from March to May of the same year. (Jassby et al. 1995; Kimmerer et al. 2009.) The statistical relationship has remained constant since the early years of the San Francisco Bay Study, which began in 1980. The mechanism underlying the abundance relationship is not known but may be an increase in the passive transport of juvenile shrimp up-estuary by strong bottom currents during high outflows years. (Kimmerer et al. 2009, Moyle 2002, DFG 1992.) Other potential mechanisms include the effects of freshwater outflow on the amount and location of habitat, the abundance of food organisms and predators, and the timing of the downstream movement of mature shrimp. (DFG 1, p. 23.)

Delta outflow recommendations (Table 14) were received from both the DFG (DFG 1, p. 23) and TBI/NRDC. (TBI/NRDC 2, p. 17). TBI/NRDC analyzed the productivity of *C. franciscorum* as a function of net Delta outflow between March and May. The analysis suggests that estuary populations increased in about half of all years when flows between March and May were approximately 5 million acre-feet (MAF), or about 28,000 cfs per month. TBI/NRDC recommended that flow be maintained in most years above 28,000 cfs during these three months to insure population growth about half the time. The DFG recommended a net Delta outflow criterion of 11,400 to 26,800 cfs between February and June of all water years to aid immigration of late stage larvae and small juveniles.

Table 14. Participant Recommendations for Delta Outflows to Protect Bay Shrimp

	Water Year	**Feb**	**Mar**	**Apr**	**May**	**Jun**
TBI/NRDC Exhibit 2	Most years		28,000			
Fish and Game Exhibit 1	all	11,400 to 26,815				

Population Abundance Goal

The goal is to maintain the juvenile C*. franciscorum* population abundance index, as measured by the San Francisco Bay Study otter trawl, in half of all years above a target value of 103. An index of 103 is the median longterm index value for this species in the San Francisco Estuary.

Species-Specific Recommendations

The State Water Board determines the Delta outflow criteria in Table 15 are needed to protect C*rangon franciscorum*. The purpose of the outflow criteria is to maintain population abundance at a long term median index value of 103. Positive population growth is expected in half of all years under these flow conditions. The Delta outflow criteria are similar to those proposed for protection of both longfin smelt and delta smelt. The nursery area for C*. franciscorum* is usually downstream of the influence of the pumps, therefore no OMR flow recommendations were received and no review was conducted.

Table 15. Criteria for Delta Outflows to Protect Bay Shrimp

Flow Type	Water Year Type	Jan	Feb	Mar	April	May
Net Delta Outflow	C	14,000 – 21,000			10,000 – 17,500	
	D	21,000 – 35,200			17,500 – 29,000	
	BN	35,200 – >50,000			29,000 – 42,000	
	AN	>50,000			>42,000	
	W	>50,000			>42,000	

Zooplankton (*E. affinis* and *N. mercedis*)

Status

Eurytemora affinis is a non-native species that is not listed pursuant to either the ESA or CESA. *Neomysis mercedis* is a native species that is not listed pursuant to either the ESA or CESA.

Life History[14]

Zooplankton is a general term for small aquatic animals that constitute an essential food source for fish, especially young fish and all stages of pelagic fishes that mature at a small size, such as longfin smelt and delta smelt (DFG 1987b). Although DFG follows trends of numerous zooplankton taxa (e.g., Hennessy 2009), two upper estuary zooplankton taxa of particular importance to pelagic fishes have exhibited abundance relationships to Delta outflow. The first is the mysid shrimp *Neomysis mercedis*, which before its decline, beginning in the late 1980s, was an important food of most small fishes in the upper estuary (see Feyrer et al. 2003). Prior to 1988, *N. mercedis* mean summer abundance (June through October) increased significantly as X2 moved downstream (mean March through November location, Kimmerer 2002a. Table 1). After 1987, *N. mercedis* abundance declined rapidly and is currently barely detectable (Kimmerer 2002a, Hennessy 2009). The second is a calanoid copepod, *Eurytemora affinis*, which also declined sharply after 1987, but more so in summer than in spring (Kimmerer 2002a). Before 1987, *E. affinis* was abundant in the low salinity habitat (0.8-6.3 ‰) throughout the estuary (Orsi and Mecum 1986). *E. affinis* is an important food for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished).

Population Abundance and Relationship to Flow

E. affinis was historically abundant throughout the year, particularly in spring and summer, but after 1987 abundance declined in all seasons, most notably in summer and fall. (Hennessy 2009, as cited in DFG 1, p. 26.) After 1987, *E. affinis* spring abundance (March through May) has significantly increased as spring X2 has moved downstream. (Kimmerer 2002a. Table 1, as cited in DFG 1, p. 26.) Relative abundance in recent years is highest in spring and persistence of abundance is related to spring outflow. As flows decrease in late spring, abundance decreases to extremely low levels throughout the estuary. (Hennessey 2009, as cited in DFG 1, p. 26.)

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[14] This section was largely extracted from DFG Exhibit 1, page 25.

The only outflow recommendation identified in the record specifically for *E. affinis* and *N. mercedis* was submitted by DFG, in their closing comments (Table 16). According to DFG, their current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. The Bay Institute provided flow recommendations for a suite of species, including *E. affinis (*Table 17*).*

Table 16. DFG's Delta Outflow Recommendation to Protect *E. affinis* and *N. mercedis* (DFG Closing Comments)

Species	**Parameter**	**Effect or Mechanism**	**Timing**	**Minimum**	**Maximum**	**Reference**
Zooplankton	Flows	Habitat	February - June	X2 at 75 km	X2 at 64 km	DFG Exhibit 1, p.25-26; Exhibit 2, p.6

Table 17. The Bay Institute's Delta Outflow Recommendations to Protect Zooplankton Species Including *E. affinis*

Species	Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eurytemora affinis	Habitat	81-100% (driest years)	14000-21000 cfs		10000-17500 cfs			3000-4200 cfs						
		61-80%	21000-35000 cfs		17500-29000 cfs			4200-5000 cfs						
		41-60%	35200-55000 cfs		29000-42500 cfs			5000-8500 cfs						
		21-40%	55000-87500 cfs		42500-62500 cfs			8500-25000 cfs						
		0-20% (wettest years)	87500-140000 cfs		62500-110000 cfs			25000 - 50000 cfs						

Species-Specific Recommendations

Table 18 shows the State Water Board's determination for Delta outflows needed to protect zooplankton. These recommendations are consistent with those submitted by DFG. (closing comments, p. 7.) The State Water Board concurs with DFG's current science-based conceptual model which concludes that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) Maintaining X2 at 75 km and 64 km corresponds to net Delta outflows of approximately 11,400 cfs and 29,200 cfs, respectively. No explicit recommendations concerning zooplankton and inflow or hydrodynamic requirements were identified in the record.

Table 18. Criteria for Delta Outflows to Protect Zooplankton

Effect or Mechanism	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Habitat	All	--	X2[1] – 75 to 64 km (~11400 – 29200 cfs)					--	--	--	--	--	--

4.3 Other Measures

Information in the record for this proceeding broadly supports the five key points submitted by the DEFG of experts (DEFG 1):

1) Environmental flows are more than just volumes of inflows and outflows
2) Recent flow regimes both harm native species and encourage non-native species
3) Flow is a major determinant of habitat and transport
4) Recent Delta environmental flows are insufficient to support native Delta fishes for today’s habitats
5) A strong science program and a flexible management regime are essential to improving flow criteria

These key points recognize that although adequate environmental flows are a necessary element to protect public trust resources in the Delta ecosystem, flows alone are not sufficient to provide this protection. These key points and other information in the record warrant a brief summary discussion of other information in the record that should be considered in the development of flow criteria, consistent with the charge of SB1 that “the flow criteria include the volume, quality, and timing of water necessary for the Delta ecosystem. “ Based on review of the information in the record this charge is expanded to include specific consideration of:

- Variability, flow paths, and the hydrograph
- Floodplain activation and other habitat improvements
- Water quality and contaminants
- Cold water pool management
- Adaptive management

4.3.1 Variability, Flow Paths, and the Hydrograph

The first of the five key points submitted by the DEFG of experts stated, in part: “There is no one correct flow number. Seasonal, interannual, and spatial variability, to which our native species are adapted, are as important as quantity.“ Species and biological systems respond to combinations of quantity, timing, duration, frequency and how these inputs vary spatially. (DEFG 1.) Based on their review of the literature in *Habitat Variability and Complexity in the Upper San Francisco Estuary*, Moyle *et al* (2010) find:

> “… unmodified estuaries are highly variable and complex systems, renowned for their high production of fish and other organisms (McClusky and Elliott 2004). The San Francisco Estuary, however, is one of the most highly modified and controlled estuaries in the world (Nichols et al. 1986). As a consequence, the

> estuarine ecosystem has lost much of its former variability and complexity and has recently suffered major declines of many of its fish resources (Sommer et al. 2007).
>
> …the concept of the "natural flow regime" (Poff et al. 1997) is increasingly regarded as an important strategy for establishing flow regimes to benefit native species in regulated rivers (Postel and Richter 2003; Poff et al. 2007; Moyle and Mount 2007). For estuaries worldwide, the degree of environmental variability is regarded as fundamental in regulating biotic assemblages (McLusky and Elliott 2004). Many studies have shown that estuarine biotic assemblages are generally regulated by a combination of somewhat predictable changes (e.g., tidal cycles, seasonal freshwater inflows) and stochastic factors, such as recruitment variability and large-scale episodes of flood or drought (e.g., Thiel and Potter 2001). The persistence and resilience of estuarine assemblages is further decreased by various human alterations, ranging from diking of wetlands, to regulation of inflows, to invasions of alien species (McLusky and Elliott 2004, Peterson 2003).
>
> …a key to returning the estuary to a state that supports more of the desirable organisms (e.g., Chinook salmon, striped bass, delta smelt) is increasing variability in physical habitat, tidal and riverine flows, and water chemistry, especially salinity, over multiple scales of time and space. It is also important that the stationary physical habitat be associated with the right physical-chemical conditions in the water at times when the fish can use the habitat most effectively (Peterson 2003)."

An example of a major change in the natural flow regime of the Delta is demonstrated by the increase in net OMR reverse flows just north of the SWP and CVP pumping facilities. Reverse flows are now a regular occurrence in the Delta channels because Sacramento River water enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south. This results in a net water movement across the Delta in a north-south direction along a web of channels including OMR instead of the more natural pattern from east to west or from land to sea. Positive net flows, connected flow paths, and salinity gradients are important features of an estuary. Natural net channel flows move water and some biota toward Suisun Bay and maintain downstream directed salinity gradients. Today, Delta gates and diversions can substantially redirect tidal flows creating net flow patterns and salinity and turbidity distributions that did not occur historically. These changes may influence migratory cues for some fishes. These cues are further scrambled by a reverse salinity gradient in the south Delta caused by higher salinity in agricultural runoff. (DEFG 1.)

Per the DEFG's paper, *Habitat Variability and Complexity in the Upper San Francisco Estuary* (Moyle et al., 2010), a more variable Delta has multiple benefits:

> "Achieving a variable, more complex estuary requires establishing seaward gradients in salinity and other water quality variables, diverse habitats throughout the estuary, more floodplain habitat along inflowing rivers, and improved water quality. These goals in turn encourage policies which: (1) establish internal Delta flows that create a tidally-mixed, upstream-downstream gradient (without cross-Delta flows) in water quality; (2) create slough networks with more natural channel

> geometry and less diked rip-rapped channel habitat; (3) improve flows from the Sacramento and San Joaquin rivers; (4) increase tidal marsh habitat, including shallow (1-2 m) subtidal areas, in both fresh and brackish zones of the estuary; (5) create/allow large expanses of low salinity (1-4 ppt) open water habitat in the Delta; (6) create a hydrodynamic regime where salinities in parts of the Delta and Suisun Bay and Marsh range from near-fresh to 8-10 ppt periodically (does not have to be annual) to discourage alien species and favor desirable species; (7) take species-specific actions that reduce abundance of non-native species and increase abundance of desirable species; (8) establish abundant annual floodplain habitat, with additional large areas that flood in less frequent wet years; (9) reduce inflow of agricultural and urban pollutants; and (10) improve the temperature regime in large areas of the estuary so temperatures rarely exceed 20°C during summer and fall months."

Similarly, reliance upon water year classification as a trigger for flow volumes has contributed to reduced flow variability in the estuary. The information received during this proceeding supports the notion that reliance upon water year classification as a trigger for flow volumes is an imperfect means of varying flows. Any individual month or season might have a dramatically different hydrology than the overall hydrology for the year. A critically dry year, for example, can have one or two very wet months, just as a wet year may have several disproportionately dry months. Figure 10 demonstrates how this actually occurs. Unimpaired Delta outflow for the month of June from 1922 through 2003 has historically been highly variable. Many June months that occur in years classified as wet have had much lower flows than June flows in years classified as below normal. The opposite is also true; several June flows in years classified as critically dry are higher than some years classified as above normal. Depending on the direction of this divergence of monthly flows (higher or lower) relative to the water year, reliance upon water year classification can provide less than optimal protection of the ecosystem or more than needed water supply impacts. The figure also shows the actual June flows for various periods of years, demonstrating how much lower actual flows have been than unimpaired flows. The primary reason for the lower historical flows is consumption of water in the watershed. The three periods shown, however, are not directly comparable to the unimpaired flow record because the shorter time frame may have been wetter or drier than the full historical record.

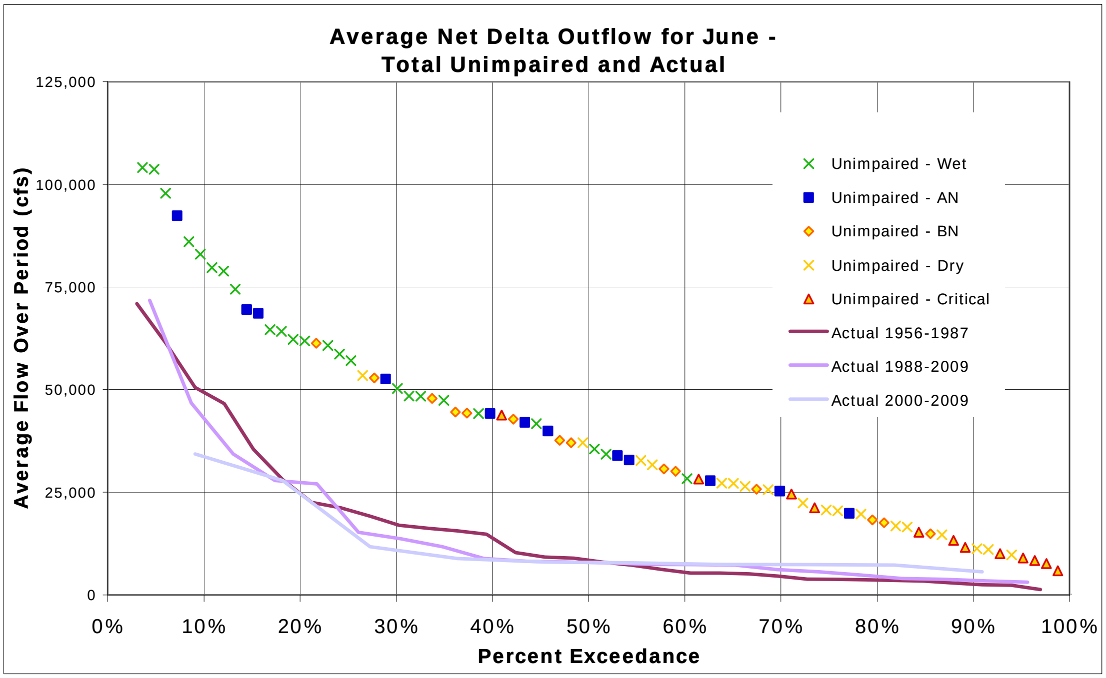


Figure 10. Actual and Unimpaired June Delta Outflow

Proportionality is one of the key attributes of restoring ecosystem functions by mimicking the natural hydrograph in tributaries to the Delta and providing for connectivity. Currently, inflows to the Delta are largely controlled by upstream water withdrawals and releases for water supply, power production, and flood control. As a result, inflows from tributaries frequently do not contribute flow to the Delta in the same proportions as they would have naturally, and to which native fish adapted. There is consensus in contemporary science that improving ecosystem function in the watershed, mainstem rivers, and the Delta is a means to improving productivity of migratory species. (e.g.,Williams 2005; NRC 1996, 2004a, 2004b as cited in NAS 2010, p. 42.) NAS found that, “Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the Delta were not made satisfactory.” (NAS 2010, p. 42.) “Propst and Gido (2004) support this hypothesis and suggest that manipulating spring discharge to mimic a natural flow regime enhances native fish recruitment (Propst and Gido, 2004 and Marchetti and Moyle, 2001).” (DOI, 1 p. 25.) Specifically, providing pulse flows to mimic the natural hydrograph could diversify ocean entry size and timing for anadromous fishes so that in many years at least some portion of the fish arrive in saltwater during periods favoring rapid growth and survival. (DOI 1, p. 30.) Food production may also be improved by maintaining the attributes of a natural hydrograph (EFG 1, p. 8.) Connectivity between natal streams and the Delta is critical for anadromous species that require sufficient flows to emigrate out of natal streams to the Delta and ocean, and sufficient flows upon returning, including flows necessary to achieve homing fidelity. Specifically, it is necessary for the scent of the river to enter the Bay in order for adult salmonids to find their way back to their natal river. (NMFS 2009, p.407 as cited in EDF 1, p. 48.) Further, insuring adequate flows from all of the tributaries that support native fish is important to maintain genetic diversity and species resilience in the face of catastrophic events.

4.3.2 Floodplain Activation and Other Habitat Improvements

Most floodplains in the Central Valley have been isolated from their rivers by levees. Due to the effects of levees and dams, side channel and floodplain inundating flows have been substantially reduced. At present, besides the Yolo Bypass, the only other Delta region with substantial connectivity to portions of the historical floodplain is the Cosumnes River, a small undammed watershed. (Sommer et al. 2001b.) Floodplains are capable of providing substantial benefits to numerous aquatic, terrestrial, and wetland species. (Sommer et al. 2001b.) Inundation of floodplains facilitates an exchange of organisms, nutrients, sediment, and organic material between the river and floodplain, and provides a medium in which biogeochemical processes and biotic activity (e.g., phytoplankton blooms, zooplankton and invertebrate growth and reproduction) can occur. (AR/NHI 1, p. 22.) This exchange of material can benefit downstream areas. For example, studies suggest phytoplankton, zooplankton, and other organic material transported from the Yolo Bypass enhances the food web of the San Francisco Estuary. (Jassby and Cloern 2000; Mueller-Solger et al. 2002; Sommer et al. 2004.)

Many fishes rear opportunistically on floodplains. (Moyle et al. 2007, as cited in Moyle et al. 2010), and juvenile salmon grow faster and become larger on floodplains than in the main-stem river channels. (Sommer et al. 2001a; Jeffres et al. 2008; DOI 1, p. 27; AR/NHI 1, p. 24.) Splittail require floodplains for spawning (Moyle et al. 2007), with large-scale juvenile recruitment occurring only in years with significant protracted (greater than or equal to 30 days) floodplain inundation, particularly in the Sutter and Yolo bypasses. (Meng and Moyle 1995, Sommer et al. 1997, Feyrer et al. 2006a.) Managing the frequency and duration of floodplain inundation during the winter and spring, followed by complete drainage by the end of the flooding season, could favor splittail and other native fish over non-natives. (Moyle et al. 2007, Grimaldo et al. 2004.) In addition, modeling conducted by Moyle et al. (2004) shows that while splittail are resilient, managing floodplains to promote frequent successful spawning is needed to keep them abundant. Improving management of the Yolo Bypass for fish, increasing floodplain areas along other rivers (e.g., Cosumnes and Mokelumne rivers), and developing floodplain habitat along the lower San Joaquin River, including a bypass in the Delta, represent opportunities to increase the frequency and extent of floodplain inundation. (Moyle et al. 2010.) The BDCP is currently evaluating structural modifications to the Fremont Weir (e.g., notch weir and install operable “inundation gates”), as a means of increasing the interannual frequency and duration of floodplain inundation in the Yolo Bypass. (BDCP 2009.)

The NMFS Opinion stipulates that USBR and DWR, in cooperation with DFG, USFWS, NMFS, and USACE, shall, to the maximum extent of their authorities (excluding condemnation authority), provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. (NMFS 3, p. 608.) Per this NMFS Opinion, USBR and DWR are to submit a plan to implement this action to NMFS by December 31, 2011. (Id.) This plan is to include an evaluation of options to, among other things, increase inundation of publicly and privately owned suitable acreage within the Yolo Bypass, and modify operations of the Sacramento Weir or Fremont Weir to increase rearing habitat. (Id.)

Moyle et al. (2010) discuss the value of creating more slough networks with natural geometry and less diked, rip-rapped channel habitat, the value of tidal marsh habitat, and low salinity, open water habitat in the Delta:

> "Re-establishing the historical extensive dendritic sloughs and marshes is essential for re-establishing diverse habitats and gradients in salinity, depth and other environmental characteristics important to desirable fish and other organisms (e.g., Brown and May 2008). These shallow drainages are likely to increase overall estuarine productivity if they are near extensive areas of open water, because they can deliver nutrients and organic matter to the more open areas. Dendritic slough networks will develop naturally in Suisun Marsh after large areas become inundated following dike failures and they can be recreated fairly readily in the Cache Slough region by reconnecting existing networks. In the Delta, the present simplified habitat in the channels between islands needs to be made more suitable as habitat for desirable species. Many levees are maintained in a nearly vegetation-free state, providing little opportunity for complex habitat (e.g., marshes and fallen trees) to develop. Much of the low-value channel habitat in the western and central Delta will disappear as islands flood, but remaining levees in submerged areas should be managed to increase habitat complexity (e.g., through planting vegetation), especially in the cooler northern and eastern parts of the Delta.
>
> [Subtidal] habitat has been greatly depleted because marshes in the Delta and throughout the estuary have been diked and drained, mostly for farming and hunting (Figure 3). Unfortunately, most such habitat in shallow water today is dominated by alien fishes, including highly abundant species such as Mississippi silverside which are competitors with and predators on native fishes (Moyle and Bennett 1996; Brown 2003). Such habitat could become more favorable for native fishes with increased variability in water quality, especially salinity. In particular, increasing the amount of tidal and subtidal habitat in Suisun Marsh should favor native fishes, given the natural variability in salinity and temperature that occurs there. The few areas of the marsh with natural tidal channels tend to support the highest diversity of native fishes, as well as more striped bass (Matern et al. 2002; Moyle, unpublished data). With sea level rise, many diked areas of Suisun Marsh currently managed for waterfowl (mainly dabbling ducks and geese) will return to tidal marsh and will likely favor native fishes such as splittail and tule perch (Hysterocarpus traski), as well as (perhaps) migratory fishes such as juvenile Chinook salmon. Experimental (planned) conversions of some of these areas would be desirable for learning how to manage these inevitable changes to optimize habitat for desired fishes.
>
> Open water habitat is most likely to be created by the flooding of subsided islands in the Delta, as well as diked marshland 'islands' in Suisun Marsh (Lund et al. 2007, 2010; Moyle 2008). The depth and hydrodynamics of many of these islands when flooded should prevent establishment of alien aquatic plants while variable salinities in the western Delta should prevent establishment of dense populations of alien clams (Lund et al. 2007).

> Although it is hard to predict the exact nature of these habitats, they are most likely to be better habitat for pelagic fishes than the rock-lined, steep-sided and often submerged vegetation-choked channels that run between islands today (Nobriga et al. 2005). Experiments with controlled flooding of islands should provide information to help to ensure that these changes will favor desired species. Controlled flooding also has the potential to allow for better management of hydrodynamics and other characteristics of flooded islands (through breach location and size) than would be possible with unplanned flooding."

4.3.3 Water Quality and Contaminants

Toxic effects are one of three general factors identified by scientists with the IEP in 2005 as contributing to the decline in pelagic productivity. The life history requirements and water quality sections above identify specific species sensitivities to water quality issues.

Though the information received in this proceeding supports the recommendation that modification to flow through the Delta is a necessary first step in improving the health of the ecosystem, it also supports the recommendation that flow alone is insufficient. The Delta and San Francisco Bay are listed under section 303(d) of the Federal Clean Water Act as impaired for a variety of toxic contaminants that may contribute to reduced population abundance of important fish and invertebrates. The contaminants include organophosphate and pyrethrin pesticides, mercury, selenium and unknown toxicity. In addition, low DO levels periodically develop in the San Joaquin River at the DWSC and in OMR. The low oxygen levels in the DWSC inhibit the upstream migration of adult fall-run Chinook salmon and adversely impact other resident aquatic organisms.

There is concern that a number of non-303(d) listed contaminants, such as ammonia, pharmaceuticals, endocrine disrupting compounds, and blue-green algal blooms could also limit biological productivity and impair beneficial uses. Sources of these contaminants include agricultural, municipal and industrial wastewater, urban storm water discharges, discharges from wetlands, and channel dredging activities. More work is needed to determine their impact on the aquatic community.

Ammonia has emerged as a contaminant of special concern in the Delta. Recent hypotheses are that ammonia is causing toxicity to delta smelt, other local fish, and zooplankton and is reducing primary production rates in the Sacramento River below the SRWTP and in Suisun Bay. A newer hypothesis is that ammonia and nitrogen to phosphorus ratios have altered phytoplankton species composition and these changes have had a detrimental effect on zooplankton and fish population abundance. (Glibert 2010.) More experiments are needed to evaluate the effect of nutrients, including ammonia, on primary production and species composition in the Sacramento River and Delta.

4.3.4 Cold Water Pool Management

As mentioned in the specific flow criteria, the criteria contained in this report should be tempered by the additional need to maintain cold water resources in reservoirs on tributaries to the Delta until improved passage and other measures are taken that would reduce the need for maintaining cold water reserves in reservoirs. As discussed in the Chinook salmon section, salmon have specific temperature tolerances during various portions of their life-cycle. Historically salmonids were able to take advantage of cooler upstream temperatures for parts of their life-cycle to avoid adverse temperature effects. Since construction of the various dams in the Central Valley, access to much of the cooler historic spawning and rearing habitat has been blocked. To mitigate for these impacts, reservoirs must be managed to preserve cold water resources for release during salmonid spawning and rearing periods. As reservoir levels drop, availability of cold water resources also diminishes. Accordingly, it may not be possible to attain all of the identified flow criteria in all years and meet the thermal needs of the various runs of Chinook salmon and other sensitive species. Thorough temperature and water supply modeling analyses should be conducted to adaptively manage any application of these flow criteria to suit real world conditions and to best manage the competing demands for water needed for the protection of public trust resources, especially in the face of future climate change.

Specifically, these criteria should not be construed as contradicting existing and future cold water management requirements that may be needed for the protection of public trust resources, including those for the Sacramento River needed to protect the only remaining population of winter-run Chinook salmon. (see NMFS 3, p. 590-603.)

4.3.5 Adaptive Management

Any environmental flow prescription for native species in the Delta will be imperfect. The problem is too complex, uncertainties are too large, and the situation in the Delta is changing too rapidly in too many ways for any single flow prescription to be correct, or correct for long. (Fleenor et al. 2010.) Some degree of certainty regarding future conditions in the Delta is needed before long term flow criteria can be developed. Since it is unlikely that certainty will be achieved before actions or responses are required by geologic, biological, and legal processes, it might be valuable to provide substantial financial and water reserve resources, along with responsible institutional wherewithal to respond to changes and undertake necessary experiments for more successfully transitioning into the largely unexplored new Delta. (Fleenor et al. 2010.) This confounding need for certainty of operations and water supply at the same time there is uncertainty underlying ecosystem needs, provides good rationale to rely upon adaptive management to address this uncertainty.

The Delta is continually changing. Flow criteria developed for the present Delta ecosystem will become less reflective of ecosystem needs with the passage of time. Accordingly, it is important that flow criteria be adaptive to future changes. Flows, habitat restoration, and measures to address other stressors should be managed adaptively. (AR/NHI Closing Comments.)

Adaptive management is “an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to specific management actions.” (NRC 1999 as cited in DOI Ex.1.) This notion of treating actions as experiments is key, because information received in this proceeding indicates that the mechanisms underlying the relationship between flows and the health of the Delta ecosystem are, at times, unclear. Adaptive management is the most suitable approach for managing with uncertainty. (DEFG 1.)

Murray and Marmorek (2004) describe an adaptive management approach as:

- exploring alternative ways to meet management objectives
- predicting the outcomes of alternatives based on the current state of knowledge
- implementing one or more of these alternatives
- monitoring to learn about the impacts of management actions
- using the results to update knowledge and adjust management actions

An adaptive approach provides a framework for making good decisions in the face of critical uncertainties, and a formal process for reducing uncertainties so that management performance can be improved over time. (Williams et al. 2007.)

Adaptive management does not postpone action until "enough" is known but acknowledges that time and resources are too short to defer *some* action, particularly actions to address urgent problems. (Lee 1999.) Adaptive management provides a means of informing planning and management decisions in spite of uncertainty. Key point number 5 of the DEFG states: “a strong science program and a flexible management regime are essential to improving flow criteria. (DEFG 1.)

Adaptive management can be used to manage uncertainty in two ways, over two time frames. Over the short-term, adaptive management could allow for a specific response to real time conditions so long as the response is otherwise consistent with the constraints of some overarching regulatory framework. Over the longer term, adaptive management could allow for the more nimble modification of regulatory constraints, so long as these modifications fell within the clearly defined parameters of the overarching regulatory framework.

Short-term Adaptive Management

Per the DEFG’s assessment regarding the role of uncertainty…

> “…despite [our] extensive scientific understanding substantial knowledge gaps remain about the ecosystem's likely response to flows. First, ecosystem processes in a turbid estuary are mostly invisible, and can be inferred only through sampling. Second, monitoring programs only scratch the surface of ecosystem function by estimating numbers of fish and other organisms, whereas the system’s dynamics depend on birth, growth, movement, and death rates which can rarely be monitored. Third, this system is highly variable in space (vertical, cross-channel, along-channel, and larger-scale), time (tidal, seasonal, and interannual), flow, salinity, temperature, physical habitat type, and species composition. Each of the hundreds of species has a different role in the system, and these differences can be subtle but important. As a result, we have little ability to predict how the ecosystem will respond to the numerous anticipated deliberate and uncontrolled changes.” (DEFG 1.)

Flexible management can be designed into a regulatory framework so that any requirements rely upon real time information and real time decisions to guide specific real-time action. A current example of this is the Delta Smelt Working Group that provides information and analyses used to guide real time operation of export facilities so that these facilities can be operated in a manner that conforms with the current NMFS and USFWS opinions. Any such flexible management will need to consider the processes and governance structures required to make sound scienfically-based real-time decisions. The Delta Smelt Working Group is a good example of how scientific assessment of real-time data, including the presence of fish, can better inform the real-time operation of export facilities.

<u>Long-term Adaptive Management</u>
Over the longer term, adaptive management can be used to more nimbly modify regulatory constraints so that fishery and water resource agencies are not locked into prescriptive constraints well past the time that current scientific understanding can support. This longer term adaptive management has bearing on a number of the flow criteria being considered in this report because many of these criteria lack sufficiently robust information to support a specific numeric criterion. Although the functional basis for a beneficial flow may be understood, the basis for a specific numeric criteria may not. Some regulatory flows may therefore need to take the form of an informed experimental manipulation. Such flows would need to be implemented… "as if they were experiments, with explicit conceptual and simulation models, predicting outcomes, and feedback loops so that the course of management and investigation can change as the system develops and knowledge is gained. A talented group of people tasked to integrate, synthesize, and recommend actions based on the data being gathered are essential for making such a system work. Failure to implement an effective adaptive management program will likely lead to a continued failure to learn from the actions, and a lack of responsiveness to changing conditions and increased understanding." (DEFG 1.)

The Delta Science Program, IEP, and other institutions could be relied upon to evaluate experimental flows and make recommendations to be considered for modifications of such flows.

4.4 Expression of Criteria as a Percentage of Unimpaired Flow

In some cases, participants' recommendations were expressed as specific flows in specific months, to be applied during specific water year types or with specified probabilities of exceedance. Review of unimpaired hydrology shows there is great variability in the quantity of unimpaired flow during these specified months when categorized by water year type. Reliance upon monthly or seasonal flow prescriptions based on water year type would therefore result in widely ranging relative amounts of unimpaired flow depending upon the specific hydrology of the month or season. Also, the rather coarse division of the hydrograph into five water year types can lead to abrupt step-wise changes in flow requirements. In an attempt to more closely reflect the variation of the natural hydrograph, the State Water Board recommends that, when possible, the flow criteria be expressed as a percentage of unimpaired flow.

To develop criteria in this way, the unimpaired flow rate for a specified time period (e.g. average monthly flow over a range of months) was plotted on an exceedance probability graph (using the Weibull plotting position formula) along with the flow recommendations and desired return frequencies. The unimpaired flow rates were also plotted such that the associated water year type can be identified and their percent exceedance estimated. A percentage of unimpaired flow was selected by trial and error so that the desired flow rate and exceedance frequency was achieved. A separate exceedance plot was produced for each time period being evaluated.

The unimpaired flow estimates used in the development of these flow criteria are based on those developed in the DWR May 2007 document: *"California Central Valley Unimpaired Flow Data" Fourth Edition Draft.* (DWR 2007.) This report contains estimates of the monthly flow for 24 sub-basins in the Central Valley. Each sub-basin uses a separate calculation dependant on conditions specific to that sub-basin, available gauge data, and relationships to other sub-basins. In many cases the methods change over the period of record to incorporate changes to infrastructure within the sub-basins that need to be accounted for. Estimates are provided for 83 water years from 1922 through 2003. A water year begins in October of the previous calendar year through September of the named water year. The following describes the unimpaired flow estimates that are the basis for flow criteria for the Sacramento River at Rio Vista, the San Joaquin River at Vernalis, and Net Delta Outflow.

Sacramento Valley Unimpaired Total Outflow

Estimates of the unimpaired Sacramento Valley outflow were computed as the sum of estimates from 11 sub-basins in the watershed and are understood to represent the flow that would occur on the Sacramento River at approximately Freeport. These 11 sub-basins include the Sacramento Valley Floor, Putah Creek near Winters, Cache Creek above Rumsey, Stony Creek at Black Butte, Sacramento Valley West Side Minor Streams, Sacramento River near Red Bluff, Sacramento Valley East Side Minor Streams, Feather River near Oroville, Yuba River at Smartville, Bear River near Wheatland, and the American River at Fair Oaks.

The unimpaired Sacramento Valley outflow from DWR 2007 is used as the basis for flow criteria on the Sacramento River at Rio Vista, even though it is understood they are more representative of unimpaired flows expected at Freeport. This is a necessary simplification as such estimates do not exist at Rio Vista, but should be adequate for the purpose of these criteria. If future flow requirements are to be established at Rio Vista based on a percentage of unimpaired flow, it is recommended that new estimates of unimpaired flow be developed specific for this location.

San Joaquin Valley Unimpaired Total Outflow

Estimates of the unimpaired San Joaquin Valley outflow were computed as the sum of estimates from nine sub-basins in the watershed and are understood to represent the flow that would occur on the San Joaquin River at Vernalis. These nine sub-basins include the Stanislaus River at Melones Reservoir, San Joaquin Valley Floor, Tuolumne River at Don Pedro Reservoir, Merced River at Exchequer Reservoir, Chowchilla River at Buchanan Reservoir, Fresno River near Daulton, San Joaquin River at Millerton Reservoir, Tulare Lake Basin Outflow, San Joaquin Valley West Side Minor Streams.

Delta Unimpaired Total Outflow

Estimates of unimpaired Net Delta Outflow in DWR 2007 were computed generally as Delta Unimpaired Total Inflow minus unimpaired net use in the Delta, including both lowlands and uplands. Delta Unimpaired Total Inflows was calculated as the sum of the Sacramento Valley and San Joaquin Valley Unimpaired Total Outflows as described above and the East Side Streams Unimpaired Total Outflow. The later consists of four sub-basins including San Joaquin Valley East Side Minor Streams, Cosumnes River at Michigan Bar, Mokelumne River at Pardee Reservoir, and Calaveras River at Jenny Lind. Generally the unimpaired net use in the Delta is an estimate of the consumptive use from riparian and native vegetation (replacing historical irrigated agriculture and urban areas), plus evaporation from water surfaces, minus precipitation, and assumes that existing Delta levees and island remain intact. Unimpaired flow graphs in this report use the unimpaired flow record from 1922 to 2003.

5. Flow Criteria

Two types of criteria are provided in this report: numeric flow criteria, and other, non-numeric, measures that should be considered to complement the numeric criteria. Numeric criteria are subdivided into two categories: category “A” criteria have more and better scientific information, with less uncertainty, to support specific numeric criteria than do Category “B” criteria. Summary numeric criteria are provided for Delta outflow, as well as Sacramento River and San Joaquin River inflows, and Hydrodynamics (Old and Middle River, Inflow-Export Ratios, and Jersey Point flows) in Tables 19 through 22.

In addition to new criteria for Delta outflows, inflows, and hydrodynamics, some of the objectives for the protection of fish and wildlife from the 2006 Bay-Delta Plan are advanced as criteria in this report. While the State Water Board did not specifically reevaluate the methodology and basis for the Bay-Delta Plan objectives, the State Water Board recognizes that these flows provide some level of existing protection for fish and wildlife and, in the absence of more specific information, merit inclusion in these criteria. At the time the Bay-Delta Plan objectives were adopted, they were supported by substantial evidence, including scientific information. While the purpose of this report is to develop flow criteria using best available scientific information, water quality objectives are established taking into account scientific and other factors pursuant to Water Code section 1241.

5.1 Delta Outflows

Following are Delta outflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Net Delta Outflow: 75% of 14-day average unimpaired flow for January through June
2) Fall X2 for September through November
    - Wet years X2 less than 74 km (greater than approximately 12,400 cfs)
    - Above normal years X2 less than 81 km (greater than approximately 7,000 cfs)
3) 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Delta outflow criteria 1 is a Category A criterion because it is supported by more robust scientific information. Delta outflow criteria 2 and 3 are Category B criteria because there is less scientific information to support specific numeric criteria, but there is enough information to support the conceptual need for flows. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to implement Category B criteria. Following is discussion and rationale for these criteria.

The narrative objective of the flow criteria is to halt the population decline and increase populations of native species as well as species of commercial and recreational importance. The need to estimate the magnitude, duration, timing, and quality of Delta outflows necessary to support viable populations of these species is inherent to this objective. McElhany et al. (2000) proposed that four parameters are critical for evaluating population viability: abundance, population growth rate, population spatial structure, and diversity. Delta outflow may affect one, all, or some combination of these parameters for a number of resident and anadromous species. A species-specific analysis of flow needs for a suite of upper estuary species is included in section 4.2.4.

An analysis of generation to generation population abundance versus Delta outflows indicates that the "likelihood" of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flow volumes of approximately 9.1 MAF (51,000 cfs) and 6.3 MAF (35,000 cfs) during January through March and March through May, respectively. (TBI/NRDC 2, pp. 17-19.) The provision of sufficient flows to achieve these flow volumes during January through March and March through May in approximately 45% and 47% of years, respectively, is intended to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. Based on a comparison of the flows needs identified in section 4.2.4, it appears that winter-spring outflows designed to be protective of longfin smelt would benefit the other upper estuary species evaluated. The DFG recommended that spring outflows extend through June to fully protect a number of estuarine species. (DFG 1, pp. 2-5.) During June, sufficient outflow should be provided to maintain X2 in Suisun Bay (between 75 km and 64 km). (DFG closing comments, p. 7; DFG 2, p. 6.)

The State Water Board recognizes that the target flow volumes of 9.1 MAF (Jan-Mar, 51,000 cfs) and 6.3 MAF (Mar-May, 35,000 cfs) in greater than or equal to approximately 45% and 47% of years, respectively, and the positioning of X2 in Suisun Bay during the month of June are necessary in order to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. An approach based on a percentage of unimpaired flows is intended as a means of distributing flows to meet the above-mentioned criteria in a manner that more closely resembles the natural hydrograph. Such an approach also recognizes the importance of preserving the general attributes of the flow regimes to which the native estuarine species are adapted.

Analyses of historic conditions (1921 to 2003), indicates that at 75% of unimpaired flows, average flows of 51,000 cfs occurred between January and March in approximately 35% of years, while average flows of 35,000 cfs happened between March and May in 70% of years. At 75% of unimpaired flow, X2 would be maintained west of Chipps Island more than 90% of the time between January and June (analyses not shown). Rather than advance multiple static flow criteria for the January through March, March through May, and June time periods, the State Water Board determines, as a Category A criterion, that 75% of 14-day average unimpaired flow is needed during the January through June time period to promote increased abundance and improved productivity for longfin smelt and other desirable estuarine species. It is important to note that this criterion is not a precise number; rather it reflects the general timing and magnitude of flows needed to protect public trust resources in the Delta ecosystem. However, this criterion could serve as the basis from which future analysis and adaptive management could proceed.

Given the extensive modifications to the system there may be a need to diverge from the natural hydrograph at certain times of the year to provide more flow than might have actually occurred to compensate for such changes. Fall outflow criteria, intended to improve conditions for Delta smelt by enhancing the quantity and quality of habitat in wet and above normal water years, represent such an instance. As a Category B criterion, the State Water Board determines that sufficient outflow is needed from September through November of wet and above normal water year types to position X2 at less than or equal to 74 km and 81 km, respectively (Fall X2 action). In addition, the Delta Outflow Objectives contained within the Bay-Delta Plan for July through December are advanced as a Category B criterion. The State Water Board does not recommend increasing fall flows beyond those stipulated in the Bay-Delta Plan and Fall X2 action at this time. The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation.

Category A: Winter – Spring Net Delta Outflows

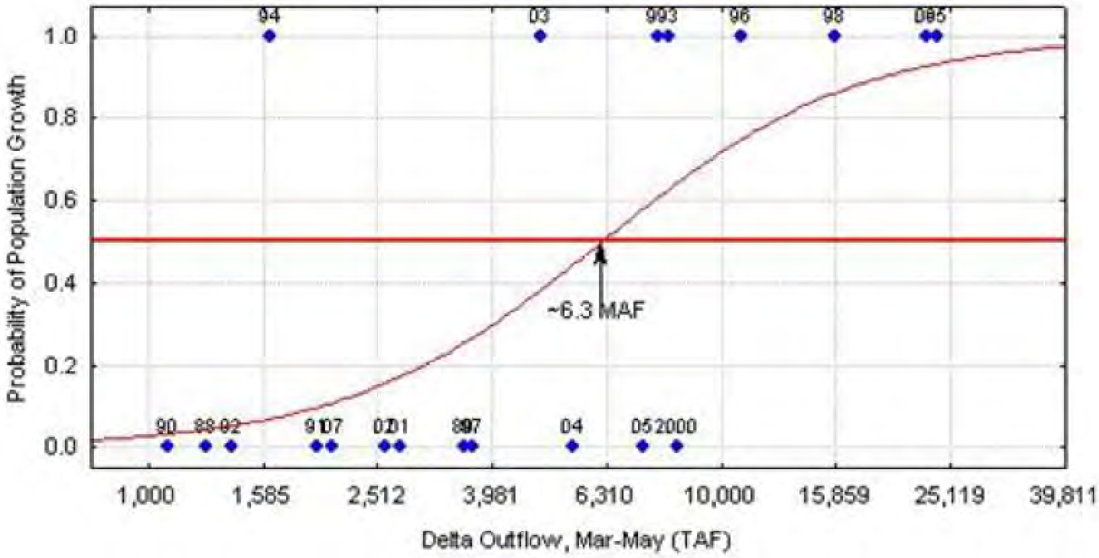
The flow regime is important in determining physical habitat in aquatic ecosystems, which is in turn a major factor in determining biotic composition. (DEFG 1.) Bunn and Arthington (2002) highlight four principles by which the natural flow regime influences aquatic biodiversity: 1) developing channel form, habitat complexity, and patch disturbance, 2) influencing life-history patterns such as fish spawning, recruitment, and migration, 3) maintaining floodplain and longitudinal connectivity, and 4) discouraging non-native species. Altering flow regimes affects aquatic biodiversity and the structure and function of aquatic ecosystems. The risk of ecological change increases with greater flow regime alteration. (Poff and Zimmerman 2010.)

A suite of native, and recreationally or commercially important species were evaluated in an effort to assess the timing, volume, and quality of water necessary to protect public trust resources. Flow criteria were developed for each of the species identified by DFG as those that are priority concern and will benefit the most as a result of improved flow conditions. (DFG closing comments, p. 3.) For Delta outflow, this included longfin smelt, delta smelt, starry flounder, American shad, bay shrimp (*Crangon* sp.), mysid shrimp, and *Eurytemora affinis*. Through this process, data or information pertaining to life history attributes (e.g., timing of migration, spawning, rearing), relationships of species abundance or habitat to Delta outflow, season or time period when flow characteristics are most important, factors influencing and/or limiting populations, and other characteristics were assessed and summarized in the individual species write-ups.

Statistically significant relationships between annual abundance and X2 (or outflow) have been demonstrated for a diverse assemblage of species within the estuary. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer *et al*. 2009.) The causal mechanisms underlying the variation in annual abundance indices of pelagic species in the estuary are poorly understood, but likely vary across species and life stages.

Longfin smelt have the strongest X2-abundance relationship of those species for which such a relationship has been demonstrated. (Kimmerer et al. 2009.) Abundance indices for this species are inversely related to X2 during its winter-spring spawning and early rearing periods. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a; Rosenfield and Baxter 2007; Kimmerer et al. 2009.) However, a four-fold decline in the relationship, with no significant change in slope, occurred after 1987, coincident with the introduction and spread of the introduced clam *Corbula amurensis.* (Kimmerer 2002a.) Reduced prey availability due to clam grazing has been identified as a likely mechanism for the decline in the X2-abundance relationship. (Kimmerer 2002a.)

One of the key biological goals of the informational proceeding was to identify the flows needed to increase abundance of native and other desirable species. Logit regression (StatSoft 2010, as cited in TBI/NRDC 2, p.17) was used to address the question: What outflow corresponded to positive longfin smelt population growth 50% of the time in the past? Logit regression is used to find a regression solution when the response variable is binary. For the purpose of this analysis, the generation-over-generation changes in abundance indices were converted to a binary variable (increase = 1 or decrease = 0). The analysis was conducted using FMWT abundance indices for the period extending from 1988 to 2007 (post-*Corbula*). Two periods of the winter-spring seasons (January to March and March to May) were evaluated, as different life stages of longfin smelt are present in the Delta during those periods (spawning adults and larvae/juveniles, respectively) and the mechanisms underlying the flow-abundance relationship may occur and/or vary in some or all of the months during these periods. (TBI/NRDC 2, p. 13.) The results were statistically significant ($p < 0.015$) and revealed that the "likelihood" of an increase in FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively. (Figure 11, TBI/NRDC 2, pp. 17-19.)



Logit regression showing relationship between March through May Delta outflow and generation-over-generation change in abundance of longfin smelt (measured as the difference between annual FMWT abundance indices). Positive changes in the abundance index were scored at "1" and declines were scored as "0". Arrow indicates flows above which growth occurred in more than 50% of years. Point labels indicate year of the FMWT index. (Source: TBI 2, Figure 15.)

Figure 11. Logit Regression Showing Relationship Between March through May Delta Outflow and Generation-Over-Generation Change in Longfin Smelt Abundance

A similar analysis was conducted for bay shrimp (*Crangon* sp.), a species whose flow-abundance relationship did not experience a "step decline" following the invasion of *Corbula.* (Kimmerer 2002a.) Results of the logit analysis indicate that abundance indices for this species increased in about 50% of years when flows during March through May were approximately 5 MAF. (TBI/NRDC 1, p. 17.) Therefore, flows associated with positive changes in the longfin smelt abundance index are anticipated to improve the likelihood of increases in bay shrimp abundance as well.

An analysis of historical longfin smelt flow-abundance relationships that corresponded to recovery targets in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (USFWS 1996) was also conducted. During the periods of January through March and March through May, cumulative Delta outflows of greater than 9.5 MAF and greater than 6.3 MAF, respectively, historically corresponded to abundance indices equal to or exceeding the recovery targets. (TBI/NRDC 2, p. 14.) These results are based on the intersection of the 1967 to1987 flow-abundance relationship and the recovery target. Use of the 1988 to 2007 flow-abundance relationship predicts lower abundance indices per any given flow, as compared to the historical relationship. Use of the pre-*Corbula* flow-abundance relationship underscores the need to address other stressors that may be affecting longfin smelt abundance concurrently with improved flow conditions. (TBI/NRDC 2, p. 14.) Applying this method and the logit regression produces very similar results.

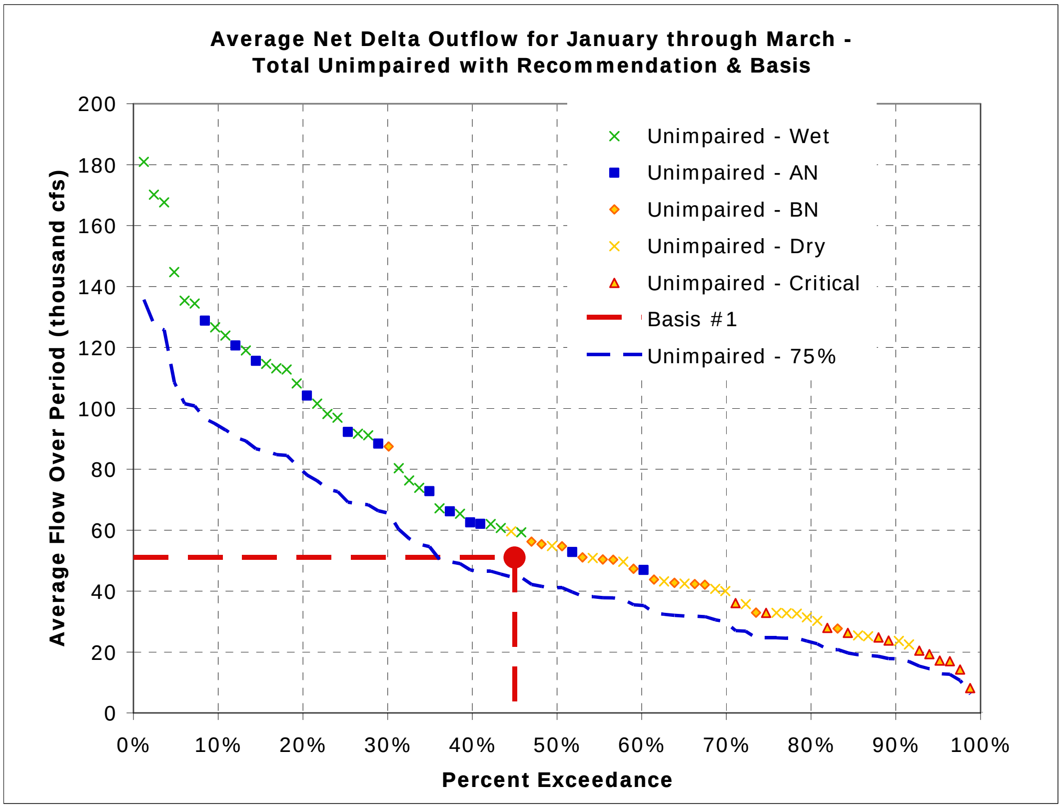
As noted above, the results of the logit analysis indicate that the “likelihood” of an increase in the longfin smelt FMWT abundance index in 50% of years corresponded with flows of approximately 9.1 MAF and 6.3 MAF during January through March and March through May, respectively. (TBI/NRDC 2, pp. 17-19.) Hereafter, these two flow volumes are reported in cubic feet per second, as 51,000 cfs and 35,000 cfs, respectively. Analyses indicate that under historic unimpaired conditions (1921 to 2003) average flows of 51,000 cfs occurred between January and March in approximately 50% of years (Figure 12a), while average flows of 35,000 cfs happened between March and May approximately 85% of the time (Figure 13a). The review of the historic record suggests that it is unrealistic to expect a 100% return frequency for the two magnitudes. A point of reference for determining a more realistic return frequency might be the actual (impaired) flows that occurred from 1956 to 1987. This was a time period when native fish were more abundant than today. Actual average flows between 1957 and 1987 of 51,000 cfs occurred between January and March in approximately 45% of years (Figure 12b). Similarly average flows of 35,000 cfs occurred between March and May 47% of the time (Figure 13b). However, since 2000, average flows of this magnitude only occurred about 27% and 33% of the time, respectively (Figures 12b and 13b). At 75% of unimpaired flow, average flows of 51,000 and 35,000 cfs would happen 35% and 70% of the time, respectively (Figure 12a and Figure 13a). Finally, the DFG has indicated that spring outflows should continue through June to fully protect a number of estuarine species (DFG 1, pp.2-5.)

A fixed 75% of unimpaired flow would extend the flow criteria to other years and distribute flows in a manner that more closely resembles the natural hydrograph. Expression of this criterion as a 14-day running average would better reflect the timing of actual flows (compared with a 30-day running average) while still allowing for a time-step to which reservoirs could be operated. The appropriateness of the 14 day averaging period warrants further evaluation. The unimpaired flows from which the 75% criterion is calculated are monthly values. Estimates of 14-day average unimpaired flows have not been published, but a cursory analysis indicates that they are likely to generate an exceedance curve similar to one generated with monthly values.

The State Water Board therefore determines that the Net Delta Outflow criterion be 75% of the 14-day average unimpaired flow between January and June (Figure 14a, Table

20). Consistent with the DFG recommendation (closing comments, p. 7) that X2 be maintained between 65 and 74 km (Chipps Island and Port Chicago) from January through June, a criterion of 75% of unimpaired flow, would maintain X2 west of Chipps Island more than 90% of the time, between January and June, based on monthly averages (analyses not shown). The return frequency for all months combined is about 98% of the time (Figure 14a). This compares with about a 90% percent return frequency between 2000 and 2009 (Figure 14b).

a)



b)

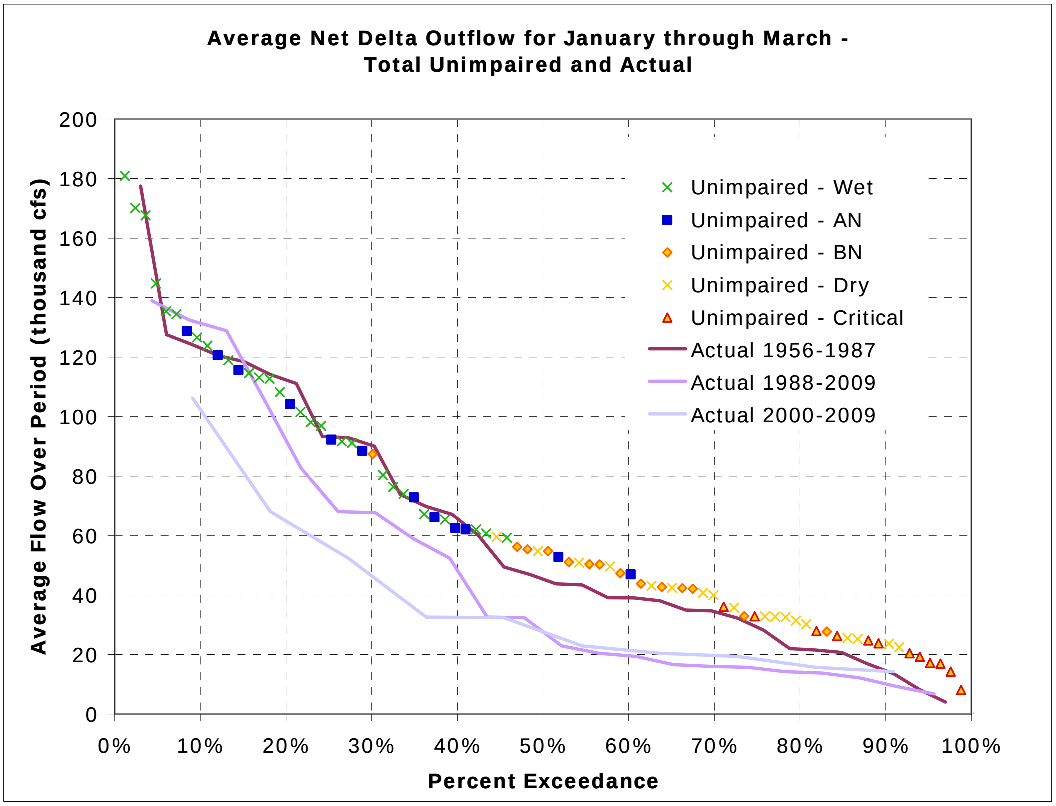


Figure 12. Net Delta Outflow Flow Exceedance Plot - January through March

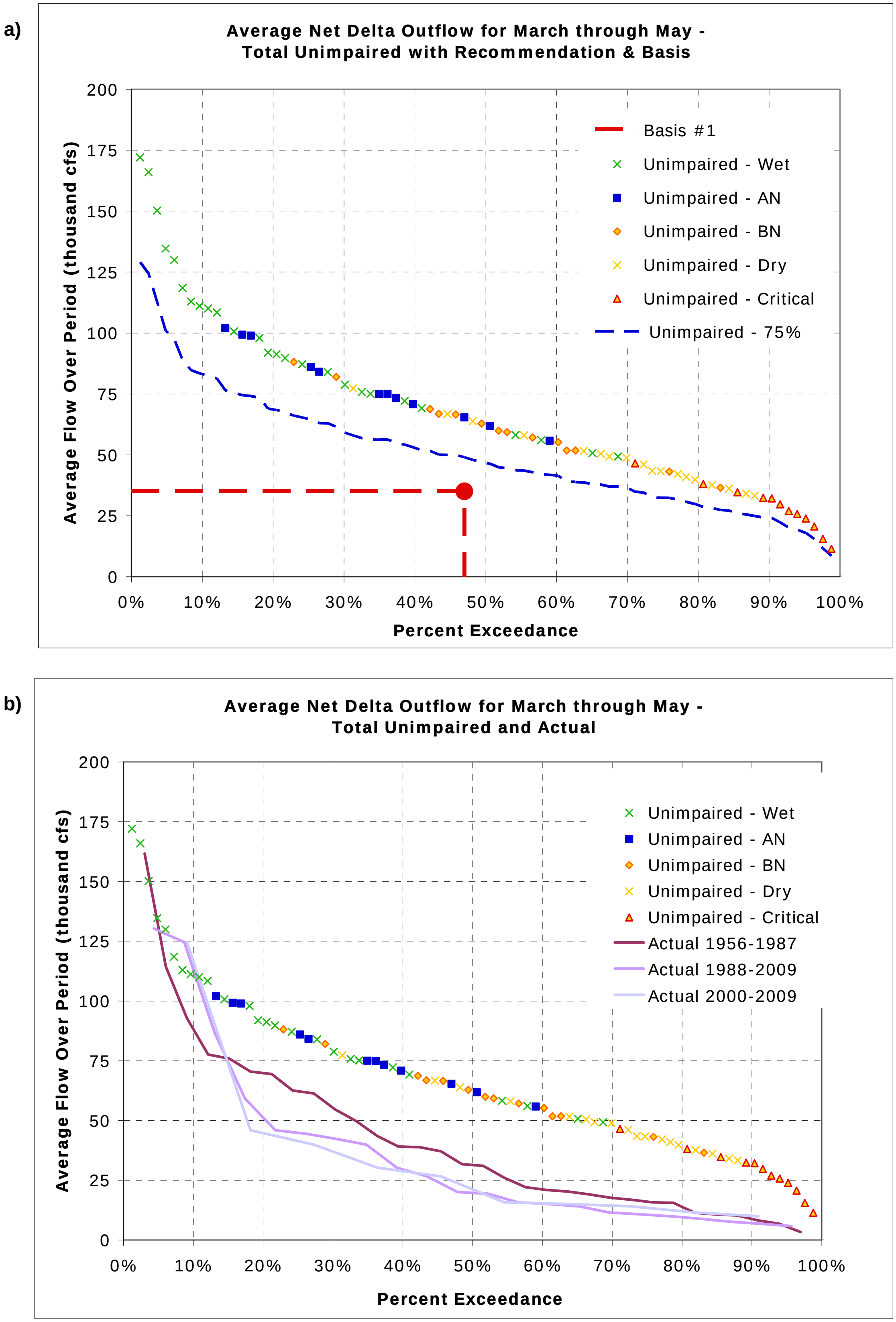


Figure 13. Net Delta Outflow Flow Exceedance Plot - March through May

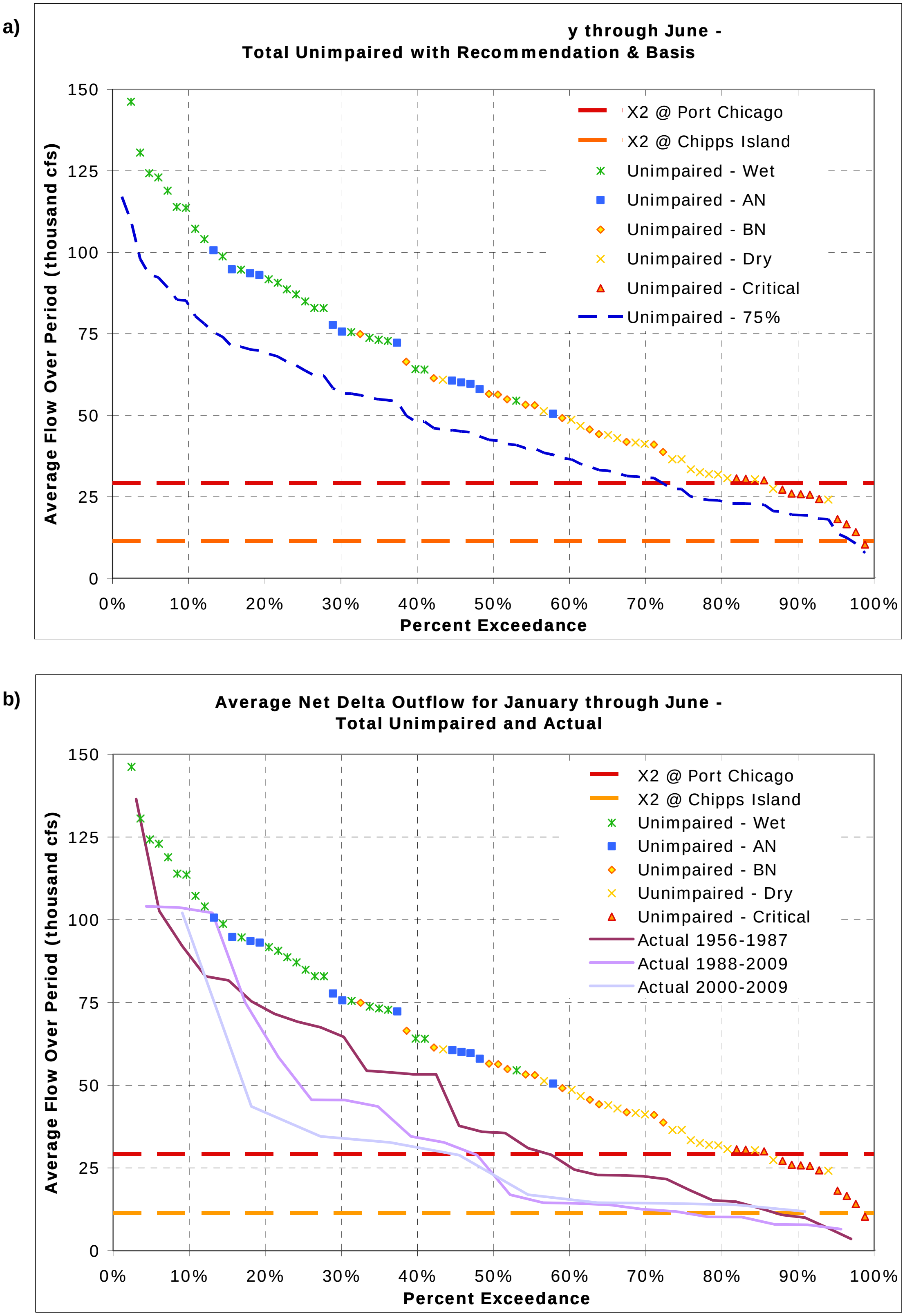


Figure 14. Net Delta Outflow Flow Exceedance Plot - January through June

The net Delta outflow criterion of 75% of unimpaired flows from January through June is anticipated to increase the likelihood of positive population growth for a number of other public trust species, notably those for which abundance-X2 relationships have been demonstrated, including American shad, striped bass, starry flounder, bay shrimp (*Crangon franciscorum*), and *Eurytemora affinis* (spring abundance). For example, the spring (March through May) abundance of *Eurytemora affinis* has been positively related to flow, following the invasion of *Corbula.* (Kimmerer 2002a.) This species represents an important prey item for most small fishes, particularly those with winter and early spring larvae, such as longfin smelt, delta smelt and striped bass. (Lott 1998, Nobriga 2002, Bryant and Arnold 2007, DFG unpublished.) Increases in the abundance of prey species, such as *E. affinis* and bay shrimp, has the potential to improve productivity of the estuarine food web and benefit a number of fishes, especially given that food limitation has been identified as a potential contributing factor in the POD. (Baxter *et al*. 2008.) Additional information concerning the relationship of population abundance to flow for these species is provided in the species life history section of this report.

Delta smelt abundance does not respond to freshwater outflow in a predictable manner similar to that of other numerous estuarine species. (Stevens and Miller 1983; Jassby et al. 1995; Kimmerer 2002a.) However, freshwater outflow during spring (March to June) does affect the distribution of delta smelt larvae by transporting them seaward toward the low salinity zone. (Dege and Brown 2004.) Ideal rearing habitat conditions for this species are believed to be shallow water areas most commonly found in Suisun Bay. (Bennett 2005.) Outflows that locate X2 in Suisun Bay (mean April through July location) produce the highest delta smelt abundance levels; however, low abundances have also been observed under the same conditions, which indicates several mechanisms must be operating. (Jassby et al. 1995; DFG 1, p. 15.) A criterion of 75% of unimpaired flow is expected to place X2 in Suisun Bay from March through June in nearly all years.

The DFG's current science-based conceptual model is that placement of X2 in Suisun Bay represents the best interaction of water quality and landscape for fisheries production given the current estuary geometry. (DFG 2, p. 6.) The DFG (closing comments, p. 7) provided recommended flow criteria for the Delta based on the placement of X2, for January through June (exact period varied by species), for longfin smelt, starry flounder, bay shrimp, zooplankton, and American shad. For each of these species, the DFG (*Id*.) recommends that sufficient outflow be provided to position X2 between 75 km and 64 km. These criteria are generally consistent with spring X2 requirements in the 2006 Bay-Delta Plan, which requires salinity at one compliance point (81 km) not to exceed 2 psu continuously, and at two other compliance points (64 km [Port Chicago] and 75 km [Chipps Island]) not to exceed 2 psu for a set number of days during February through June. Positioning X2 at 75 km and 64 km is equivalent to a 3-day running average Net Delta Outflow Index of 11,400 cfs and 29,200 cfs, respectively. Implementation of the 75% of unimpaired flow criteria would be largely consistent with the intent of the DFG's recommendations by placing X2 between Chipps Island and Port Chicago, or further to the west, in nearly all years during the January through June period.

The step-decline in the abundance-X2 relationship that occurred after 1987 for many of these species in combination with the lack of understanding concerning the causal mechanisms underlying those relationships leads to uncertainty regarding the future response of these species to elevated flows. In addition, a number of major changes to the Delta landscape, including levee failure and island flooding, are likely to occur over the next several decades. (Lund et al. 2007, 2008.) Flow regimes needed to maintain desired environmental conditions will change through time, in response to changes in the geometry of waterways, climate, and other factors. A number of "stressors" are currently being evaluated as potential contributors to the POD, including attributes of physical and chemical fish habitat. (Sommer et al. 2007; Baxter et al. 2008.) Increasing flows, without concurrent improvements to habitat and water quality, would decrease the extent of expected improvements in native species abundances and habitats. (DOI 1, p. 40.) However, the scientific information received during this proceeding supports the conclusion that flow, though not sufficient in and of itself, is necessary to protect public trust resources and that the current flow regime has harmed native species and benefited non-native species. Each of these issues adds further support to the need for a strong adaptive management program.

The specific flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water resources to support egg incubation, juvenile rearing, and holding in the Sacramento River, San Joaquin River, and associated tributary basins. It may not be possible to attain the outflow criteria and meet the thermal needs of the various runs of Chinook salmon and other sensitive species in certain years. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both outflow and cold water temperature goals.

Category B: Fall X2

Abiotic habitat parameters for delta smelt have been described for both the summer and fall seasons as combinations of salinity, temperature, and turbidity. (Nobriga et al. 2008; Feyrer et al. 2007; Feyrer et al. in review.) During fall, delta smelt typically occur in low salinity rearing habitats located around the confluence of the Sacramento and San Joaquin Rivers. Suitable abiotic habitat for delta smelt during fall has been defined as relatively turbid water (Secchi depths < 1.0 m) with a salinity of approximately 0.6-3.0 psu. (Feyrer et al. 2007.) Long-term trend analysis has shown that environmental quality, as defined by salinity and turbidity, has declined across a broad geographical range, most notably within the south-eastern and western regions of the Delta, leaving a relatively restricted area in the lower Sacramento River and around the confluence of the Sacramento and San Joaquin rivers with the least habitat alteration, compared to the rest of the upper estuary. (Feyrer et al. 2007, DOI 1, p.34.)

The amount of habitat available to delta smelt is controlled by freshwater flow and how that flow affects the position of X2, geographically, in the estuary (Figure 15). (Feyrer et al. in review.) Through the use of a 3D hydrodynamic model, Kimmerer et al. (2009) showed that the extent of delta smelt habitat, as defined by salinity, increases as X2 moves seaward. When X2 is located downstream of the confluence of the Sacramento and San Joaquin rivers, suitable abiotic habitat extends into Suisun and Grizzly bays, resulting in a large increase in the total area of suitable abiotic habitat. (Feyrer et al. in review.) The average position of X2 during fall has moved upstream, resulting in a corresponding reduction in the amount and location of suitable abiotic habitat. (Feyrer et al. 2007; Feyrer et al. in review.)

Average Net Delta Outflow for September, October, and November are presented in Figure 16, Figure 17, and Figure 18. Historically, unimpaired flows in fall were independent of water year type. Interestingly, actual outflow was greater than unimpaired flow between 1956 and 1987. However, fall outflows have fallen since then and since 2000 are almost always less than unimpaired flow. This is consistent with the observations of Feyrer et al. (2007) that fall X2 has moved upstream and this has reduced the amount of available habitat for smelt in fall.

Fall conditions may be very important for delta smelt, since this period of time coincides with the pre-spawning period for adult delta smelt. (Feyrer et al. 2007.) In general, reductions in habitat constrict the range of these fishes, which combined with an altered food web, may affect their health and survival. (Feyrer et al. 2007.) There is a statistically significant stock-recruitment relationship for delta smelt in which pre-adult abundance measured by the FMWT positively affects the abundance of juveniles the following year in the Summer Townet survey. (Bennett 2005; Feyrer et al. 2007, as cited in USFWS 2008.) Incorporating the combined effects of specific conductance and Secchi depth improved the stock-recruitment relationship. (Feyrer et al. 2007.)

Feyrer et al. (In Review) demonstrated that delta smelt are more abundant when a large amount of habitat is available. However, the relationship between habitat area and FMWT abundance is complex and not strong. (NAS 2010.) When the area of highly suitable habitat is low, either high or low FMWT indices can occur (Figure 15). Therefore, delta smelt can be successful in instances where habitat is limited. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. (Feyrer et al. in review; NAS 2010.) This potentially suggests that while reduced habitat area may be an important factor associated with the worst population collapses, it is not likely the only cause of the collapse. (NAS 2010.)

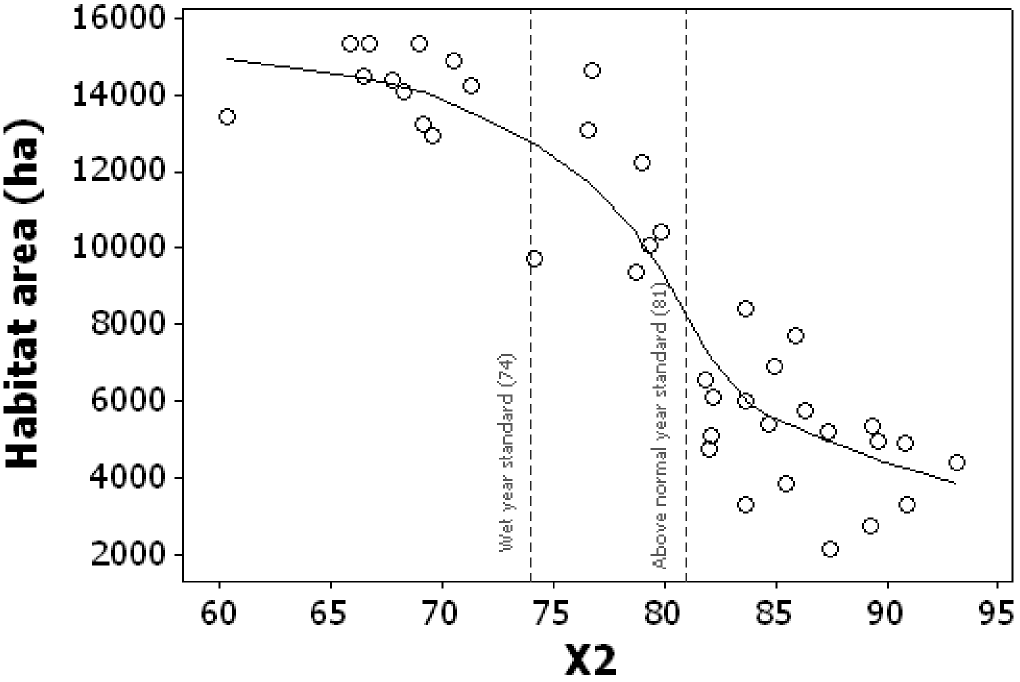
The fall X2 action described in the USFWS Opinion is focused on wet and above normal years because these are the years in which project operations have most significantly affected fall outflows. Actions in these years are more likely to benefit delta smelt. (USFWS 2008.) The action calls for maintaining X2 in the fall of wet years and above-normal years at 74 km and 81 km, respectively. (Figures 14, 15, and 16; USFWS 2008.) In addition to increasing the quality and quantity of habitat for delta smelt, moving X2 westward in the fall may also reduce the risk of entrainment by increasing the geographic and hydrologic distance of delta smelt from the influence of the Project export facilities. (DOI 1, p. 34.)

The NAS (2010) commented on this action in their review of the USFWS Opinion and concluded:

> “The X2 action is conceptually sound in that to the degree that habitat for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance), with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions (memorandum from USFWS and NMFS, January 15, 2010). As a result, how specific X2

> targets were chosen and their likely beneficial effects need further clarification."

The State Water Board determines that inclusion of the delta smelt fall X2 action as a Category B flow criterion, consistent with requirements stipulated in the USFWS Opinion will likely improve habitat conditions for delta smelt. However, in light of the uncertainty about specific X2 targets and the overall effectiveness of the fall X2 action, the State Water Board recommends this action be implemented within the context of an adaptive management program. The program should include studies designed to clarify the mechanisms underlying the effects of fall habitat on the delta smelt populations, the establishment and peer review of performance measures and performance evaluation related to the action, and a comprehensive review of the outcomes of the action and effectiveness of the adaptive management program. (USFWS 2008.) Absent study results demonstrating the importance of fall X2 to the survival of delta smelt, fall flows beyond those stipulated in the fall X2 action for the protection of delta smelt are not recommended at this time.



Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years. (Source: USFWS 2008, Figure B17).

Figure 15. X2 Versus Habitat Area for Delta Smelt During Fall

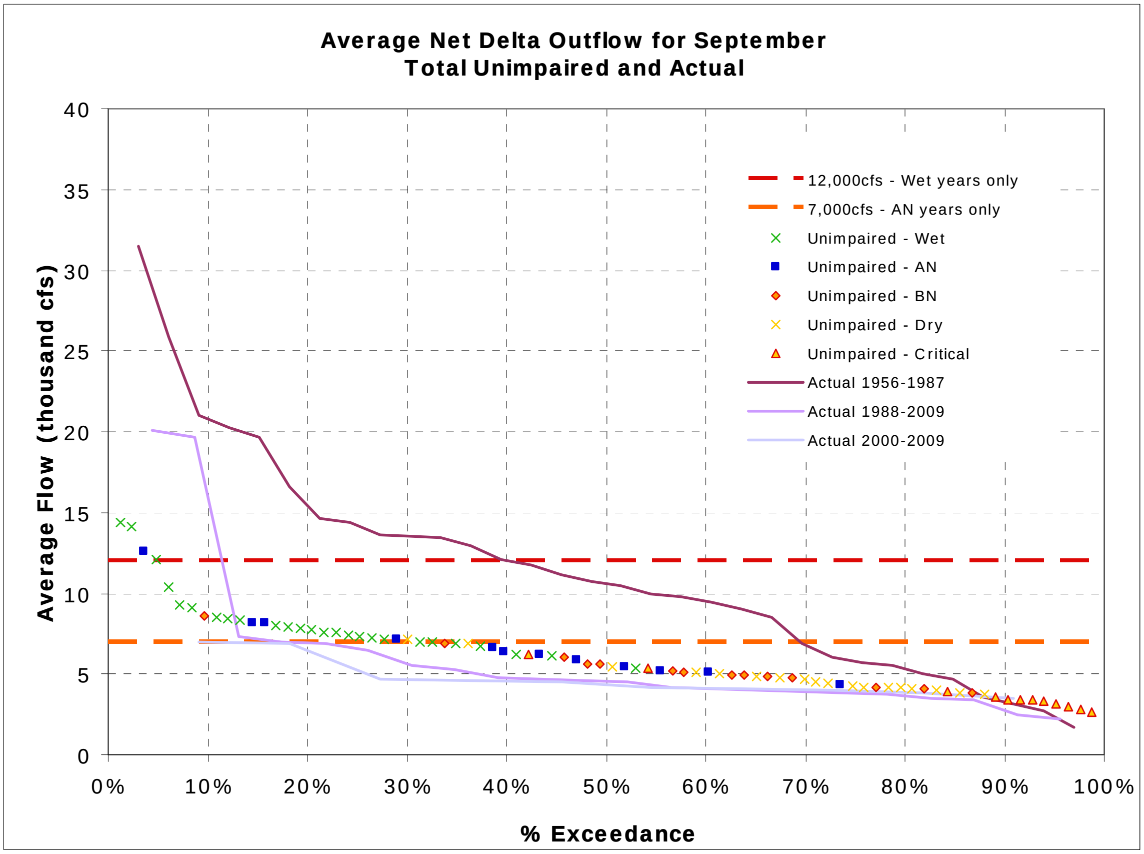


Figure 16. Net Delta Outflow Flow Exceedance Plot - September

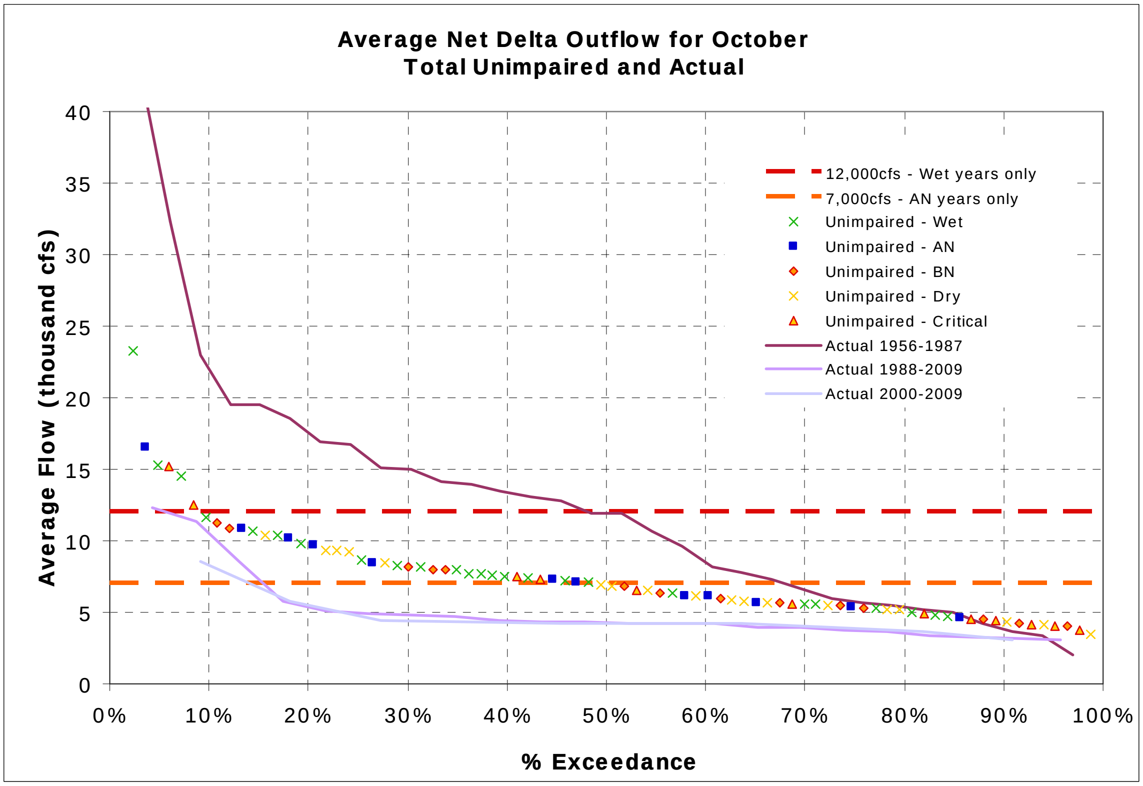


Figure 17. Net Delta Outflow Flow Exceedance Plot - October

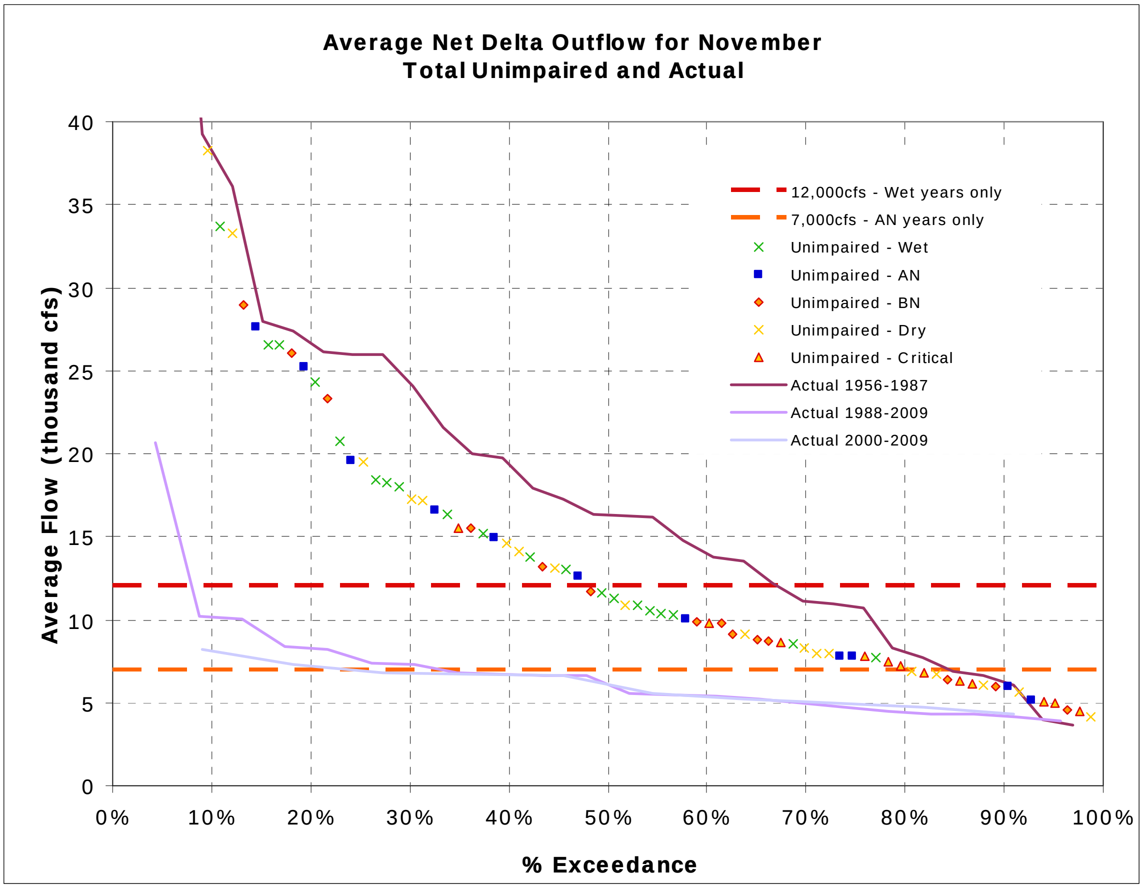


Figure 18. Net Delta Outflow Flow Exceedance Plot - November

The specific Delta outflow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows on tributaries to the Delta. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of all of the sensitive species in the Delta Watershed. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

<u>Category B: 2006 Bay-Delta Plan</u> <u>Summer – Fall Delta Outflow</u>
Resident estuarine species, such as delta smelt, require flows sufficient to provide adequate habitat throughout the year. Delta outflow criteria for January through June are discussed above. In addition to providing flows to support resident species, sufficient flows must also be provided in the fall to provide attraction cues and a homing mechanism for returning adult salmon. Criteria for fall salmon attraction flows on the Sacramento and San Joaquin rivers are discussed in Sections 5.2 and 5.3. The 2006 Bay-Delta Plan contains summer – fall Delta outflow water quality objectives for fish and wildlife beneficial uses, which are summarized below in Table 19.

Table 19. 2006 Bay-Delta Plan Delta Outflow Objectives for July through December

Water Year	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Critical	4000	3000	3000	3000	3500	3500
Dry	5000	3500	3000	4000	4500	4500
Below Normal	6500	4000	3000	4000	4500	4500
Above Normal	8000	4000	3000	4000	4500	4500
Wet	8000	4000	3000	4000	4500	4500

Multiple participants submitted testimony concerning the need for additional flows in the fall to benefit delta smelt, striped bass, and other resident species (CSPA 1, p. 7; CWIN 2, p. 29; DOI 1, pp. 46-48; EDF 1, pp. 49-50; TBI/NRDC 2, pp. 27-37), and as a means to potentially control the spread of harmful invasive species (e.g., *Corbula* and toxic algae). (TBI/NRDC 2, pp. 27-37.) The recommendations were based largely on recent research conducted by Feyrer *et al*. (2007 and In Review) and the fall X2 action in the USFWS's Opinion. The Fall X2 action in the USFWS Opinion requires that sufficient outflow be provided in September through November of Above Normal and Wet water year types to position X2 at 81 km and 74 km, respectively. This action was restricted to Above Normal and Wet years because these are the years in which project operations have most significantly affected fall outflows and to limit potential conflicts with cold water pool storage. (USFWS 2008.)

Following its review of the USFWS Opinion, the NAS (2010) noted that:

> "[a]lthough there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand… The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful… the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification."

The USFWS Opinion also recognized uncertainty concerning the position of fall X2 and subsequent abundance of delta smelt and requires that the action be implemented with an adaptive management program to provide for learning and improvement of the action over time.

However, some participants provided flow recommendations that called for increased fall outflows during all water year types, as compared to the objectives in the 2006 Bay-Delta Plan, and in certain instances in excess of those required by the USFWS Opinion. Given the need for improved understanding concerning the fall X2 criterion, including the mechanisms underlying the effects of fall habitat on delta smelt populations, determination of specific X2 targets, potential conflicts with cold water pool storage, and the likely effectiveness of the action, the State Water Board is not advancing criteria for increased fall flows in Critical, Dry, and Below Normal water year types beyond those required in the 2006 Bay-Delta Plan and in Above Normal and Wet water year types beyond those stipulated in the fall X2 action (Category B). The quantity and timing of fall outflows necessary to protect public trust resources warrants further evaluation and underscores the need for a well-designed adaptive management program. The potential to use variability in flows during summer and fall months as a means of controlling the distribution and abundance of invasive species should also be evaluated.

5.2 Sacramento River

Following are the Sacramento River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from April through June to increases juvenile salmon outmigration survival for fall-run Chinook salmon
2) Sacramento River Flow at Rio Vista: 75 percent of 14-day average unimpaired flow from November through March to increases juvenile salmon outmigration survival for other runs of Chinook salmon
3) Sacramento River at Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coincident with fall/early winter storm events; the timing, magnitude, duration, and number of pulses should be determined on an adaptive management basis informed by unimpaired flow conditions and monitoring of juvenile salmon migration to promote juvenile salmon emigration
4) Sacramento River Flow at Freeport: Provide flows of 13,000 to 17,000 cfs in the Sacramento River downstream of confluence with Georgiana Slough when salmon are migrating through the Delta from November through June to increase juvenile salmon outmigration survival by reducing straying into Georgiana Slough and the central Delta
5) Sacramento River at Rio Vista: 2006 Bay-Delta Plan flow objectives for September and October to provide Fall adult Chinook salmon attraction flows

The magnitude, duration, timing, and source of Sacramento River inflows are important to all runs of Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the Sacramento River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the Sacramento River and its tributaries, and other functions. Sacramento River inflows are important throughout the year to support various life stages of the different Chinook salmon runs inhabiting the Sacramento River. However, given the focus of this proceeding on inflows to the Delta and the importance of the juvenile salmon emigration period, the Sacramento River inflow criteria included in this report focus primarily on flows needed to support emigrating juvenile Chinook salmon from natal streams through the Delta. Following is a brief summary of the Sacramento River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon. Less information is available for the other runs of Chinook salmon on the Sacramento River. However, outmigration flows needed to protect other races are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs with some exceptions. In addition, analyses indicate that providing pulse flows of 20,000 cfs at Wilkins Slough on the Sacramento River beginning in November and extending through the first of the year provides for earlier migration timing and increased survival of juvenile winter, spring, and late-fall run Chinook salmon. In addition, information indicates that flows of 13,000 cfs to 17,000 cfs may be needed on the Sacramento River at Freeport to prevent salmon from migrating through Georgiana Slough and the interior Delta where survival is substantially lower.

Continuity of flows from natal stream through the Delta and flow variability are also important so rather than static April through June threshold flows of 20,000 to 30,000 cfs, the State Water Board determines, as a Category A criterion, that 75% of unimpaired flow is needed to achieve a threshold flow of 25,000 cfs (average of 20,000 and 30,000 cfs) approximately 50% of the time. The same percentage of unimpaired flow for the November through March period is also advanced as a Category B criterion due to the lack of information upon which this criterion was based. In addition, as Category B criteria, the State Water Board determines that shorter pulse flows of 20,000 cfs for 7 days at Wilkins Slough are needed starting in November and extending through the first of the year and flows of 13,000 cfs to 17,000 cfs at Freeport are needed from November through June to provide additional protection for Sacramento River Chinook salmon. The State Water Board also advances the Sacramento River flow objectives from the Bay-Delta Plan during September and October to provide a minimal level of protection during these months pending development of additional information concerning flow needs during this period. All of the Sacramento River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other Sacramento River flow needs.

Sacramento River Inflow as a Percentage of Unimpaired Flows

It appears to be important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted over time. Information indicates that Chinook salmon respond to variations in flows and need some continuity of flow between natal streams and the Delta for transport and homing fidelity. As such, the historic practice of developing monthly flow criteria to be met from limited sources may be less than optimal for protecting Chinook salmon runs. At the same time, given the impediments to fish passage into historic spawning and rearing areas, there may also be a need to diverge from the natural hydrograph at certain times of year to provide more flow than might have naturally occurred or less flow such that those flows are available at other times of year to mitigate for passage and habitat issues (e.g. cold water pool management).

Based on the above, the State Water Board developed Sacramento River inflow criteria, intended to mimic the natural hydrograph during the peak emigration period, to protect emigrating juvenile Chinook salmon. While emigration of some runs may occur outside of this period, peak emigration is generally believed to occur between November through June. As such, the criteria are recommended to apply to this time period. To achieve the attributes of a natural hydrograph, the criteria are recommended as a percentage of unimpaired flow on a 14-day average, to be provided generally on a proportional basis from the tributaries to the Sacramento River. The 14-day average is intended to better capture the peaks of actual flows compared to a 30-day average time-step, while still allowing for a time-step at which facilities can be operated. The appropriateness of this time-step for protecting public trust resources should be further evaluated.

Spring Sacramento River Inflows at Rio Vista

The species-specific flow needs analyses for salmon in section 4.2.3 indicates that average April through June flows of 20,000 to 30,000 cfs on the Sacramento River at Rio Vista provide for improved survival and abundance of juvenile fall-run Chinook salmon on the Sacramento River.

Flow exceedance graphs were used to determine the percentage of flow needed to achieve various flows needed to protect Chinook salmon. Analysis of unimpaired flows at Freeport (Figure 19) shows that under historic unimpaired conditions, average April through June flows of 30,000 cfs or more would occur in approximately 60% of years. Flows of 25,000 cfs or more would occur is approximately 72% of years, and flows of 20,000 cfs or more would occur in roughly 85% of years. At 75% of unimpaired flows, average flows of 30,000 cfs would be achieved between April and June in roughly 37% of years, flows of 25,000 cfs would be achieved in roughly 50% of years, and flows of 20,000 cfs would be achieved in approximately 70% of years. At 50% of unimpaired flows, flows of 30,000 cfs would be achieved in approximately 15% of years, flows of 25,000 cfs in roughly 25% of years, and flows of 20,000 cfs in roughly 35% of years. Actual flows of 30,000, 25,000, and 20,000 cfs were met in 26, 32, and 39% of years, respectively between 1986 and 2005. It is important to note, however, that unimpaired flows between 1986 through 2005 are not necessarily representative of the longer term unimpaired flow record. Flow criteria equal to 75% of unimpaired flows during the April through June period, on average, would therefore provide favorable conditions for fall-run juvenile Chinook salmon in at least 50% of years (assuming 25,000 cfs flows). As a result, the State Water Board advances 75% of unimpaired flows on a 14-day average from April through June as a potential means to achieve the 20,000 to 30,000 cfs Sacramento River flow threshold discussed above while maintaining variability and the attributes of the natural hydrograph. This criterion is included as criterion 1) for Sacramento River flows and is a Category A criterion.

The unimpaired estimates from which the 75% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but are expected to generate an exceedance curve similar to one generated with monthly estimates. This specific percent of unimpaired flow and the averaging period should be adaptively managed. More information and analyses should be conducted to determine if there are maximum flows above which no, or significantly diminishing, additional biological or geomorphological benefits are obtained. This criterion would allow for flows to vary over time coincident with precipitation events reflecting the natural hydrograph. Climate change, however, and its associated effect on flow patterns will likely change how effective such flows are in protecting Chinook salmon. As such, these flow criteria would need to be adaptively managed in the future to ensure the protection of Chinook salmon.

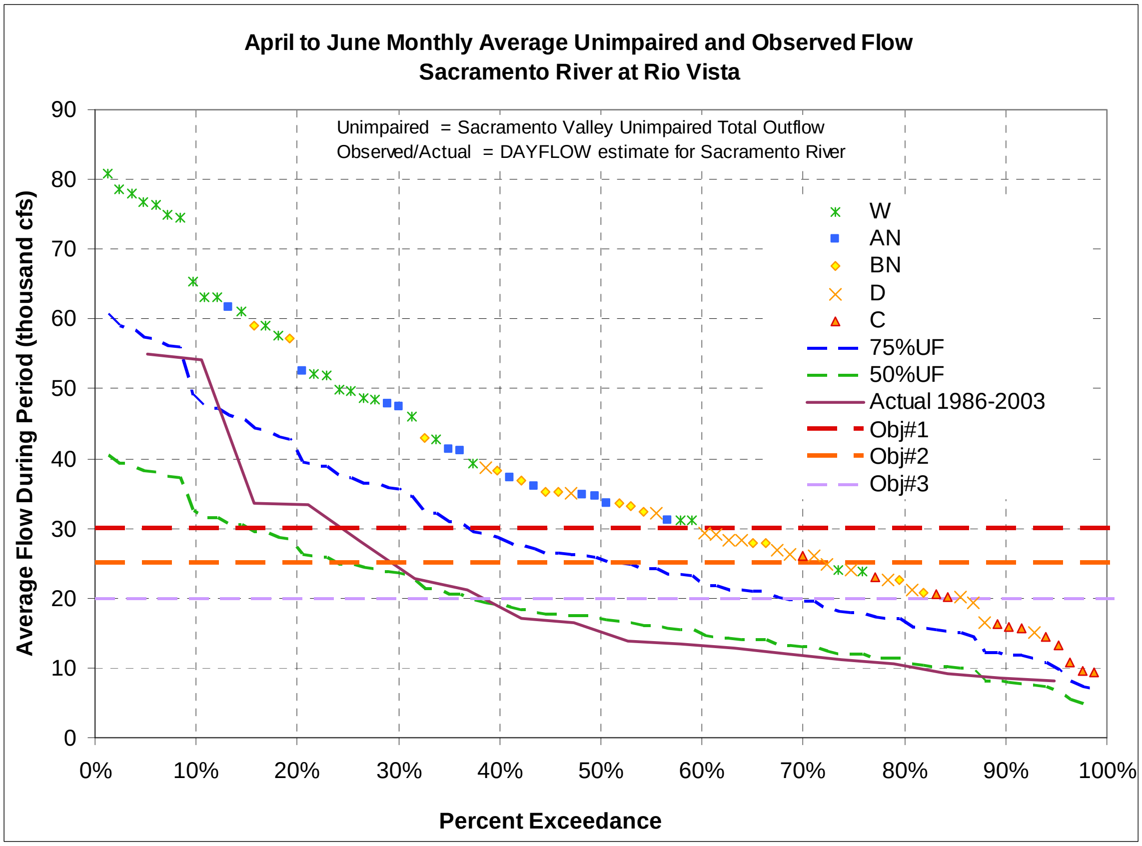


Figure 19. Sacramento River Flow Exceedance Plot - April through June

Fall and Winter Sacramento River Inflows at Rio Vista

Available data and analysis focus primarily on juvenile fall-run Chinook salmon outmigration. Outmigration flows to protect other races and life stages are assumed to be generally the same since factors that affect fall-run survival are generally applicable to other runs, with some exceptions including temperature, which may not be a concern in the winter months. (USFWS 1992, p. 8.) In the absence of sufficient data and analyses regarding flows needed for other Chinook salmon runs, however, the State Water Board advances 75% of unimpaired flows between November and March as an initial criterion from which future analysis and adaptive management could proceed. There is, however, no specific information that indicates that 75% is the correct percent of unimpaired flow. Additional quantitative analyses should be conducted to determine the specific flow needs of winter, spring, and late-fall run Chinook salmon.

Sacramento River Flow at Freeport

Analyses show that Chinook salmon survival is significantly lower for fish migrating through Georgiana Slough. Reverse flows in the vicinity of Georgiana Slough increase the occurrence of salmon migrating through Georgiana Slough. The available data show that flows of 13,000 to 17,000 cfs on the Sacramento River at Freeport provide adequate flow conditions to prevent reverse flows in Georgiana Slough. Flow criteria of 13,000 to 17,000 cfs on the Sacramento River at Freeport when salmon are migrating through the Delta during the November through June period is advanced as a Category B criterion. Additional analyses should be conducted to verify that flows of this magnitude are needed to achieve the desired outcome of significantly reducing straying of outmigrating juvenile Chinook salmon. These flows are also expected to benefit adult Chinook salmon returning to the Sacramento River basin to spawn during this period. However, additional analyses regarding the relationship of adult Chinook salmon and reverse flows in Georgiana Slough should also be conducted.

Sacramento River Flow at Wilkins Slough

Information discussed in the species-specific flow needs analyses for salmon in section 4.2.3 indicates that significant precipitation in the Sacramento River in the fall facilitates emigration of juvenile Chinook salmon. When this flow is delayed, emigration of salmon is also delayed resulting in reduced survival to the Delta. The available data show that juvenile salmon require flows of 15,000 cfs to 20,000 cfs at Wilkins Slough by November continuing through the first of the year to facilitate emigration. These flows are needed to provide ecological continuity from natal streams to the Delta. Information supports a range of pulse flows of 15,000 cfs to 20,000 cfs at Wilkins Slough to be provided coincident with fall and early winter storm events. This range should be adaptively managed and further evaluated. Absent additional information, flows of 20,000 cfs for seven days are advanced. Such an approach will retain the attributes of the natural hydrograph and provide for ecological continuity. The timing, magnitude, duration, and number of pulses should be determined through adaptive management, informed by unimpaired flow conditions and monitoring of juvenile salmon migration. Additional analyses should be conducted regarding this flow relationship to refine these criteria and inform adaptive management.

Sacramento River at Rio Vista: 2006 Bay-Delta Plan Objectives

The above criteria cover flows on the Sacramento River from the November through June time period. In addition, the Bay-Delta Plan provides minimum flows from September through December. Aside from what is discussed above, there was no new information submitted in the record for this proceeding on fall flows and the Sacramento River fall flow objectives were not specifically reviewed. In the absence of any new information, the State Water Board advances the 2006 Bay Delta Plan Sacramento River inflow objectives for September and October as a Category B criterion. Given that Chinook salmon may also be present in the Sacramento River during July and August, it is likely warranted that some minimal flows be provided during those months as well. However, adequate information on which to base such flows was not readily available for this proceeding. Further, adequate minimal flows during this time period may be provided by temperature and other requirements and reservoir releases for power production and export operations.

The specific Sacramento River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the Sacramento River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of the various runs of Chinook salmon and other sensitive species in the Sacramento River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

5.3 San Joaquin River

Following are the San Joaquin River inflow criteria based on analysis of the species-specific flow criteria and other measures:

1) San Joaquin River at Vernalis: 60%of 14-day average unimpaired flow from February through June
2) San Joaquin River at Vernalis: 10 day minimum pulse of 3,600 cfs in late October
3) San Joaquin River at Vernalis: 2006 Bay-Delta Plan flow objective for October

San Joaquin River inflow criterion 1 and 2 are Category A criteria because they are supported by sufficiently robust scientific information. The 2006 Bay-Delta Plan San Joaquin River inflow objective for October is included as a Category B criterion because it is not clear that eliminating this criterion in lieu of criteria 2 would provide adequate protection to migrating adult Chinook salmon. Following is discussion and rationale for these criteria. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criterion. Following is discussion and rationale for these criteria.

As discussed in the Sacramento River inflow section, the magnitude, duration, timing, and source of San Joaquin River inflows are important to Chinook salmon migrating through the Bay-Delta and several different aspects of their life history. Inflows are needed to provide appropriate conditions to cue upstream adult migration to the San Joaquin River and its tributaries, adult holding, egg incubation, juvenile rearing, emigration from the San Joaquin River and its tributaries, and other functions. San Joaquin River inflows are important for much of the year to support various life stages of San Joaquin basin fall-run Chinook salmon (and spring-run when they are reintroduced). However, given the focus of this proceeding on inflows to the Delta and the lack of information received concerning spring-run flow needs on the San Joaquin River, the San Joaquin River inflow criteria included in this report focus on flows needed to support migrating fall-run Chinook salmon from and to natal streams through the Delta. Following is a brief summary of the San Joaquin River inflow criteria that were developed based on the species-specific flow needs analyses for salmon included in section 4.2.3 followed by a detailed discussion.

Available scientific information indicates that average March through June flows of 5,000 cfs on the San Joaquin River at Vernalis represent a flow threshold at which survival of juveniles and subsequent adult abundance is substantially improved for fall-run Chinook salmon and that average flows of 10,000 cfs during this period may provide conditions necessary to achieve doubling of San Joaquin basin fall-run. Both the AFRP and DFG flow recommendations to achieve doubling also seem to support these general levels of flow, though the time periods are somewhat different (AFRP is for February through May and DFG is for March 15 through June 15). Available information also indicates that flows of 3,000 to 3,600 cfs for 10 to 14 days are needed during mid to late October to reduce straying, improve olfactory homing fidelity, and improve gamete viability for San Joaquin basin returning adult Chinook salmon.

Continuity of flows from natal stream through the Delta and flow variability are also important, so rather than advancing static flow criteria for the spring period to support emigration of juvenile San Joaquin basin fall-run Chinook salmon, the State Water Board determines, as a Category A criterion, that 60% of unimpaired flow from February through June is needed in order to achieve a threshold flow of 5,000 cfs or more in most years (over 85% of years) and flows of 10,000 cfs slightly less than half of the time (45% of years). Given that the focus of this proceeding is on protection of public trust resources, the State Water Board determines that the time period for these flows should be extended to cover all three periods supported by the DFG, AFRP, and TBI/NRDC analyses concerning flow needs. In addition, the State Water Board determines, as a Category A criterion, that flows of 3,600 cfs are needed for 10 days in late October. These flows could also be provided in a manner that better reflects the natural hydrograph to coincide with natural storm events. Until additional information is developed, maintaining the October pulse flow called for in the 2006 Bay-Delta Plan is also determined to be a Category B criterion to assure that the existing protection provided during this period is not diminished. All of the San Joaquin River flow criteria are not precise; rather they reflect the general timing and magnitude of flows needed to protect public trust resources, but could serve as a reasonable basis from which future analysis and adaptive management could proceed. The criteria also do not consider other San Joaquin River flow needs.

San Joaquin River Inflows as a Percentage of Unimpaired Flow During the Spring

As discussed in the Sacramento River inflow section, it is important to preserve the general attributes of the natural hydrograph to which the various salmon runs adapted to over time, including variations in flows and continuity of flows. Accordingly, as with the Sacramento River flow criteria, the State Water Board developed flow criteria for San Joaquin River inflows to protect emigrating juvenile Chinook salmon intended to mimic the natural hydrograph during the peak emigration period of February through June. This period may also cover a portion of the rearing period for juveniles as well. As with the Sacramento River flow criteria, to achieve the attributes of a natural hydrograph, the criteria are advanced as a percentage of unimpaired flow on a 14-day average, to be achieved on a proportional basis from the tributaries to the San Joaquin River. The unimpaired estimates from which the 60% criterion is calculated are monthly estimates. Estimates of 14-day unimpaired flow have not been published, but the exceedance curve is likely similar to one generated with monthly estimates. The appropriateness of this time-step and the percentage of unimpaired flows should be further evaluated.

To determine the percentage of unimpaired flow needed to protect Chinook salmon, the State Water Board reviewed flow exceedance information to determine what percentage of flow would be needed to achieve various flows. The analysis in section 4.2.3 indicates that increasing spring flows on the San Joaquin River and its tributaries is needed to protect Chinook salmon in the San Joaquin River basin. The TBI/NRDC analyses of temperatures and population growth indicate that there is a threshold response for fall-run Chinook salmon survival to flows above 5,000 cfs during the spring period and that average flows of 10,000 cfs during this same period may provide adequate flows to achieve doubling. Both the AFRP and DFG modeling analyses also seem to support these flows. However, the time periods for the AFRP recommended flows is from February through May and the time period for the DFG recommended flows is from March 15 through June 15. AFRP, DFG, and TBI/NRDC provide different recommendations for how to distribute flows during the spring period in different years, with increasing flows in increasingly wet years. All are generally consistent with an approach that mimics the natural flow regime to which these fish were adapted. Other analyses speak to the validity of this approach. (Propst and Gido, 2004 and Marchetti and Moyle, 2001, as cited in DOI 1, p. 25.) San Joaquin River flow criteria for the

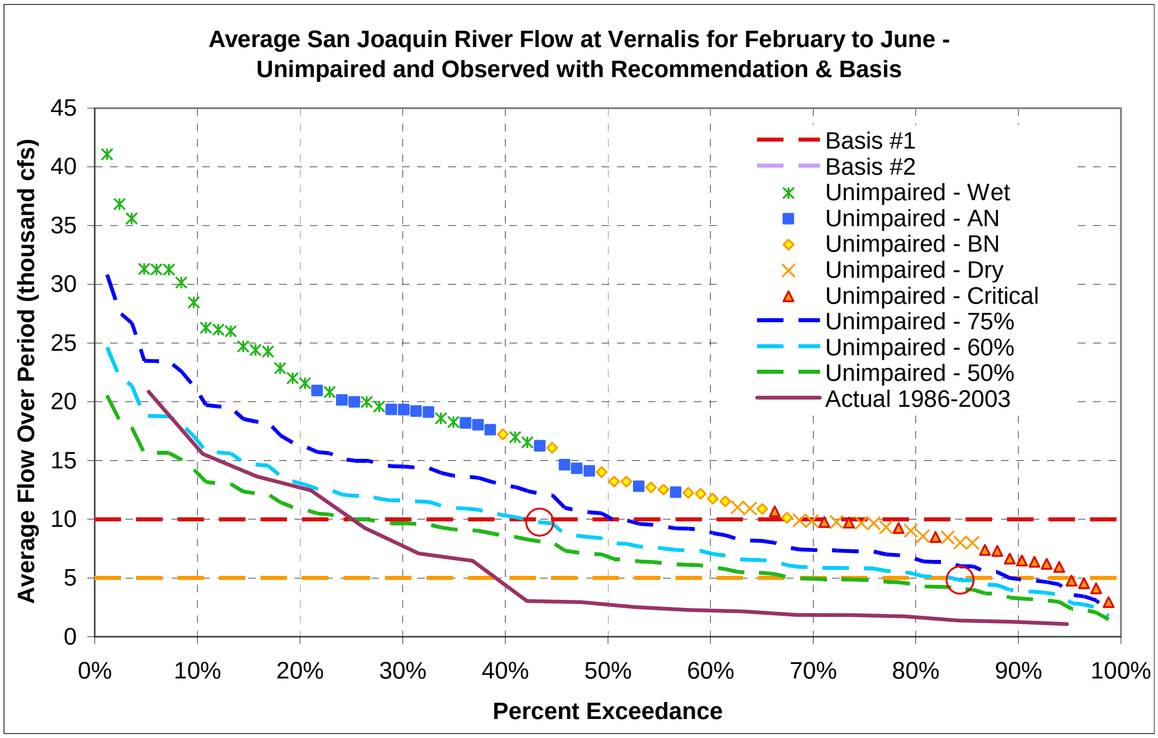
February through June period are determined to be 60% of unimpaired flows. Figure 20b shows that if 60% of unimpaired San Joaquin River flow at Vernalis were provided, average March through June flows would meet or exceed 5,000 cfs in over 85% of years (shown by red circle). An unimpaired flow of 60% during this period would also meet or exceed 10,000 cfs during the March through June time period in approximately 45% of years. The exceedance rates are not significantly different if applied to the February through June period as shown in Figure 20a. Additional information should be developed to determine whether these flows could be lower or higher and still meet the Chinook salmon doubling goal in the long term.

San Joaquin River Fall Flows

In addition to spring flows, fall pulse flows on the San Joaquin River are needed to provide adequate temperature and DO conditions for adult salmon upstream migration, to reduce straying, improve gamete viability, and improve olfactory homing fidelity for San Joaquin basin salmon. Analyses support a range of flows from 3,000 to 3,600 cfs for 10 to 14 days during mid to late October. Absent additional information, the State Water Board determines flow criteria for late fall to be 3,600 cfs for a minimum of 10 days in mid to late October. Providing these flows from the tributaries to the San Joaquin River that support fall-run Chinook salmon appears to be a critical factor to achieve homing fidelity and continuity of flows from the tributaries to the mainstem and Delta. Until additional information is developed regarding the need to maintain the 2006 Bay-Delta Plan October flow objective, these flows supplement and do not replace the 2006 Bay-Delta Plan October flow requirements such that flows do not drop below historic conditions during the remainder of October when the pulse flow criteria would not apply. Additional analyses should be conducted to determine the need to expand the pulse flow time period and modify the criteria to better mimic the natural hydrograph by coinciding pulse flows with natural storm events in order to potentially improve protection by mimicking the natural hydrograph.

Given that salmon and steelhead may be present in the San Joaquin River and its tributaries for all or most of the year (including spring-run in the future) and that the Bay-Delta plan does not currently include any flow requirements from July through September and November through January, additional flow criteria for the remainder of the year may be needed to protect Chinook salmon and their habitat. Specifically, additional criteria for spawning, egg incubation, rearing and riparian vegetation recruitment may be needed. However, adequate information is not available in the record for this proceeding upon which to base such criteria at this time. Additional information, building on the AFRP and other analyses, should be developed to determine needed flows for the remainder of the year.

a)



b)

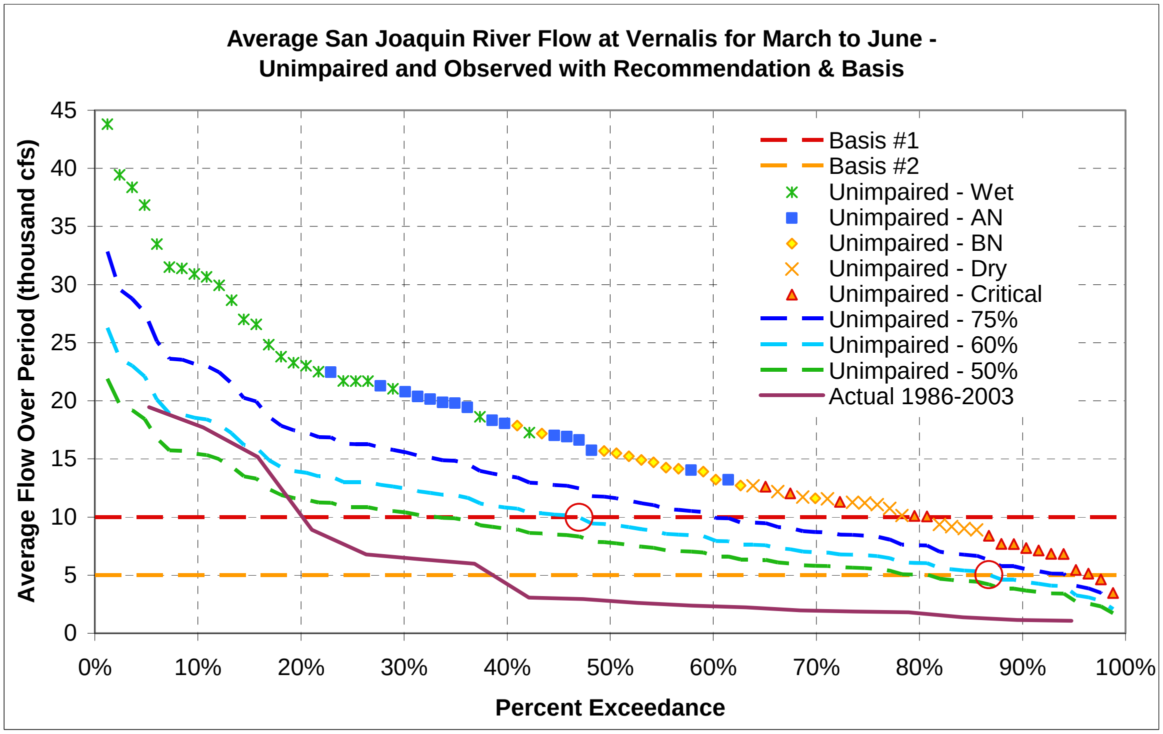


Figure 20. San Joaquin River Flow Exceedance Plot - February through June

The specific San Joaquin River flow criteria may need to be tempered by the need to maintain water in reservoirs to provide adequate cold water and tributary specific flows in the San Joaquin River basin. It may not be possible to attain both the flow criteria and meet the thermal and tributary specific flow needs of steelhead, fall-run Chinook salmon, and other sensitive species in the San Joaquin River basin. Water supply modeling and temperature analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

5.4 Hydrodynamics

The following hydrodynamic related criteria have been developed based on analysis of the species-specific flow criteria and other measures discussed above:

1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports great than .33 during the 10 day San Joaquin River pulse flow in October
2) Old and Middle River Flows: greater than -1,500 cfs in March and June of Critical and Dry water years
3) Old and Middle River Flows: greater than 0 or -1,500 cfs in April and May of Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively
4) Old and Middle River Flows: greater than -5,000 cfs from December through February in all water year types
5) Old and Middle River Flows: greater than -2,500 when salmon smolts are determined to be present in the Delta from November through June
6) San Joaquin River Flow to export Ratio: Vernalis flow to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in the mainstem San Joaquin River from March through June
7) San Joaquin River at Jersey Point Flows: Positive flows when salmon are present in the Delta from November through June
8) 2006 Bay-Delta Plan Exports to Delta Inflow Limits for the Entire Year

Hydrodynamic criteria 1 is a Category A criterion because it is supported by more robust scientific information. Hydrodynamic criteria 2-7 are Category B criteria because there is less scientific information, with more uncertainty, to support the specific numeric criteria. The 2006 Bay-Delta Plan exports to Delta inflow objective (criteria 8) is offered as a Category B criterion as a minimal level of protection when the other criteria above do not apply. However, the validity of the specific export restrictions included in the 2006 Bay-Delta Plan were not specifically reevaluated. Category A and B criteria are both equally important for protection of the public trust resource, but there is more uncertainty about the appropriate volume of flow required to achieve the goals of the Category B criteria. Following is discussion and rationale for these criteria.

Pelagic Species Criteria

Net OMR reverse flows have increased in both magnitude and frequency with the development of the California water projects (Figure 8) and are having a detrimental effect on biotic resources in the Delta. (Brown et al. 1996.) It is also clear that the negative impact of net OMR reverse flows increases as Sacramento River inflows and net Delta outflow decreases. (Grimaldo et al. 2009; Kimmerer 2008; USFWS 2008; NMFS, 2009.) Net OMR flow restrictions for the protection of longfin and Delta smelt are only recommended for dry and critically dry water years when less Delta outflow may be available (Table 23, criteria 2 and 3). No spring restrictions for the protection of longfin and delta smelt are proposed for other water year types if the higher net Delta outflow criteria are met. If higher outflows are not provided in wetter years, then restrictions on OMR may be needed in these years as well. The State Water Board determines that net OMR flow criteria of greater than -5,000 cfs, from December through February in all water year types, to protect upstream migrating adult smelt are needed. The -5,000 cfs criterion may need to be made more protective if a large portion of the smelt population moves into the central Delta. The additional restrictions would be recommended after consultation with the USFWS (2008) Smelt Working Group. Spring and winter net OMR flow criteria for the protection of longfin and Delta smelt are classified as Category B because, as noted by the NAS (2010),

> "… the data do not permit a confident identification of the threshold [OMR] values to use … and … do not permit a confident assessment of the benefits to the population… As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management and additional analyses that permit regular review and adjustment of strategies as knowledge improves…"

Chinook Salmon Criteria

Salmon must migrate through the Delta past the effects of the south Delta export facilities and the associated inhospitable conditions in the central Delta, first as juveniles on their way to the ocean, and later as adults returning to spawn. Exports change the hydrodynamic patterns in the Delta, drawing water across the Delta rather than allowing water to flow out of the Delta in a natural pattern. Over the years, different criteria have been developed to attempt to protect migrating salmon from the adverse hydrodynamic conditions caused by the south Delta export facilities in order to preserve the functional flows needed for migration that could be used to protect public trust resources. Net OMR flows, Jersey Point flows, and Vernalis flow to export ratios are all criteria that can be used to protect migrating salmon. The State Water Board advances a combination of these criteria to protect migrating salmon from export effects.

Increasingly negative net OMR flows have been shown to increase particle entrainment, particularly beginning at flows between -2,500 and -3,500 cfs. While juvenile salmon do not necessarily behave like particles, the particle entrainment estimates are a useful guide until additional information can be developed using evolving acoustic tracking methods and other appropriate techniques. Reduced negative net OMR flows should also provide some level of protection from the indirect reverse flow effects related to fish entering the central Delta where predation and other sources of mortality are higher. Based on the above, the State Water Board determines criteria for net OMR flows should be for greater than -2,500 cfs when salmon are present in the Delta during the peak juvenile outmigration period of November through June, for the protection of Chinook salmon. This is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time. Such information should be developed to better understand the relationship between salmon survival and net OMR flows to determine more specific criteria that would protect against entrainment and other factors leading to indirect mortality.

Increased reverse flows at Jersey Point have also been shown to decrease survival of salmon smolts migrating through the lower San Joaquin River. However, the precise Jersey Point flow that is necessary to protect migrating salmon is unclear. In addition, it is unclear whether the same functions of such a flow could be better met using different criteria such as net OMR flows or San Joaquin River flow to export ratios. The State Water Board therefore advances positive Jersey Point flows when salmon are present in the Delta during the peak juvenile salmon outmigration period of November through June. Again, this is a Category B criterion because there is limited information upon which to base a specific numeric criteria at this time.

Increased San Joaquin River flow to export ratios appear to improve survival for San Joaquin River salmon, though the exact ratio that is needed to protect public trust resources is not well understood. A San Joaquin River flow to export ratio of greater than 4.0 is recommended as a Category B criterion when San Joaquin River juvenile salmon are outmigrating from the San Joaquin River from March through June. There is, however, sufficient information in the record to support a Category A criterion for exports to be kept to less than 300% of San Joaquin River flows (equal to a San Joaquin River flow to export ratio of more than 0.33) at the same time that the recommended San Joaquin River pulse flows are provided. Additional analyses should be conducted to determine if this time frame should be extended to capture more of the San Joaquin River adult Chinook salmon return period between October and January.

The NAS review concerning OMR restrictions for salmon concluded that:

> "…the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2009) should be used to improve our understanding of smolt responses to OMR flow levels." (NAS 2010, p. 44.)

Much additional work is needed to better understand the magnitude and timing of the recommended criteria and how net OMR flow criteria should be integrated with other criteria for San Joaquin River flows, San Joaquin River flows to export ratios, Sacramento River flows, and net OMR flow restrictions for the protection of pelagic species. For all of the OMR, Jersey Point, and Vernalis flows to export ratiocriteria, further analysis and consideration is needed to determine: 1) how salmon presence should be measured and the information used to temper the criteria; 2) an appropriate averaging period; and 3) how to adaptively manage to assure that flows are sufficiently, but not overly, protective.

The October San Joaquin River flow to export ratio criteria is a Category A criterion since the basis for this minimum criterion is sufficiently understood to develop a quantitative criteria. Additional analyses should still, however, be conducted to determine if this criteria could be refined to provide better protection for migrating adult San Joaquin River Chinook salmon. All of the other hydrodynamic criteria for the protection of Chinook salmon are Category B criteria.

The San Joaquin River flow to export criterion during the spring is also a Category B criterion due to a lack of certainty regarding the needed protection level. Regarding this issue, the NAS concluded that:

> "…the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the 6-year steelhead smolt survival study (action IV.2.2) could provide useful insight

> as to the actual effectiveness of the proposed flow management actions as a long-term solution.” (NAS 2010, p. 45.)

In addition, based on similar uncertainty regarding needed protection levels and interaction between net OMR flows and San Joaquin River flows to export ratios, the San Joaquin River at Jersey Point criterion is also a Category B criterion. More work is needed to develop a suite of operational tools and an operational strategy for applying those tools to protect public trust resources in the Delta from the adverse hydrodynamic effects of water diversions, channel configurations, reduced flows, and other effects.

2006 Bay-Delta Plan Export Objectives
The 2006 Bay-Delta Plan includes export limitations for the entire year. From February through June exports are limited to 35-45% of Delta inflow. (State Water Board 2006a, pp. 184-187.) From July through January, exports are limited to 65% of Delta inflow. (*Id.)* The export to Delta inflow restrictions are intended to protect the habitat of estuarine-dependent species. (State Water Board 2006b, pp. 46-47.) These export restrictions provide a minimum level of protection for public trust uses and should be maintained to the extent that the other recommended criteria do not override them.

For all of the hydrodynamic criteria, biologically appropriate averaging periods need to be developed. Averaging periods may need to include a two-step approach whereby a shorter averaging period is included that allows for some divergence from the criteria and a longer averaging period is included that does not.

5.5 Other Inflows - Eastside Rivers and Streams

The Cosumnes and Mokelumne rivers, and smaller streams such as the Calaveras River, Bear Creek, Dry Creek, Stockton Diversion Channel, French Camp Slough, Marsh Creek, and Morrison Creek are all tributary to the Delta. Flows should generally be provided from tributaries in proportion to their contribution to unimpaired flow.

5.6 Other Measures

5.6.1 Variability, Flow Paths, and the Hydrograph

Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified herein are expressed as a percentage of the unimpaired flow rather than as a single number or range of numbers that vary by water year type. Additional efforts should focus on restoring habitat complexity. Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow in order to assure connection between Delta flows and upstream tributaries, to the extent that such connections are beneficial to protecting public trust resources. Flows should be at levels that maintain flow paths and positive salinity gradients through the Delta. This concept is reflected in the specific determinations made above. More study is needed to determine to which tributaries such criteria should apply. For example, since the percent of unimpaired flow criteria determined to protect public trust uses for San Joaquin River inflows is at times lower than the criteria determined for Delta outflow, more study is needed to determine the appropriate source of such flows to protect public trust resources. All determined flow criteria must also be tempered by the need to protect health and safety. No flow criteria, for example, should be in excess of flows that would lead to flooding. For all of the flow criteria, there may be a need to reshape the specified flows to better protect public trust resources based on real-time considerations. All of the criteria should be implemented adaptively to allow for such appropriate reshaping to improve biological and geomorphological processes.

Moyle *et al* (2010) concluded, however, that there is a fundamental conflict between restoring variability and maintaining the current Delta:

> “restoring environmental variability in the Delta is fundamentally inconsistent with continuing to move large volumes of water through the Delta for export. The drinking and agricultural water quality requirements of through-Delta exports, and perhaps even some current in-Delta uses, are at odds with the water quality and variability needs of desirable Delta species.”

5.6.2 Floodplain Activation and Other Habitat Improvements

Activated floodplains stimulate food web activity and provide spawning and rearing habitat for floodplain adapted fish. The frequency of low-magnitude floods that occurred historically has been reduced, primarily by low water control levees. The record supports the conclusion that topography changes associated with future floodplain restoration will provide improved ecosystem function with less water. Studies and demonstration projects for, and implementation of, floodplain restoration projects should therefore proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta.

<u>Floodplain Flow Determinations for Protection of Salmon and Splittail</u>:
Floodplain and off-channel inundation are required for splittail spawning and appear to be important in protecting Chinook salmon. At the same time, it is also important how and when such inundation occurs. Due to the effects of levees and dams, natural side channel and floodplain inundating flows have been substantially reduced. As a result, modification to weirs and other changes may be needed to substantially improve floodplain inundation conditions on the Sacramento and San Joaquin rivers. Based on the above, the State Water Board determines that an effort be made to provide appropriate additional seasonal floodplain habitat for salmon, splittail, and other species in the Central Valley. The various recommendations the State Water Board received for floodplain inundation are included in Appendix A.1. The State Water Board has no specific flow determinations for floodplain inundation. The State Water Board recommends that BDCP, the Council, and others continue to explore the various issues concerning flood protection, weir modifications, and property rights related to floodplain inundation.

Other future habitat improvements will likely change the response of native fishes to flow and allow flow criteria to be modified. Habitat restoration should proceed to allow for the possible reduction of flows required to protect public trust resources in the Delta. Other future habitat restoration that should be reviewed and implemented include:

- Development of slough networks with natural channel geometry and less diked and rip-rapped channel habitat
- Increased tidal marsh habitat, including shallow (one to two meters) subtidal areas in both fresh and brackish zones of the estuary (in Suisun Marsh, for example)

- Create large expanses of low salinity open water habitat in the Delta

5.6.3 Water Quality and Contaminants

Any set of flow criteria should include the capacity to readily adjust the flows to adapt to changing future conditions and improved understanding. (DEFG 1.) As our understanding of the effect of contaminants on primary production and species composition in the Sacramento River and Delta improves, flow criteria may need to be revisited.

The Central Valley and San Francisco Regional Water Boards should continue developing Total Maximum Daily Loads (TMDLs) for all listed pollutants and adopting programs to implement control actions. Specifically, the Central Valley Regional Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients, including ammonia.

5.6.4 Coldwater Pool Resources and Instream Flow Needs on Tributaries

The flow criteria contained in this report should be tempered by the need to maintain cold water resources and meet tributary specific flow needs in the Delta watershed. It may not be possible to attain all of the identified flow criteria in all years and meet the tributary flow needs and thermal needs of the various runs of Chinook salmon, steelhead, and other sensitive species. Temperature and water supply modeling analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals. In addition, these flow determinations do not consider the needs of other non-fish species and terrestrial species which should be considered before any implementation of these criteria.

5.6.5 Adaptive Management

The numeric criteria are all short term criteria that are only appropriate for the current physical system and climate. There is uncertainty in these criteria even for the current physical system and climate, and therefore for the short term. Long term numeric criteria, beyond five years, for example, and assuming a modified physical system, are highly speculative. Only the underlying principles for the proposed numeric criteria and the other measures are advanced as long term determinations.

The information received in this proceeding suggests that the relationships between hydrology, hydrodynamics, water quality, and the abundance of desirable species are often unclear. In preparing for the long term, resources should be directed toward better understanding these relationships. In particular, there is significant uncertainty associated with Category B numeric criteria advcanced in this report. Category B criteria should therefore be high priority candidates for grant funded research.

A strong science program and a flexible management regime are critical to improving flow criteria. The relationship between flow, habitat, and abundance is not well enough understood to recommend flows in the Delta ecosystem without some reliance on adaptive management to better manage these flows. The State Water Board intends to work with the Council, the Delta Science Program, IEP, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of flows in the Delta. The State Water Board will consider supporting and incorporating into its regulations greater reliance upon adaptive management in its flow regulations.

5.7 Summary Determinations

Table 20 through Table 23 provide summary determinations for Delta outflows, Sacramento inflows, San Joaquin River inflows, and hydrodynamics, respectively. Each table shows various numbered criteria, applicable to the shaded range of months. Criteria fall into two categories. Category "A" criteria have more robust scientific information to support specific numeric criteria than do Category "B" criteria. Both categories of criteria are considered equally important for protection of public trust resources in the Delta ecosystem, and are supported by scientific information on function-based species or ecosystem needs. The basis and explanation for each criterion is provided. Each table is appended with the following notes to explain the limitations and constraints of how the criteria should be considered:

- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria have been determined or where Bay-Delta Plan flow objectives are advanced, but adequate information is not available at this time to determine such flows

These criteria are made specifically to achieve the stated goal of halting the population decline and increase populations of native species as well as species of commercial and recreational importance. Additionally, positive changes in the Delta ecosystem resulting from improved flow or flow patterns will benefit humans as well as fish and wildlife, especially when accompanied by large-scale habitat restoration and pollution reduction. (Moyle *et al*, 2010.)

In addition, Table 24 contains a summary of other issues and concepts that should be considered in conjunction with the numeric criteria. These other measures are also based on a synthesis of the best scientific information submitted by participants in the State Water Board's Informational Proceeding. These criteria and other measures, however, must be further qualified as to their limitations. The limitations of this and any other flow prescription are described at the end of the Fleenor *et al*. (2010) "flow prescriptions" report as a "further note of caution":

> "How much water do fish need?" has been a common refrain in Delta water management for many years… it is highly unlikely that any fixed or predetermined prescription will be a "silver bullet". The performance of native and desirable fish populations in the Delta requires much more than fresh water flows. Fish need enough water of appropriate quality over the temporal and spatial extent of habitats to which they adapted their life history strategies. Typically, this requires habitat having a particular range of physical characteristics, appropriate variability, adequate food supply and a diminished set of invasive species. While folks ask "How much water do fish need?" they might well also ask, "How much habitat of different types and locations, suitable water quality,

> improved food supply and fewer invasive species that is maintained by better governance institutions, competent implementation and directed research do fish need?" The answers to these questions are interdependent. We cannot know all of this now, perhaps ever, but we do know things that should help us move in a better direction, especially the urgency for being proactive. We do know that current policies have been disastrous for desirable fish. It took over a century to change the Delta's ecosystem to a less desirable state; it will take many decades to put it back together again with a different physical, biological, economic, and institutional environment."

The State Water Board concurs with this cautionary note and recommends the flow criteria and other conclusions advanced in this report be used to inform the planning efforts for the Delta Plan and BDCP and as a report that can be used to guide needed research by the Delta Science Program and other research institutions.

Table 20. Delta Outflow Summary Criteria

Delta Outflows

Category A

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
			▨	▨	▨	▨	▨	▨				1) Net Delta Outflows: 75% of 14-day average unimpaired flow

Category B

O	N	D	J	F	M	A	M	J	J	A	S	Criteria
▨	▨										▨	2) Fall X2 a. Wet years: X2 less than 74 km (greater than approximately 12,400 cfs) b. Above normal years: X2 less than 81 km (greater than approximately 7,100 cfs)
▨	▨								▨	▨	▨	3) Net Delta Outflows: 2006 Bay-Delta Plan Delta Outflow Objectives - applies during critical, dry, and below normal years

Basis for Criteria and Explanation

1) Promote increased abundance and improved productivity (positive population growth) for longfin smelt and other desirable estuarine species
2) Increase quantity and quality of habitat for delta smelt; fall X2 requirement limited to above normal and wet years to reduce potential conflicts with cold water pool storage, while promoting variability with respect to fall flows and habitat conditions in above normal and wet water year types; expected to result in improved conditions for delta smelt, however, the statistical relationship between fall X2 and abundance is not strong; note 2) above regarding need for improved understanding concerning the fall X2 action also applies
3) Fish and wildlife beneficial use protection

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 21. Sacramento River Inflow Summary Criteria

Sacramento River Inflows

Category A

Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
						▨	▨	▨				1) Rio Vista: 75% of 14-day average unimpaired flow[1]

Category B

Water Year												**Criteria**
O	N	D	J	F	M	A	M	J	J	A	S	
	▨	▨	▨	▨	▨							2) Rio Vista: 75% of 14-day average unimpaired flow to support same functions as #1 for other runs of Chinook salmon
	▨	▨	▨									3) Wilkins Slough: Provide pulse flows of 20,000 cfs for 7 days starting in November coinciding with storm events producing unimpaired flows at Wilkins Slough above 20,000 cfs until monitoring indicates that majority of smolts have moved downstream[2]
	▨	▨	▨	▨	▨	▨	▨	▨				4) Freeport: Positive flows in Sacramento River downstream of confluence with Georgiana Slough while juvenile salmon are present (approximately 13,000 to 17,000 cfs)
▨											▨	5) Rio Vista: 2006 Bay-Delta Plan flow objectives

Basis for Criteria and Explanation, and Notes

1) Increase juvenile salmon outmigration survival and abundance for fall-run Chinook salmon
2) Promote juvenile salmon emigration for other runs of Chinook salmon
3) Increase juvenile salmon outmigration survival by reducing diversion into Georgiana Slough and the central Delta
4) Increases juvenile salmon outmigration survival
5) Fall adult Chinook salmon attraction flows

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow critiera should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

[1] 75% of unimpaired flow at Freeport applied to Rio Vista

[2] Definition of storm, number of storms, and how to determine when the majority of juveniles have outmigrated needs to be determined.

Table 22. San Joaquin River Inflow Summary Criteria

San Joaquin River Inflows												
Category A												
Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
				▨	▨	▨	▨	▨				1) Vernalis: 60% of 14-day average unimpaired flow
▨												2) Vernalis: 10 day minimum pulse flow of 3,600 cfs in late October (e.g., October 15 to 26)
Category B												
Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
▨												3) Vernaisl: 2006 Bay-Delta Plan October flows
Basis for Criteria and Explanation, and Notes												

1) Increase juvenile Chinook salmon outmigration survival and abundance and provide conditions that will generally produce positive population growth in most years and achieve the doubling goal in more than half of years
2) Minimum adult Chinook salmon attraction flows to decrease straying, increase DO, reduce temperatures, and improve olfactory homing fidelity
3) Adult Chinook salmon attraction flows

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow criteria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 23. Hydrodynamics Summary Criteria

Hydrodynamics: Net OMR, Inflow-Export Ratios, and Jersey Point

Category A

Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
▨												1) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 0.33 during fall pulse flow (e.g., October 15 – 26); complementary action to San Joaquin River inflow critieria #2

Category B

Water Year												Criteria
O	N	D	J	F	M	A	M	J	J	A	S	
					▨			▨				2) Net OMR Flows: greater than -1,500 cfs in Critical and Dry water years
						▨	▨					3) Net OMR Flows: greater than 0 or -1,500 cfs in Critical and Dry water years, when FMWT index for longfin smelt is less than 500, or greater than 500, respectively
		▨	▨	▨								4) Net OMR Flows: greater than -5,000 cfs in all water year types
	▨	▨	▨	▨	▨	▨	▨	▨				5) Net OMR Flows: greater than -2,500 cfs when salmon smolts are determined to be present in the Delta
					▨	▨	▨	▨				6) San Joaquin River Flow to Export Ratio: Vernalis flows to exports greater than 4.0 when juvenile San Joaquin River salmon are migrating in mainstem San Joaquin River
	▨	▨	▨	▨	▨	▨	▨	▨				7) Jersey Point: Positive flows when salmon present in the Delta
▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	8) Exports to Delta Inflows: 2006 Bay-Delta Plan exports to inflows restrictions

Basis for Criteria and Explanation

1) Reduce straying and improve homing fidelity for San Joaquin basin adult salmon
2) Reduce entrainment of larval / juvenile delta smelt, longfin smelt, and provide benefits to other desirable species
3) Same as number 2), but if the previous FMWT index for longfin smelt is less than 500, then OMR must be greater than 0 (to reduce entrainment losses when abundance is low), or greater than -1,500 if the previous FMWT index for longfin smelt is greater than 500
4) Reduce entrainment of adult delta smelt, longfin smelt, and other species; less negative flows may be warranted during periods when significant portions of the adult smelt population migrate into the south or central Delta; thresholds for such flows need to be determined
5) Reduce risk of juvenile salmon entrainment and straying to central Delta at times when juveniles are present in the Delta; will also provide associated benefits for adult migration
6) Improve survival of San Joaquin River juvenile salmon emigrating down the San Joaquin River and improve subsequent escapement 2.5 years later
7) Increase survival of outmigrating smolts, decrease diversion of smolts into central Delta where survival is low, and provide attraction flows for adult returns
8) Protection of estuarine dependent species

(cont.)

Notes:

- These flow criteria do not consider any balancing of public trust resource protection with public interest needs for water.
- All flows are subject to appropriate ramping rates to avoid ramping impacts to public trust resources.
- These flow critieria should be tempered by tributary specific flow needs and the need to manage cold-water resources for the protection of public trust resources.
- Criteria for percentages of unimpaired flows apply only up to a specified maximum cap; appropriate maximum flow caps still need to be determined based on public trust needs and to avoid flooding.
- Additional flows may be needed for the protection of public trust resources for periods of time for which no flow criteria are recommended or where 2006 Bay-Delta Plan flow objectives are recommended, but adequate information is not available at this time to recommend such flows.

Table 24. Other Summary Determinations

Variability and the Natural Hydrograph:

- Criteria should reflect the frequency, duration, timing, and rate of change of flows, and not just volumes or magnitudes. Accordingly, whenever possible, the criteria specified above are expressed as a percentage of the unimpaired hydrograph.
- Inflows should generally be provided from tributaries to the Delta watershed in proportion to their contribution to unimpaired flow unless otherwise indicated. This concept is reflected in the specific criteria above.

Floodplain Activation and Other Habitat Improvements:

- Studies and demonstration projects for, and implementation of, floodplain restoration, improved connectivity and passage, and other habitat improvements should proceed to provide additional protection of public trust uses and potentially allow for the reduction of flows otherwise needed to protect public trust resources in the Delta.

Water Quality and Contaminants:

- The Central Valley and San Francisco Regional Water Boards should continue developing TMDLs for all listed pollutants and adopting programs to implement control actions.
- The Central Valley Regional Board should require additional studies and incorporate discharge limits and other controls into permits, as appropriate, for the control of nutrients and ammonia.

Coldwater Pool Resources and Instream Flow Needs on Tributaries:

- Temperature and water supply modeling and analyses should be conducted to identify conflicting requirements to achieve both flow and cold water temperature goals.

Adaptive Management:

- A strong science program and a flexible management regime are critical to improving flow criteria. The State Water Board should work with the Council, the Delta Science Program, IEP, and others to develop the framework for adaptive management that could be relied upon for the management and regulation of Delta flows.
- The numeric criteria in this report are all short term criteria that are only appropriate for the current physical system and climate; actual flows should be informed by adaptive management
- Only the underlying principles for the numeric criteria and these other measures are advanced as long termcriteria.

6. References

Exhibits Cited

American Rivers (AR), Natural Heritage Institute (NHI). Exhibit 1. Testimony of John R. Cain, Dr. Jeff Opperman, and Dr. Mark Tompkins on Sacramento and San Joaquin Flows, Floodplains, Other Stressors, and Adaptive Management.

California Department of Fish and Game (DFG). Exhibit 1. Effects of Delta Inflow and Outflow on Several Native, Recreational, and Commercial Species.

California Department of Fish and Game (DFG). Exhibit 2. Development of an Estuarine Fish Habitat Suitability Indicator Based on Delta Outflow and Other Factors.

California Department of Fish and Game (DFG). Exhibit 3. Flows Needed in the Delta to Restore Anadromous Salmonid Passage from the San Joaquin River at Vernalis to Chipps Island.

California Department of Fish and Game (DFG). Exhibit 4. Effects of Water Temperature on Anadromous Salmonids in the San Joaquin River Basin.

California Sportfishing Protection Alliance (CSPA). Exhibit 1. Testimony of Bill Jennings.

California Sportfishing Protection Alliance (CSPA). Exhibit 7. Testimony of Carl Mesick, Statement Of Key Issues On The Volume, Quality, And Timing Of Delta Outflows Necessary For The Delta Ecosystem to Protect Public Trust Resources With Particular Reference To Fall-Run Chinook Salmon In The San Joaquin River Basin.

California Sportfishing Protection Alliance (CSPA). Exhibit 14. The High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases. Carl Mesick, Ph.D. Energy and Instream Flow Branch U.S. Fish and Wildlife Service.

California Water Impact Network (CWIN). Exhibit 2. Testimony of Tim Stroshane.

Delta Environmental Flows Group (DEFG). Exhibit 1. Key Points on Delta Environmental Flows for the State Water Resources Control Board.

Delta Environmental Flows Group (DEFG). Exhibit 2. Changing ecosystems: a brief ecological history of the Delta.

Environmental Defense Fund (EDF). Exhibit 1. A Focal Species and Ecosystem Functions Approach for Developing Public Trust Flows in the Sacramento and San Joaquin River Delta. Testimony prepared by Stillwater Sciences.

National Marine Fisheries Service (NMFS). Exhibit 3. NMFS OCAP Biological Opinion & Appendices (June 2009)

National Marine Fisheries Service (NMFS). Exhibit 5. Public Draft Recovery Plan for Central Valley Salmon and Steelhead & Appendices (October 2009).

National Marine Fisheries Service (NMFS). Exhibit 7. Residence of Winter-Run Chinook Salmon in the Sacramento-San Joaquin Delta: The role of Sacramento River hydrology in driving juvenile abundance and migration patterns in the Delta.

National Marine Fisheries Service (NMFS). Written Summary.

Pacific Coast Federation of Fishermen's Associations (PCFFA). Exhibit 2. Testimony of William M. Kier. San Francisco Bay-Delta estuary water quality and flow criteria necessary to protect Sacramento River fall-fun chinook salmon.

State and Federal Water Contractors (SFWC). Exhibit 1. Written Testimony: The Information Proceeding to Develop Flow Criteria for the Delta Ecosystem. Submitted on behalf of the San Luis and Delta Mendota Water Authority, State Water Contractors, Westland Water District, Santa Clara Valley Water District, Kern County Water Agency, and Metropolitan Water District of Southern California.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). Exhibit 1. Written Testimony of Jonathan Rosenfield, Ph.D., Christina Swanson, Ph.D., John Cain, and Carson Cox Regarding General Analytical Framework.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). Exhibit 2 – Written Testimony of Jonathan Rosenfield, Ph.D. and Christina Swanson, Ph.D. Regarding Flow Criteria for the Delta Necessary to Protect Public Trust Resources: Delta Outflows.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). Exhibit 3. Written Testimony of Christina Swanson, Ph.D., John Cain, Jeff Opperman, Ph.D., and Mark Tompkins, Ph.D. Regarding Delta Inflows.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). Exhibit 4. Written Testimony of Christina Swanson, Ph.D. Regarding Delta Hydrodynamics.

United States Department of the Interior (DOI). Exhibit 1. Comments regarding the California State Water Resources Control Board notice of public informational proceeding to develop Delta flow criteria for the Delta ecosystem necessary to protect public trust resources.

Closing Comments Cited

American Rivers (AR), Natural Heritage Institute (NHI). Closing Comments.

California Department of Fish and Game (DFG). Closing Comments.

California Sportfishing Protection Alliance (CSPA). Closing Comments.

California Water Impact Network (CWIN). Closing Comments.

Contra Costa Water District (CCWD). Closing Comments.

Department of Water Resources (DWR). Closing Comments.

Environmental Defense Fund (EDF). Closing Comments.

The Bay Institute (TBI) and Natural Resources Defense Council (NRDC). Closing Comments.

State and Federal Water Contractors (SFWC). Closing Comments.

Literature Cited

Anadromous Fish Restoration Program (AFRP). 2005. Recommended streamflow schedules to meet the AFRP doubling goal in the San Joaquin River Basin. 27 September 2005.

Baxter, R.D. 1999. Pleuronectiformes. Pages 369-442 In J. Orsi, editor. Report on the 1980-1995 fish, shrimp and crab sampling in the San Francisco Estuary. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Technical Report 63.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller-Solger, M. Nobriga, T. Sommer and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. Interagency Ecological Program for the San Francisco Estuary. http://www/science.calwater.ca.gov/pdf/workshops/POD/IEP_POD_2007_synthesis_report_031408.pdf

Baxter, R. M. Nobriga, S. Slater and R. Fujimura. 2009. Effects Analysis. State Water Project Effects on Longfin Smelt. California Department of Fish and Game, Sacramento, CA.

Bay Delta Conservation Plan (BDCP). 2009. Working Draft Conservation Strategy, Chapter 3. 27 July 2009.

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science [Internet]:3(2). http://repositories.cdlib.org/jmie/sfews/vol3/iss2/art1

Brandes, P.L. and J S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: R.L. Brown, editor, Contributions to the biology of Central Valley salmonids. Volume 2. California Department of Fish and Game Fish Bulletin 179:39-136.

Brown, L.R. 2003. Will tidal wetland restoration enhance populations of native fishes? San Francisco Estuary and Watershed Science 1, Article 2. http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art2

Brown, L.R and J.T. May. 2006. Variation in spring nearshore resident fish species composition and life histories in the Lower Sacramento-San Joaquin watershed and Delta. San Francisco Estuary and Watershed Science 4. Article 1. http://escholarship.org/uc/item/09j597dn?query=Brown,%20L.R.

Brown, L. R., and D. Michniuk. 2007. Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California, 1980-1983 and 2001-2003. Estuaries and Coasts 30:186-200.

Brown, L.R., W. Kimmerer, and R. Brown. 2008. Managing water to protect fish: a review of California's Environmental Water Account, 2001-2005. Environmental Management DOI 10.1007/s00267-008-9213-4 http://www.springerlink.com/content/u4022223x2181287/fulltext.pdf

Bunn, S.E. and A.H. Arthington. 2002. Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. Environmental Management 30(4):492-507.

CALFED Bay-Delta Program. 2000. Strategic plan for ecosystem restoration. Sacramento, CA.

California Department of Fish and Game (DFG). 1987. Requirements of American Shad (*Alosa sapidissima*) in the Sacramento-San Joaquin River System. Exhibit 23, Entered by the DFG for the State Water Resources Control Board 1987 Water Quality/Water Rights Proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta.

California Department of Fish and Game (DFG). 1987b. Long-term trends in zooplankton distribution and abundance in the Sacramento-San Joaquin Estuary. Exhibit 28, Entered by DFG for the State Water Resources Control Board 1987 Water Quality and Water Rights Proceedings on the San Francisco Bay and Sacramento-San Joaquin Delta.

California Department of Fish and Game (DFG). 1992. Estuary dependent species. Exhibit 6, Entered by the DFG for the State Water Resources Control Board 1992 Water Quality/Water Rights Proceedings on the San Francisco Bay/Sacramento-San Joaquin Delta.

California Department of Fish and Game (DFG). 1998. A status review of the spring run Chinook salmon in the Sacramento River drainage. Report to the Fish and Game Commission. Candidate species status report 98-1. Sacramento, California. June. 394 pp.

California Department of Fish and Game (DFG). 2009. California Endangered Species Act Incidental Take Permit No. 2081-2009-001-03, Department of Water Resources, California State Water Project Delta Facilities and Operations.

California Department of Fish and Game (DFG). 2010. State and Federally Listed Endangered and Threatened Animals of California. January 2010. Biogeographic Data Branch, California Natural Diversity Database.

Central Valley Regional Water Quality Control Board. 2009. The Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region, The Sacramento River Basin and The San Joaquin River Basin, Fourth Edition. Revised September 2009 (with Approved Amendments).

Daniels, R.A., and P.B. Moyle. 1983. Life history of the Sacramento splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in the Sacramento–San Joaquin estuary. Fishery Bulletin 81:647–654.

Dege, M., and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution of larval and juvenile fishes in the upper San Francisco Estuary. Pages 49–65 In F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, eds. Early life history of fishes in the San Francisco estuary and watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Delta Smelt Working Group (DSWG). 2006. Meeting Notes dated September 26, 2006. http://www.fws.gov/sacramento/es/documents/ds_working_group/DSWG_Minutes_26Sep06.pdf

Department of Water Resources (DWR). 2006. California Central Valley Unimpaired Flow Data, Fourth Edition, Bay-Delta Office, California Department of Water Resources, Sacramento, CA.

Department of Water Resources (DWR). 2007. Sacramento-San Joaquin Delta Overview. State of California. See http://baydeltaoffice.water.ca.gov/sdb/tbp/deltaoverview/index.cfm

Dettman, D.H., D.W. Kelley, and W.T. Mitchell. 1987. The influence of flow on Central Valley salmon. Prepared for the California Department of Water Resources. Revised July 1987. (Available from D.W. Kelley and Associates, 8955 Langs Hill Rd., P.O. Box 634, Newcastle, CA 95658).

Dugdale, R.C., F.P. Wilkerson, V.E. Hogue, and A. Marchi. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay, Estuarine Coastal and Shelf Science 73:17-29.

Emmett, R.L., S.A. Hinton, S.L. Stone, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries Volume II: species life history summaries. NOAA/NOS Strategic Environmental Assessments Division, 8, Rockville, MD. 329 pp.

Feyrer, F. 2004. Ecological segregation of native and alien larval fish assemblages in the southern Sacramento-San Joaquin Delta. Pages 67-80 in F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, editors. Early Life History of Fishes in the San Francisco Estuary and Watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Feyrer, F. and M.P. Healey. 2003. Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta. Environmental Biology of Fishes 66(2):123-132.

Feyrer, F., B. Herbold, S.A. Matern, and P.B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67(3):277-288.

Feyrer, F., T. Sommer, and R.D. Baxter. 2005. Spatial-temporal distribution and habitat associations of age-0 splittail in the lower San Francisco watershed. Copeia 2005(1):159-168.

Feyrer, F., T. Sommer, and W. Harrell. 2006a. Managing floodplain inundation for native fish: production dyanmics of age-0 splittail (*Pogonichtys macrolepidotus*) in California's Yolo Bypass. Hydrobiologia 573:213-226.

Feyrer, F.T., T. Sommer and W. Harrell. 2006b. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: Evidence from two adjacent engineered floodplains on the Sacramento River, California. North American Journal of Fisheries Management 26(2):408-417.

Feyrer, F, M.L. Nobriga, T.R. Sommer. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723-734.

Feyrer, F., T. Sommer, and J. Hobbs. 2007a. Living in a dynamic environment: variability in life history traits of age-0 splittail in tributaries of San Francisco Bay. Transactions American Fisheries Society 136:1393-1405.

Feyrer, F., K. Newman, M.L. Nobriga, and T.R.Sommer. In review. Modeling the effects of future freshwater flow on the abiotic habitat of an imperiled estuarine fish. Manuscript submitted to Estuaries and Coasts.

Fleenor, W., W. Bennett, P. Moyle, and J. Lund. 2010. On developing prescriptions for freshwater flows to sustain desirable fishes in the Sacramento-San Joaquin Delta. Submitted to the State Water Resources Control Board regarding flow criteria for the Delta necessary to protect public trust resources. 43 pp.

Foe, C., A. Ballard, and S. Fong. 2010. Nutrient concentrations and biological effects in the Sacramento-San Joaquin Delta, Draft Report. Central Valley Regional Water Quality Control Board.

Glibert, P.M. 2010. Long-term changes in nutrient loading and stoichiometry and their relationships with changes in the food web and dominant pelagic fish species in the San Francisco Estuary, California. Pre-publication copy. Reviews in Fisheries Science.

Grimaldo, L.F., T. Sommer. N. Van Ark, G. Jones, E. Holland, P.B. Moyle, and B. Herbold. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? North American Journal of Fisheries Management 29:1253–1270.

Hallock, R.J., W.F. Van Woert, and L. Shapovalov. 1961. An evaluation of stocking hatchery-reared steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River system. California Department of Fish and Game. Fish Bulletin No. 14. 74 pp.

Harrell, W.C., and T.R. Sommer. 2003. Patterns of Adult Fish Use on California's Yolo Bypass Floodplain. California riparian systems: Processes and floodplain management, ecology, and restoration. Pages 88-93 in P.M. Faber, editor of 2001 Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, California.

Hatfield, S. 1985. Seasonal and interannual variation in distribution and population abundance of the shrimp *Crangon franciscorum* in San Francisco Bay. Hydrobiologia 129:199–210.

Haugen, C.W. 1992. Starry flounder. Pages 103-104 In W. S. Leet, C. D. Dewees, and C. W. Haugen, eds. California's living marine resources and their utilization. Sea Grant Extension Program, UCSGEP-92-12. Department of Wildlife and Fisheries Biology, University of California, Davis, California.

Healey, M.C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). In C. Groot and L. Margolis, editors, Pacific Salmon Life Histories, pages 396-445 [check. Another reference said Pages 313-393]. University of British Columbia Press, Vancouver, British Columbia. 564 pp.

Hennessy, A. 2009. Zooplankton monitoring 2008. Interagency Ecological Program for the Sacramento-San Joaquin Estuary Newsletter 22(2):10-16.

Hieb, K. 1999. Caridean Shrimp. In: J. Orsi, editor, Report on the 1980-1995 fish, shrimp, and crab sampling in the San Francisco Estuary, California. IEP Technical Report 63, 501 pp.

Hughes, R.M., J.N. Rinne, and B. Calamusso. 2005. Historical changes in large river fish assemblages of the Americas: a synthesis. American Fisheries Society Symposium 45:603-612.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5(1):272-289.

Jassby, A.D., and J.E. Cloern. 2000. Organic matter sources and rehabilitation of the Sacramento-San Joaquin Delta (California, USA). Aquatic Conservation: Freshwater and Marine Ecosystems 10:323-352.

Jassby, A.D. 2008. Phytoplankton in the Upper San Francisco Estuary: Recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science. 6(1):Article 2.

Jeffres, C. A., J.J. Opperman, and P.B. Moyle. 2008. Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes 83:449-458.

Karpov, K.A., D.P. Albin, and W.H. Van Buskirk. 1995. The marine recreational fishery in northern and central California: A historical comparison (1958-86), status of stocks (1980-86) and effects of changes in the California current. California Department of Fish and Game, Fish Bulletin. 176 pp.

Kimmerer, W.J. 2002a. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages? Marine Ecology Progress Series 243:39-55.

Kimmerer, W.J. 2002b. Physical, biological and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25:1275-1290.

Kimmerer, W.J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological processes. San Francisco Estuary and Watershed Science [Internet] 2(1) http://repositories.cdlib.org/jmie/sfews/vol2/iss1/art1

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and Delta smelt (*Hypomesus transpacificus*) to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 6(2):Article 2.

Kimmerer, W. and M. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using a Particle Tracking Model. San Francisco Estuary and Watershed Science 6(1):Article 4.

Kimmerer, W.J., E.S. Gross, and M.L. MacWilliams. 2009. Is the response of estuarine neckton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32:375-389.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1981. Influences of freshwater inflow on Chinook salmon (*Oncorhynchus tshawytscha*) in the Sacramento-San Joaquin Estuary. In P.D. Cross and D.L. Williams, editors, Proceedings of the National Symposium on Freshwater Inflow to Estuaries, pp. 88-108. U.S. Fish and Wildlife Service, FWS/OBS-81-04.

Kjelson, M.A., P.F. Raquel, and F.W. Fisher. 1982. Life history of fall-run juvenile chinook salmon, *Oncorhynchus tshawytscha*, in the Sacramento-San Joaquin estuary, California. In V.S. Kennedy (editor), Estuarine comparisons, pp. 393-411. Academic Press, New York, New York.

Kjelson, M.A., and P.L. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin rivers, California. Pages 100-115 in Levings, C.D., L.B. Holtby, and M.A. Henderson. (ed.) Proceedings of the National Workshop on Effects of Habitat alteration on salmonid Stocks. Can. Spec. Publ. Fish. Aquat. Sci. 105:100-115.

Lee, K.N. 1999. Appraising Adaptive Management. Conservation Ecology 3(2):3. http://www.consecol.org/vol3/iss2/art3.

Lott, J. 1998. Feeding habits of juvenile and adult delta smelt from the Sacramento-San Joaquin River Estuary. Interagency Ecological Program Newsletter 11(1):14-19.

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. Envisioning futures for the Sacramento-San Joaquin Delta, Public Policy Institute of California, San Francisco, CA. 284 pp.

Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2008. Comparing Futures for the Sacramento-San Joaquin Delta, Public Policy Institute of California, San Francisco, CA. 184 pp.

Lund, J., E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle. 2010. Comparing Futures for the Sacramento-San Joaquin Delta. University of California Press, Berkeley, CA. 256 pp.

MacFarlane, B.R. and E.C. Norton. 2002. Physiological ecology of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fisheries Bulletin 100:244-257.

Mager, R.C. 1996. Gametogenesis, Reproduction and Artificial Propogation of Delta Smelt, *Hypomesus transpacificus*. [Dissertation] Davis: University of California, Davis. 115 pp.

Maslin, P., M Lennox, and W. McKinney. 1997. Intermittent streams as rearing habitat for Sacramento River Chinook salmon (*Oncorhynchus tshawytscha*). California State University, Chico, Department of Biological Sciences. 89 pp.

Matern, S.A., P.B. Moyle and L.C. Pierce. 2002. Native and alien fishes in a California estuarine marsh: twenty-one years of changing assemblages. Transactions of the American Fisheries Society 131:797-816.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-42. 156 pp.

McEwan, D. and T. A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game. Sacramento, California. 234 pp.

Meng, L., P.B. Moyle, and B. Herbold. 1994. Changes in abundance and distribution of native and introduced fishes of Suisun Marsh. Transactions of the American Fisheries Society 123:498-507.

Meng, L., and P.B. Moyle. 1995. Status of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 124:538-549.

Mesick, C. 2009. The high risk of extinction for the natural fall-run chinook salmon population in the lower Tuolumne River due to insufficient instream flow releases. U.S. Fish and Wildlife Service, Energy and Instream Flow Branch, Sacramento, CA. 4 September 2009. Exhibit No. FWS-50.

Miller, D.J., and R.N. Lea. 1972. Guide to the coastal marine fishes of California, volume 157.

Moyle, P.B., J.E. Williams, and E.D. Wikramanayake. 1989. Fish species of special concern of California. Wildlife and Fisheries Biology Department, University of California, Davis. Prepared for The Resources Agency, California Department of Fish and Game, Rancho Cordova.

Moyle, P.B. 2002. Inland Fishes of California, 2nd Edition. University of California Press, Berkeley, California. 502 pp.

Moyle, P.B., R.D. Baxter, T. Sommer, T.C. Foin, and S.A. Matern. 2004. Biology and population dynamics of Sacramento splittail (*Pogonichthys macrolepidotus*) in the San Francisco Estuary: A review. San Francisco Estuary and Watershed Science 2(2): Article 3.

Moyle, P.B., P.K. Crain, and K. Whitener. 2007. Patterns in the use of a restored California floodplain by native and alien fishes. San Francisco Estuary and Watershed Science 5(3), 1-27. http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1

Moyle, P.B. 2008. The future of fish in response to large-scale change in the San Francisco Estuary, California. Pages 357-374 in K.D. McLaughlin, editor. Mitigating impacts of natural hazards on fishery ecosystems. American Fisheries Society, Symposium 64, Bethesda, Maryland.

Moyle, P. B. and W.A. Bennett. 2008. The future of the Delta ecosystem and its fish. Technical Appendix D. Comparing Futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California. San Francisco, CA., 1-38.

Moyle, P.B., W.A. Bennet, W.E. Fleenor, and J.R. Lund. 2010. Habitat variability and complexity in the Upper San Francisco Estuary. Working Paper, Delta Solutions, Center for Watershed Sciences, University of California, Davis.

Müller-Solger, A., A.D. Jassby, and D.C. Müller-Navarra. 2002. Nutritional quality of food resources for zooplankton (Daphnia) in a tidal freshwater system (Sacramento-San Joaquin River Delta). Limnol Oceanogr 47(5):1468-1476.

Murray, C. and D.R. Marmorek. 2004. Adaptive management: A science-based approach to managing ecosystems in the face of uncertainty. In: N.W.P. Munro, T.B. Herman, K. Beazley and P. Dearden (eds.). Making Ecosystem-based Management Work: Proceedings of the Fifth International Conference on Science and Management of Protected Areas, Victoria, BC, May, 2003. Science and Management of Protected Areas Association, Wolfville, Nova Scotia. http://www.essa.com/downloads/AM_paper_Fifth_International_SAMPAA_Conference.pdf

National Academy of Sciences. 2010. A scientific assessment of alternatives for reducing water management effects on threatened and endangered fishes in the California's Bay Delta. Committee on Sustainable Water and Environmental Management in the California Bay-Delta. The National Academies Press; National Research Council, Washington, D.C. http://www.nap.edu/catalog/12881.html

National Marine Fisheries Service (NMFS). 1994. Status of Sacramento River Winter-run Chinook Salmon, Final Rule. Federal Register 59(2):440-450.

National Marine Fisheries Service (NMFS). 1998. Threatened Status for Two ESUs of Steelhead in Washington, Oregon, and California, Final Rule. Federal Register 63(53):13347-13371.

National Marine Fisheries Service (NMFS). 1999. Threatened Status for Two Chinook Salmon Evolutionarily Significant Units (ESUs) in California, Final Rule. Federal Register 64(179):50394-50415.

National Marine Fisheries Service (NMFS). 2004. Establishment of Species of Concern List, Addition of Species to Species of Concern List, Description of Factors for Identifying Species of Concern, and Revision of Candidate Species List Under the Endangered Species Act. Federal Register 69(73):19975-19979.

National Marine Fisheries Service (NMFS). 2005. Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs, Final Rule. Federal Register 70(123):37160-37204.

National Marine Fisheries Service (NMFS). 2006a. Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead, Final Rule. Federal Register 71(3):834-862.

National Marine Fisheries Service (NMFS). 2006b. Threatened Status for Southern Distinct Population Segment of North American Green Sturgeon, Final Rule. Federal Register 71(67):17757-17766.

National Marine Fisheries Service (NMFS). 2009. Public draft recovery plan for the evolutionarily significant units of Sacramento River winter-run Chinook salmon and Central Valley spring-run Chinook salmon and the distinct population segment of Central Valley steelhead. Sacramento Protected Resources Division. http://swr.nmfs.noaa.gov/recovery/cent_val/Public_Draft_Recovery_Plan.pdf

Newman, K.B. 2003. Modelling paired release-recovery data in the presence of survival and capture heterogeneity with application to marked juvenile salmon. Statistical Modelling 3:157-177.

Nobriga, M.L., F. Feyrer, R.D. Baxter, and M. Chotowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. Estuaries 28:776-785.

Nobriga, M.L., F. Feyrer, and R.D. Baxter. 2006. Aspects of Sacramento pikeminnow biology in nearhsore habitats of the Sacramento-San Joaquin Delta, California. Western North American Naturalist 66:106-114.

Nobriga, M.L., T.R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-term trends in summertime habitat suitability for delta smelt (*Hypomesus transpacificus*). San Francisco Estuary and Watershed Science 6:1–13.

Orcutt, H.G. 1950. The life history of the starry flounder, *Platichthys stellatus* (Pallas). Fish Bulletin 78:64 pp.

Perry, R.W. and J.R. Skalski. 2008. Migration and survival of juvenile Chinook salmon through the Sacramento-San Joaquin River Delta during the winter of 2006-2007. Report prepared for the U.S. Fish and Wildlife Service. September 2008. 32 pp.

Perry, R.W. and J.R. Skalski. 2009. Survival and migration route probabilities of juvenile chinook salmon in the Sacramento-San Joaquin River Delta during the winter of 2007-2008. Report prepared for the U.S. Fish and Wildlife Service. 15 July 2009. 54 pp.

Poff, N.L. and J.K.H. Zimmerman. 2010. Ecological responses to altered flow regimes: a literature review to inform environmental flows science and management. Freshwater Biology 55:194-20.

Reilly, P., K. Walters, and D. Richardson. 2001. Bay Shrimp. pp. 439-442 and 453, In W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson, eds. California's Living Marine Resources: A Status Report, California Department of Fish and Game, 593 pp.

Ribeiro, F., P.K. Crain, and P.B. Moyle. 2004. Variation in Condition Factor and Growth in Young-of-Year Fishes in Floodplain and Riverine Habitats of the Cosumnes River, California. Hydrobiologia 527:7-84.

Rosenfield, J.A. and R.D. Baxter. 2007. Population dynamics and distribution patters of longfin smelt in the San Francisco Estuary. Transactions of the American Fisheries Society 136:1577-1592.

Rutter, C. 1904. Natural history of the quinnat salmon. Investigations on Sacramento River, 1896-1901. Bulletin of the U.S. Fish Commission. 22:65-141.

San Joaquin River Group Authority (SJRGA). 2007. 2006 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. January. 137 pp.

San Joaquin River Group Authority (SJRGA). 2008. 2007 Annual Technical Report: On implementation and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan. Prepared for the California Water Resources Control Board incompliance with D-1641. 128 pp.

Snider, B. 2001. Evaluation of effects of flow fluctuations on the anadromous fish populations in the lower American River. California Department of Fish and Game, Habitat Conservation Division. Stream Evaluation Program. Tech. Reports No. 1 and 2 with appendices 1-3. Sacramento, California

Sommer, T., R. Baxter, and B. Herbold. 1997. Resilience of splittail in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 126:961-976.

Sommer, T.R., M. L. Nobriga, W.C. Harrell, W. Batham, and W. Kimmerer. 2001a. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences 58:325-333.

Sommer, T., B. Harrell, M. Nobriga, R. Brown, P. Moyle, W. Kimmerer, and L. Schemel. 2001b. California's Yolo Bypass: evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries 26:6–16.

Sommer, T.R., W.C. Harrell, A. Mueller-Solger, B. Tom, and W. Kimmerer. 2004. Effects of flow variation on channel and floodplain biota and habitats of the Sacramento River, California, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 14:247-261.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32:270–277.

Sommer, T., K. Reece, F. Mejia, and M. Nobriga. 2009. Delta smelt life history contingents: a possible upstream rearing strategy. IEP Newsletter 22(1):11-13.

State Water Resources Control Board. 1999. Final Environmental Impact Report for Implementation of the 1995 Bay/Delta Water Quality Control Plan. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/eirs/eir1999/index.shtml

State Water Resources Control Board. 2006a. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. http://www.waterrights.ca.gov/baydelta/docs/2006_plan_final.pdf

State Water Resources Control Board. 2006b. Plan Amendment Report, Appendix 1 to the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_app1_final.pdf

State Water Resources Control Board. 2008. Strategic Workplan for Activities in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. http://www.waterrights.ca.gov/baydelta/docs/strategic_plan/baydelta_workplan_final.pdf

Stevens, D.E. and L.W. Miller. 1983. Effects of river flow on abundance of young Chinook salmon, American shad, longfin smelt, and delta smelt in the Sacramento-San Joaquin river system. North American Journal of Fisheries Management 3:425-437.

U.S. Environmental Protection Agency. 1999. 1999 Update of Ambient Water Quality Criteria for Ammonia. EPA 822-R-99-014.http://www.epa.gov/waterscience/criteria/ammonia/99update.pdf

U.S. Fish and Wildlife Service (USFWS). 1987. Exhibit 31: The Needs of Chinook Salmon, *Oncorhyncus tshawytscha*, in the Sacramento-San Joaquin Estuary. Entered by the U.S. Fish and Wildlife Service for the State Water Resources Control Board, 1987

Water Quality/Water Rights Proceeding on the San Francisco Bay/Sacramento-San Joaquin Delta.

U.S. Fish and Wildlife Service (USFWS). 1992. Expert testimony of United States Fish and Wildlife Service on chinook salmon technical information for State Water Resources Control Board Water Rights phase of the Bay/Delta Estuary Proceedings, 6 July 1992. WRINT-USFWS-7.

U.S. Fish and Wildlife Service (USFWS). 1993. Determination of Threatened Status for the Delta Smelt, Final Rule. Federal Register 58(42):12854-12864.

U.S. Fish and Wildlife Service (USFWS). 1995b. Working Paper on restoration needs: habitat restoration actions to double natural production of anadromous fish in the Central Valley of California. Volume 3. May 9, 1995. Prepared for the U.S. Fish and Wildlife Services under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

U.S. Fish and Wildlife Service (USFWS). 1996. Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes. U.S. Fish and Wildlife Service, Portland, Oregon.

U.S. Fish and Wildlife Service (USFWS). 2008. Biological opinion on coordinated operations of the central valley project and state water project. http://www.fws.gov/sacramento/es/documents/swp-cvp_ops_bo_12-5_final_ocr.pdf.

U.S. Fish and Wildlife Service (USFWS). 2009. 12-Month Finding on a Petition to List the San Francisco Bay-Delta Population of the Longfin Smelt (*Spirinchus thaleichthys*) as Endangered. Federal Register 74(67):16169-16175.

U.S. Fish and Wildlife Service (USFWS). 2010. 12-Month Finding on a Petition to Reclassify the Delta Smelt from Threatened to Endangered Throughout Its Range. Federal Register 75(66):17667-17680.

Vogel, D.A. 2004. Juvenile Chinook salmon radio-telemetry studies in the northern and central Sacramento-San Joaquin Delta, 2002-2003. Report to the National Fish and Wildlife Foundation, Southwest Region. January. 44 pp.

Vogel, D.A. 2008. Pilot study to evaluate acoustic-tagged juvenile Chinook salmon smolt migration in the Northern Sacramento-San Joaquin Delta 2006-2007. Report prepared for the California Department of Water Resources, Bay/Delta Office. Natural Resource Scientists, Inc. March. 43 pp.

Wang, J. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: a guide to the early life stages. Interagency Ecological Studies Program Technical Report 9. Sacramento, California.

Wang, J.C.S. 2007. Spawning, early life stages, and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. Tracy Fish Facilities Studies California Volume 38. U.S. Bureau of Reclamation, Mid-Pacific Region.

Werner, I. L. Deanovic, M. Stillway, and D. Markiewicz 2008. The effects of wastewater treatment effluent associated contaminants on delta smelt. Final report to the State Water Resources Control Board. 60 pp.

Werner, I., L. Deanovic, M. Stillway, and D. Markiewicz. 2009. Acute Toxicity of Ammonia/um and Wastewater Treatment Effluent-Associated Contaminants on Delta Smelt, Final Report. 3 April 2009.

Wilkerson, F.P., R.C. Dugdale, V.E. Hogue, and A. Marchi. 2006. Phytoplankton Blooms and Nitrogen Productivity in the San Francisco Bay. Estuaries and Coasts. 29(3):401-416.

Williams, B. K., R. C. Szaro, and C. D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2007. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Pages 71-176 in Brown, R.L. (ed.), Contributions to the biology of Central Valley salmonids. (Fish Bulletin 179 v.1). Sacramento, CA. California Deptartment of Fish and Game.

7. Appendices

Appendix A: Summary of Participant Recommendations

Appendix A, Table 1. Delta outflow recommendations summary table (cfs unless otherwise noted).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
Unimpaired Flow 1956-2003	C	16092	23292	31045	29103	27552	15301	5974	3880	4096	8167	8372	12531	
	D	24670	37460	52907	45810	39512	18994	6801	4759	5180	7221	16635	19339	
	BN	32402	63985	52056	53471	49644	25325	9091	5683	6004	7027	12842	16911	
	AN	88051	99722	86990	69589	78076	50019	18214	7932	7862	8162	13980	26763	
	W	113261	114512	103250	92975	96911	68197	27987	11354	8717	11804	30357	77204	
Historical Flow 1956-2003	C / D	14117	17916	17597	9193	7367	4504	3952	3334	4285	6896	9663	12734	87
	BN	27274	48832	32673	14991	10100	4336	3952	5025	7798	12116	15192	18996	
	AN	61801	70133	70404	32283	27876	13444	7172	5985	7865	6766	10940	17093	
	W	94930	111565	87497	67642	46530	29897	14279	10588	15545	13385	23024	60061	
D1641	C	4500 (1)	7100 - 29200 (2)					4000	3000	3000	3000	3500		1, 2
	D	4500	7100 - 29200					5000	3500	3000	4000	4500		
	BN	4500	7100 - 29200					6500	4000	3000	4000	4500		
	AN	4500	7100 - 29200					8000	4000	3000	4000	4500		
	W	4500	7100 - 29200					8000	4000	3000	4000	4500		
Draft D1630	All				6700									3
	C					3300	3100	2900						4
	D					4300	3600	3200						
	BN					11400	9500	6500						
	AN					14000	10700	7700						
	W					14000	14000	10000						
	W		10000											5
	BN & AN	12000												6
	All	6600 (if > flow not required by other standards)												7
TBI / NRDC / AR / NHI / EDF	81-100% (driest years)	14000 - 21000			10000 - 17500		3000 - 4200			5750 - 7500				8
	61-80%	21000 - 35000			17500 - 29000		4200 - 5000			7500 - 9000				
	41-60%	35200 - 55000			29000 - 42500		5000 - 8500			9700 - 12400				
	21-40%	55000 - 87500			42500 - 62500		8500 - 25000			12400 - 16100				
	0-20% (wettest years)	87500 - 140000			62500 - 110000		25000 - 50000			16100 - 19000				
CSPA / C-WIN	C	4100	9100		6700				4100					9
	D	9200	23500		10800				9200					
	BN	12100	41000		14400				12100					
	AN	14600	90800		23000				14600					
	W	29000	91800		43000				29000					
EDF / Stillwater (monthly average)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	10, 11, 12
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	26800	26800	26800	26800	11500	7500	7500	7500	7500	7500	11500	
	AN	26800	26800	26800	26800	26800	11500	11500	11500	11500	11500	11500	17500	
	W	26800	26800	26800	26800	26800	17500	17500	17500	17500	17500	17500	26800	
EDF / Stillwater (peak flows)	C	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	13
	D	11500	26800	26800	17500	17500	7500	4800	4800	4800	6500	5300	7500	
	BN	26800	90800 (14)	90800 (15)	26800	26800	11500	7500	7500	7500	7500	7500	11500	14, 15
	AN	26800	105600 (16)	105600 (17)	26800	26800	11500	11500	11500	11500	11500	11500	17500	16, 17
	W	26800	105600 (18)	105600 (19)	26800	26800	17500	17500	17500	17500	17500	17500	26800	18, 19
USFWS - OCAP Bio Op	AN									X2 ≤ 81 km (approx. 7000)		X2 ≤ 81 km		20
	W									X2 ≤ 74 km (approx. 12400)		X2 ≤ 74 km		

Appendix A, Table 1. Delta outflow recommendations summary table - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	All	Recommendation in X2 format: 64 - 75 km (approx. 29200 - 11400 cfs)												21
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	5 of 10 yrs			48000										23

Appendix A, Table 2. Sacramento River inflow recommendations (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C									3000		3500		
	D									3000	4000	4500		
	BN									3000	4000	4500		
	AN									3000	4000	4500		
	W									3000	4000	4500		
Draft D1630	All				≥18000									24
	All				≥13000 (14-day running average) and ≥9000 (min mean daily flow)									25
	C	1500	2500	2000				1000	1000	1500				26
	D	1500	2500	2500				1000	1000	1500				
	BN	2500	2500	3000				2000	1000	2500				
	AN	2500	2500	3000				2000	1000	2500				
	W	2500	3000	5000				3000	1000	5000				
CDFG	All		6000 (base flows)											27
	All				20000 - 30000 (pulse flows @ Rio Vista)									
C-WIN / CSPA	All		6000 (minimum base flows, measured @ Rio Vista)											28
	All				30000 (Freeport to Chipps Island)									29
PCFFA	All				25000 (Hood to Chipps Island)									30
USFWS					The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista. The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20000 cfs..."									31
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks										See Jan - May		32
	All	Sac Riv at Wilkins Slough and Freeport - Pulse flows of 15000 at Wilkins Slough, and up to 20000 at Freeport, should occur for a duration of 7 days or longer. There should be at least 5 such events in dry years and more in wet years											See Jan - May	33
TBI / NRDC / AR / NHI	C (0-20 percentile)			27500 for 15 cont days										34
	D (20-40 percentile)			27500 for 30 cont days										
	BN		30000 for 60 cont days											
	AN		32500 for 90 continous days											
	W	35000 for 120 continuous days												
NMFS	AN & W		≥ 17700 (at Grimes RM125)											35
	AN & W		≥ 31100 (at Verona RM80)											
	All	Provide pulse flows ≥ 20000 cfs, measured at Freeport periodically during winter-run emigration season to facilitate outmigration past Chipps Island (ie, Dec-Apr)											See Jan-Apr	36

Appendix A, Table 2. Sacramento River inflow recommendations - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
EDF / Stillwater	C	3500		10000			Determined based on Delta outflows (^{38})			3000 - 3500 (^{39})			3500	37, 38, 39
	D	4500		10000						3000 - 4500			4500	
	BN	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 21 consecutive days)												
	AN	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 35 consecutive days)												
	W	4500		10000						3000 - 4500			4500	
		64000 (pulse flow, 49 consecutive days)												
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	6 of 10 yrs	10000									10000			40
	6 of 10 yrs			25000										
	1 of 10 yrs	70000												41
	8 of 10 yrs		Yolo Bypass 2500 (Sac Riv ~45750)											42
	6 of 10 yrs			Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)										

Appendix A, Table 3. San Joaquin River inflow recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	C		710 or 1140 (43)		3110 or 3540 (44)	710 or 1140 (43)					1000 (45)			43, 44, 45
	D		1420 or 2280		4020 or 4880	1420 or 2280					1000			
	BN		1420 or 2280		4620 or 5480	1420 or 2280					1000			
	AN		2130 or 3420		5730 or 7020	2130 or 3420					1000			
	W		2130 or 3420		7330 or 8620	2130 or 3420					1000			
Draft D1630	C				2000 (46)						≥2000 (47)			46, 47
	D				4000						≥2000			
	BN				6000						≥2000			
	AN				8000						≥2000			
	W				10000						≥2000			
CDFG	C			1500 (Base)	5500 (Pulse) (4/15-5/15) (Total 7000)									48
	D			2125 (Base)	4875 (Pulse) (4/11-5/20) (Total 7000)									
	BN			2258 (Base)	6242 (Pulse) (4/6-5/25) (Total 8500)									
	AN			4339 (Base)	5661 (Pulse) (4/1-5/30) (Total 10000)									
	W			6315 (Base)	8685 (Pulse) (3/27-6/4) (Total 15000)									
C-WIN / CSPA	C		13400	4500	6700 8900	1200					5400			49
	D		13400 (2 days)	4500	6700 8900	1200					5400			
	BN		13400 (16 days), 26800 (2 days)	4500	6700 8900	11200 1200					5400			
	AN		13400 (13 days), 26800 (5 days)	4500	6700 8900	11200 1200					5400			
	W		13400 (17 days), 26800 (5 days)	13400		14900					5400			
TBI / NRDC	100% of years (all yrs)	2000			5000		2000							50
	80% (D yrs)	2000			5000 10000	7000 5000	2000							
	60% (BN yrs)	2000			20000 10000	7000 5000	2000							
	40% (AN yrs)	2000		5000	20000	7000	2000							
	20% (W yrs)	2000		5000	20000	7000	2000							

Appendix A, Table 3. San Joaquin River inflow recommendations summary table - con't. (p. 2 of 3)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
AR / NHI	100% of years (all yrs)			3000 4000	5000	2000								51
	80% (D yrs)			3000 4000	5000 10000	7000 5000	2000							
	60% (BN yrs)			3000 5000	20000 10000	7000 5000	2000							
	40% (AN yrs)			3000 5000	20000	7000	2000							
	20% (W yrs)			3000 5000	20000	7000	2000							
	All			Flows of approx. 10000 cfs should occur at Vernalis for ≥5 days. There should be at least 2 such events in dry years, and more in wetter years.										
EDF / Stillwater	All									> 1800 in DWSC				52
	All			Discuss USFWS (1995) and D-1641, no clear recommendation (55)			Determined based on Delta outflows (38)				3500 (10-14 days) (54)	FERC (53)		38, 53, 54, 55
	C & D	1000 (positive flows at Jersey Pt)											See Jan-Feb	56
	BN & AN	2000 (positive flows at Jersey Pt)											See Jan-Feb	
	W	3000 (positive flows at Jersey Pt)											See Jan-Feb	
	AN	14800 (pulse flow, ≥ 21 consecutive days)												57
	W	14800 (pulse flow, ≥ 35 consecutive days)												
USFWS			"...the Board should consider the Vernalis flows contained in USFWS (2005) [AFRP] and DFG's San Joaquin Escapement Model as a starting point for establishing flow for the protection of salmon and steelhead migrating from the San Joaquin basin"											58
AFRP (salmon doubling)	C		1744	2832	4912	5665								59
	D		1784	3146	5883	7787								
	BN		1809	3481	6721	9912								
	AN		2581	5162	8151	13732								
	W		4433	8866	10487	17369								
AFRP (53% Increase in Salmon Production)	C		1250	1665	2888	3331								60
	D		1350	1850	3459	4579								
	BN		1450	1933	3733	5505								
	AN		1638	2703	4266	7194								
	W		2333	4667	5520	9142								
NMFS OCAP Bio Op					Interim Operations in 2010-2011, min flows at Vernalis ranging from 1500 - 6000 based on New Melones Index									61
		In addition, USBR/DWR shall seek supplemental agreement with SJRGA as soon as possible to achieve the min flows listed below at Vernalis												
	C				1500									
	D				3000									
	BN				4500									
	AN				6000									
	W				6000									

Appendix A, Table 3. San Joaquin River inflow recommendations summary table - con't. (p. 3 of 3)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
NMFS	AN & W		≥ 14000 (at Vernalis)											62
	AN & W		≥ 7000 (at Newman)											
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22
The following is from Fleenor et al. 2010 (Preliminary Draft) - Functional flow approach with exports occurring via a peripheral canal, tunnel, or other alternative form of conveyance.														
Delta Solutions Group	C	2000			5000	2000								63
	D	2000			7000	2000								
	BN	2000			10000		2000							
	AN	2000			15000		2000							
	W	2000			20000			2000						

Appendix A, Table 4. Old and Middle River flow, export restriction, San Joaquin River flows at Jersey Point (e.g., QWEST) recommendations summary table (cfs unless noted otherwise).

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
D1641	All	See Jul-Dec	Export/Inflow Ratio: 35% of Delta Inflow (64)					Export/Inflow Ratio: 65% of Delta Inflow						64
	All				Export Limit: > of 1500 or 100% of 3-day avg. Vernalis flow									65
Draft D1630	All	QWEST > -2000	No reverse flow for all year types on a 14-day running average in the Western Delta (QWEST > 0 cfs, as calculated in Dayflow)					QWEST > -1000	QWEST > -2000					66
	C & D				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be ≤ 4000 cfs									
	BN, AN, W				14-day running average combined export rate for Tracy, Banks, and Contra Costa pumping plants shall be ≤ 6000 cfs									
CSPA / C-WIN	All			Combined Export Rates = 0										67
	All			2000 cfs daily flow in Old and Middle Rivers										68
	C	1000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			69
	D	1500 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
	BN	2000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
	AN	2500 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
	W	3000 (positive 14-day mean flows at SJ Riv at Jersey Pt)									See Jan-June			
TBI / NRDC		Sac Salmonids, Delta Smelt, Longfin Smelt*		Sac & SJR Salmonids, D. Smelt, L. Smelt*	Sac & SJR Salmonids, D. Smelt, L. Smelt (C & D yrs)		Sac & SJR Salmonids, D. Smelt				Sac Basin Salmon		Sac Salmon, D. Smelt	70
	C	-1500 or >0*	-1500 or >0*	-1500 or >0*	>0	>0	-1500				-2000	-2000	-1500	
	D	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
	BN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
	AN	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
	W	-1500 or >0*	-1500 or >0*	>0	>0	>0	-1500				-2000	-2000	-1500	
AFRP	C / D	1000 (net seaward flows at Jersey Pt)									See Jan-June			71
	BN / AN	2000 (net seaward flows at Jersey Pt)									See Jan-June			
	W	3000 (net seaward flows at Jersey Pt)									See Jan-June			
NMFS - OCAP Bio Op	All	Limit negative flows to -2000 to -5000 cfs in Old and Middle Rivers, depending on the presence of salmonids (see decision tree upon which the negative flow objective w/in the range shall be determined)												72
	All				Export restrictions based on Vernalis flow: <6000 cfs = 1500 cfs export limit 6000-21750 cfs = 4:1 (Vernalis flow:export ratio) >21750 = Unrestricted									

Appendix A, Table 4. Old and Middle River flow, export restriction, San Joaquin River flows at Jersey Point (e.g., QWEST) recommendations summary table - con't. (p. 2 of 2)

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
USFWS	All	Board should develop reverse flow criteria that would maintain Old and Middle River flow positive during key months (Jan - Jun)						▨						73
	All	"...the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point... Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow..."						▨			See Jan - June			74
USFWS - OCAP Bio Op	All	Action 1: -2000 cfs for 14 days once turbidity or salvage trigger has been met. Action 2: range btw -1250 and -5000 cfs (^{75})			Range between -1250 and -5000 (^{76})			▨					See Jan-Mar	75, 76
CDFG Longfin Smelt Incidental Take Permit	All	Condition 5.1 (Dec - Feb): >-5000 (^{77}) Condition 5.2 (Jan - June): OMR flow between -1250 and -5000 cfs (^{78})						▨					Condition 5.1 (Dec-Feb)	77, 78
DWR / SFWC	All	Recommendation to maintain requirements stipulated in D-1641												22

Appendix A, Table 5. Floodplain inundation flow recommendations summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Note
CDFG	AN & W	≥ 30 day floodplain inundation					▨	▨	▨	▨	▨	▨	▨	79
EDF / Stillwater	BN	64000 (pulse flow, 21 consecutive days)				▨	▨	▨	▨	▨	▨	▨	▨	37 Sacr Riv - Yolo Byp
	AN	64000 (pulse flow, 35 consecutive days)				▨	▨	▨	▨	▨	▨	▨	▨	
	W	64000 (pulse flow, 49 consecutive days)				▨	▨	▨	▨	▨	▨	▨	▨	
TBI / NRDC / AR / NHI	C (0-20 percentile)	▨	▨	27500 for 15 cont days	▨	▨	▨	▨	▨	▨	▨	▨	▨	34 Sac Riv - Yolo Byp
	D (20-40 percentile)	▨	▨	27500 for 30 cont days	▨	▨	▨	▨	▨	▨	▨	▨	▨	
	BN	▨	30000 for 60 cont days			▨	▨	▨	▨	▨	▨	▨	▨	
	AN	▨	32500 for 90 continous days			▨	▨	▨	▨	▨	▨	▨	▨	
	W	35000 for 120 continuous days					▨	▨	▨	▨	▨	▨	▨	
AR / NHI	All	Sac Riv at Bend Bridge - Pulse flows continuously exceed 8000, periodically exceed 12000, for a duration exceeding 2 weeks					▨	▨	▨	▨	▨	See Jan - May		32
USFWS	6 of 10 yrs	"The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows..."					▨	▨	▨	▨	▨	▨	▨	80
NMFS - OCAP Bio Op	All	"...Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type."				▨	▨	▨	▨	▨	▨	▨	See Jan-Apr	81
NMFS - Recovery Plan	All	"Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: ... and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."						▨	▨	▨	▨	▨	▨	82
Delta Solutions Group	8 of 10 yrs	▨	Yolo Bypass 2500 (Sac Riv ~ 45750)			▨	▨	▨	▨	▨	▨	▨	▨	42
	6 of 10 yrs	▨	▨	Yolo Bypass 4000 (pulse) (Sac Riv ~ 50150)		▨	▨	▨	▨	▨	▨	▨	▨	
San Joaquin River														
EDF / Stillwater	AN	14800 (pulse flow, ≥ 21 consecutive days)				▨	▨	▨	▨	▨	▨	▨	▨	57
	W	14800 (pulse flow, ≥ 35 consecutive days)				▨	▨	▨	▨	▨	▨	▨	▨	
See TBI / NRDC and AR / NHI SJ River Inflow recommendations, flows >20000 cfs to trigger floodplain inundation														

Appendix A, Table 6. Delta Cross Channel closures summary table.

	Water Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Source / Notes
D-1641		see Nov	Gates Closed			Close for 14 days (83)						Nov-Jan - gates may be closed for up to total of 45 days		83
Draft D-1630	All	Closed if daily DOI >12000	Operated based on results of real-time monitoring											84
CSPA / C-WIN	All		Gates Closed											85
	All		Acoustic Barrier at head of Georgiana Slough at Sacramento River											
NMFS - OCAP Bio Op	All	Dec 15 - Jan 31 Gates closed	Gates Closed per D1641			Gates closed up to 14 days per D1641					Gates closed if fish are present		Gates closed except for experiments/water quality Dec 15 - Jan 31 Gates closed	86

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
1	D1641	Outflow	All water year types - Increase to 6000 if the Dec 8RI is > than 800 TAF
2	D1641	Outflow	Habitat Protection Flows, minimum Delta outflow calculated from a series of rules that are described in Tables 3 and 4 of D1641
3	Draft D1630	Outflow	Striped Bass, Antioch spawning - Delta outflow index, Sac Riv at Chipps Island, average for the period not less than value shown (cfs).
4	Draft D1630	Outflow	Striped Bass, general - Delta outflow index, Sac River at Chipps Island - average for period not less than value shown (cfs), May period = May 6-31
5	Draft D1630	Outflow	Suisun Marsh - Delta outflow index at Sac River at Chipps Island - average of daily DOI for each month, not less than value shown (cfs)
6	Draft D1630	Outflow	Suisun Marsh - Delta outlflow index, Sac River at Chipps Island - minimum daily DOI for 60 consecutive days in the period
7	Draft D1630	Outflow	Suisun Marsh - Delta outflow index, Sac River at Chipps Island - average of daily DOI for each month, not less than value shown, in cfs: applies whenever storage is at or above minimum level in flood control reservation envelope at two of the following - Shasta Reservoir, Oroville Reservoir, and CVP storage on the American River
8	TBI et al	Outflow	Water year categories represent exceedance frequencies for the 8-river index, they are not equivalent to the DWR "water year types" (which account for storage and other conditions). TBI_Exhibit 2 (Outlfow). References for correlation btw winter-spring outlfow and abundance of numerous species on p.3. Winter-spring Delta outflow criteria approximate the frequence distribution of outflow levels, i.e., the relationship btw outflow and the 8 River Index, for the 1956-1987 period. Winter and spring outlfow recommendations to benefit public trust uses of pelagic species (as represented by abundance and productivity of longfin smelt, Crangon shrimp, and starry flounder and spatial distribution of longfin smelt) (see TBI Exhibit 2, pp 21-25). Two methods were used to develop outflow criteria: an analysis of historical flow-abundance relationships that corresponded to recovery targets for longfin smelt abundance (Native Fishes Recovery Plan, USFWS 1995), and an analysis of population growth response to outflows in order to identify outflows that produced population growth more than 50% of the time. Applying these
8 cont	TBI et al	Outflow	two methods produces very similar results regarding desirable outflow levels. Break in summary table at mid-Mar is artificial, original table included Mar under both Winter and Spring, so for simplicity, it was split at 15 Mar. Fall outflows (TBI Exhibit 2, p. 35, Table 1 and Fig 27) - analyzed emerging statistical evidence of relationship btw outlfow and abundance and distribution of delta smelt and striped bass (Feyrer et al 2007; Feyrer et al In Review; DSWG notes, Aug 21, 2006), in order to develop recommendations. Recommendations occassionaly exceed unimpaired outflow in limited cases (would require reservoir releases in fall independent of antecedent conditions).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
9	CSPA / C-WIN	Outflow	Net Delta Outflow, as a 14-day running average - Source WRINT-DFG Exh 8 (1992). Feb-Mar - flows correspond to Table 8 (p.23), Alternative C (Estuarine species - target mean monthly flows based on data from DWR's 1995 Level of Development + 50% increase). Orig. recommendations by month, C-WIN/CSPA took average of Feb and Mar, and reported as such. Apr-July - flows correspond to Table 2 (p16), Alternative C (mean Delta outflows required to maintain populations of 1.7 million adult striped bass). Aug-Jan - based on Alt C (discussed above), in combination with flow recommendations developed by C-WIN for Jan. DFG identified flows for all months except Jan, C-WIN developed a method for Jan flows from DayFlow information (C-WIN extracted monthly average Delta outflows from DayFlow, sorted them, and then allocated them to water years based on unimpaired runoff data from the California Data Exchange Center. The medians of the water year types were then used as January flows in developing our optimal conditions recommendations for mean Delta outflows in the August 1 through January 31 period).
10	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Winter [Dec-Feb] outflows - p.52-53). A primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 80 km in drier water year types. Proximate function is to increasethe westward extent of fresh water into Suisun and San Francisco bays to more closely approximate historical conditions. "This will serve to increase the availability of food resources to larval fish species in late winter as well as improve access to low salinity habitat in the shallows of Grizzly and Honker bays (Feyrer et al 2009)." Flows also designed to limit the eastward distribution and density of overbite clam. "...low salinity may inhibit spawning and subsequent adult recruitment, thereby reducing grazing pressures on phytoplankton and the pelagic food web. Improvements in food resources to the western Delta will serve to increase populations of Delta smelt, striped bass, and other pelagic species that are currently in decline."
11	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Spring [Mar-May] Outlfows - p.55-56). Spring flows primarily based on delta outflows needed to maintain X2 in locations that are beneficial to delta pelagic fish populations as well as the provision of floodplain inundation in the Yolo Bypass during March Primary objective was to provide enough Delta outflow to maintain X2 westward of 65 km, w/ variations to allow eastward excursion of X2 as far as 70 km in drier water year types. References in justification: Feyrer et al. In Revision, Bennett et al 2005. Herbold 1994, Hobbs et al 2004, Bennett et al. 2008, and others). Secondary goal is to provide sufficient flows to maintain inundated season floodplain habitat in Yolo Bypass and lower SJ Riv for varying periods in March based on water year type. These floodplain inundation flows should be coordinated with flows in late winter to provide prolonged periods of inundation.
12	EDF / Stillwater	Outflow	Stillwater Focal Species Approach - Source - EDF closing comments (Table 1), Supporting Info - EDF Exhibit 1 (Fall [Sept-Nov] - pp.49-50; Summer - pp.57-58) Summer (Jun-Aug) and Fall flows based primarily on Delta outflows needed to maintain X2 in the shallow-water habitats of Suisun Bay. Secondary objective for Fall outflows from the Delta were to provide attraction flows for upstream-migrating salmonids and to maintain adequate DO concentrations for fall-run chinook salmon within the lower SJ River system. Summer and Fall - in some months and water year types, depending on water year type and month, the projected monthly outflows are higher than the unimpaired and/or current flow ranges. Thus some modification of upstream reservoir release schedules may be required to meet these flows. Fall - references in justification - Feyrer et al 2007; Feyrer et al In revision; Bennet et al 2002; Jassby et al 1995; and others

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
13	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Peak flows required to provide floodplain inundation are assumed to be concurrent between the Sac and SJ River basins as well as the east side tributaries. However, the duration of the peak flows varies by water year (see notes 69-74)
14	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River
15	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 7 days of floodplain inundation flow of 64000 cfs in the Sac River
16	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
17	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 14 days of floodplain inundation flow of 64000 cfs in the Sac River and 7 days of floodplain inundation flow of 14800 cfs in the SJ River.
18	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 28 days of floodplain inundation flow of 64000 cfs in the Sac River and 21 days of floodplain inundation flow if 14800 cfs in the SJ River
19	EDF / Stillwater	Outflow	EDF_Closing Comments (Table 1) - Includes 21 days of floodplain inundation flow of 64000 cfs in the Sac River and 14 days of floodplain inundation flow of 14800 cfs in the SJ River
20	USFWS	Outflow	Delta smelt biological opinion (RPA concerning Fall X2 requirements [pp. 282-283] - improve fall habitat [quality and quantity] for DS) (references USFWS 2008, Feyrer et al 2007, Feyrer et al in revision) - Sept-Oct in years when the preceeding precipitation and runoff period was wet or above normal, as defined by the Sacramento Basin 40-30-30 Index, USBR and DWR shall provide sufficient Delta outflow to maintain monthly average X2 no greater than 74 km and 81 km in Wet and Above Normal yrs, respectively. During any November when the preceding water yr was W or AN, as defined by Sac Basin 40-30-30 index, all inflow into the CVP/SWP reservoirs in the Sac Basin shall be added to reservoir releases in Nov to provide additional increment of outflow from Delta to augment Delta outflow up to the fall X2 of 74 km and 81 km for W and AN water yrs, respectively. In the event there is an increase in storage during any Nov this action applies, the increase in reservoir storage shall be released in December to augment the Dec outflow requirements in SWRCB D-1641.
21	CDFG	Outflow	Outflow recommendations from closing comments. Originally provided as X2 recommendations - Source - DFG Exhibit 1 and Exhibit 2 - Consolidates recommendations for American Shad, Longfin Smelt, Starry Flounder, Bay Shrimp, Zooplankton (consistent with D1641 requirements to maintain X2 at one of two compliance points in Suisun Bay [64 km or 75 km] from Feb-June). Longfin smelt = Jan - June; Starry flounder, Bay shrimp, zooplankton = Feb - Jun; and American Shad = April - June.
22	DWR / SFWC	Outflow, SJ Riv Inflow, Sac Riv Inflow, OMR	DWR_closing comments, in response to request for a table identifing recommended flows, DWR submitted summary of D-1641 objectives.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
23	UCDavis - Delta Solutions Group	Outflow	Functional Flow 5a - Delta Smelt flows, 48000 cfs, from March through May (5 out of 10 years, every other year). Maintain freshwater to low salinity habitat in the northeastern Delta to Napa River, facilitating a broad spatial and temporal range in spawning and rearing habitat (Bennett 2005, Hobbs et al 2005). Flow recommendation not based on water year type, but rather number of years out of 10. Based on exports through an alternative form of conveyance (e.g., peripheral canal or tunnel).
24	Draft D1630	Sac River Inflow	Function = Chinook salmon. Sac River at Freeport. Average flow at Freeport >18000 cfs for a 14-day continuous period corresponding to release of salmon smolts from Coleman Nat Fish Hatchery. Anticipate to occur in late April or early May. If no fish are released from the hatchery, the Executive Director shall determine the appropriate timing of this pulse flow with advice from CDFG.
25	Draft D1630	Sac River Inflow	Function = striped bass, general; Sac River at Freeport - 14-day running average at Freeport >13000 cfs for a 42-day continuous period, with minimum mean daily flow >9000 cfs. Requirement initiated when real-time monitoring indicates the presence of striped bass eggs and larvae in Sac River below Colusa. This period should begin in late April or early May in most years.
26	Draft D1630	Sac River Inflow	Function = chinook salmon. Sac River at Rio Vista - 14-day running average of minimum daily flow.
27	CDFG	Sac River Inflow	Chinook salmon, smolt outmigration. (1) Feb - Oct base flows. Source - DFG Exhibit 14 (WRINT-DFG-8, p.11). (2) Apr - Jun pulse flows. Source - DFG Exhibit 1, page 1, 6, and USFWS Exhibit 31 (Kjelson).
28	CSPA	Sac River Inflow	CSPA Closing Comments. Source - CDFG_1992_WRINT-DFG-Exhibit #8, p.11. Minimum base flow, measured at Rio Vista. 14-day average flow.
29	CSPA / C-WIN	Sac River Inflow	Sacramento River from Freeport to Chipps Island - Pulse flows - flows needed to sustain viable migration corridor for optimal smolt passage and survival. Source - USFWS Exhibit 31 (Kjelson)
30	PCFFA	Sac River Inflow	Function = salmonid juvenile outmigration. PCFFA closing comments, Source - USFWS Exhibit 31 (Kjelson). Kjelson and Brandes research - found that flows of 20000 to 30000 cfs yield the greatest survival of juvenile salmon during out-migration from Sac River to San Francisco Bay (PCFFA recommends splitting the difference and setting standard at 25000 cfs). Set from Hood to Chipps Island.
31	USFWS	Sac River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 25, 54, and 57. "The catch of juvenile salmon at Chipps Island between April and June is correlated to flow at Rio Vista (USFWS, 1987; Brandes and McLain, 2001; Brandes et al., 2006). The highest abundance leaving the Delta has been observed when flows at Rio Vista between April and June averaged above 20,000 cfs which is also the level where we have observed maximum survival in the past (USFWS, 1987)" (p.25).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
32	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments. Purpose - interconnect side channels with main channel, contribute to foodweb productivity and rearing habitat for salmon. Inundated off-channel habitat such as high flow channels can also provide rearing habitat for salmon (Peterson and Reid 1984), but regulated spring flows are generally insufficient to inundate these habitats for prolonged periods (30-60 days), A recent study of these habitats in the Sac River determined that a large proportion of secondary channels between Red Bluff and Colusa become fully connected to the river at flows above 12000 cfs (Kondolf 2007). (from AR_NHI_Exh1 p.28)
33	AR / NHI	Sac River Inflow	AR_NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments - aid migration of winter-run chinook, in later months aid migration of spring and fall-run. Recent analyses indicate that the onset of emigration of winter-run fish to the Delta at Knights Landing is triggered by flow pulses of 15000 cfs at Wilkins Slough, and emigration from the Sac River to Chipps Island follows pulse flows of 20000 cfs at Freeport (del Rosario 2009). Previous studies found that smolt survival increased with increasing Sac River flow at Rio Vista, with maximum survival observed at or above about 20000 and 30000 cfs (USFWS 1987, Exhibit 31). Despite uncertainty about the exact magnitude of flow necessary to initiate substantial bank erosion, there is growing evidence that flows between 20000 and 25000 cfs will erode some banks while flows above 50000 to 60000 cfs are likely to cause widespread bank erosion (Stillwater 2007).
34	TBI / NRDC / AR / NHI	Sac River Inflow	TBI_Exh3 (Inflows - Table 3), TBI_closing comments (Table 3), AR/NHI_Exh1 (Testimony of Cain, Opperman, and Tompkins), AR/NHI closing comments - Table 3. Flows recommended for floodplain inundation (Sutter and Yolo Bypasses) - salmonid rearing, splittail spawning and early rearing. Flows measured at Verona. Flow magnitudes assume structural modifications to the weir to allow inundation at lower flow rates than is currently possible. Reservoir releases should be timed to coincide with and extend duration of high flows that occur naturally on less regulated rivers and creeks. The duration target is fixed for each year type, but actual timing of inundation should vary across the optimal window depending on hydrology and to maintain life history diversity.
35	NMFS	Sac River Inflow	NMFS_Exh9 (from ARFP 1995), Sturgeon (Grn and Wht) - adult migration to spawning and downstream larval transport
36	NMFS	Sac River Inflow	Public Draft Recovery Plan for Central Valley Salmon and Steelhead (October 2009). NMFS_Exhibit_5. Section 6.1.1 Recovery Action Narrative, Action 1.5.9, p.158.
37	EDF / Stillwater	Sac River Inflow	Source: EDF_Exh1 (Stillwater Sciences - Focal Species Approach). Spring flows - Establishing base flows of at least 10000 cfs in the Sac Riv in spring would improve transport of eggs and larval striped bass and other young anadromous fish and to reduce egg settling and mortality at low flows (USFWS 2001, EDF_Exh1, p.53). Proximate function of Delta inflows is to maintain net transport of passively swimming fishes (juv salmonids, larval delta smelt, and striped bass) and nutrients towards Suisun and San Francisco bays (USFWS 2008). Goal of winter and spring floodplain activation flows (managed pulse flows of approx 64000 cfs at Verona) is to maintain inundated seasonal floodplain habitat conditions in much of Yolo Bypass during January and April for a minimum of 21, 35, and 49 days in Below Normal, Above Normal, and Wet water year types, respectively. The NMFS (2009) draft recovery plan for Sac winter-run chinook, CV spring-run chinook, and CV steelhead ESUs calls for an annual spring flow of 8000 cfs (approx 64000 cfs at Verona) above the initial spill level "to fully activate the Yolo Bypass floodplain." For the

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
37 cont	EDF / Stillwater	Sac River Inflow	purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Summer Delta inflows to be determined by Delta outflows. Fall Inflows - Maintenance of D1641 flow standards in necessary to provide attraction flows for Chinook salmon, although these levels would potentially need to be increased to provide adequate Delta outflows. Winter Inflows - Winter flows primarily designed to provide upstream migration passage for salmonids and striped bass during Dec and Jan, as well as to inundate floodplains such as Yolo Bypass for benefit of rearing juv salmonids and other floodplain associated species (p.50-51). See Spring for discussion of goal of combined winter-spring floodplain activation flows.
38	EDF / Stillwater	Sac Riv Inflow / SJ Riv Inflow	Inflows determined based on Delta outflows (EDF_Exh1 - Stillwater Focal Species)
39	EDF / Stillwater	Sac River Inflow	These levels may need to be increased to provide adequate Delta outflows (EDF_Exh1 - Stillwater Focal Species)
40	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2a - Sac River adult salmon - 10000 cfs to to occur from Oct - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Functional Flow 2b - Sac River juvenile salmon migration - 25000 cfs from Mar - June during 6 out of 10 years (references Newman and Rice 2002, Williams 2006, Harrell et al. 2009, USFWS Exhibit 31 1987, Kjelson and Brandes 1989). Flows not based on water year type, but rather number of years out of ten.
41	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 2c - Sacr River adult sturgeon flows - 70000 cfs to occur between Jan and May during 1 out of 10 years (flows for salmon -2a, 2b, and 1a,1b) (Kohlhorst et al 1991 [flow rate], Harrell and Sommer 2003 [passage problems at Fremont Weir]). Flows not based on water year type, but rather number of years out of ten.
42	UCDavis - Delta Solutions Group	Sac River Inflow	Functional Flow 1a - yolo bypass inundation - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flow 1b - yolo bypass pulse - salmon and splittail (area inundated based on recommended flows BDCP draft rpt 2008) (other references related to flow and corresponding extent of habitat in Yolo Bypass Moyle et al. 2004, Sommer et al. 2004, Harrell and Sommer 2003, Harrell et al. 2009). Functional Flows 1a and 1b require flows at Freeport of approx. 45750 and 50150 cfs, respectively, based on regressions of historical data.
43	D1641	SJ River Inflow	Base Vernalis minimum monthly average flow rate in cfs (the 7-day running average shall not be less than 20% below the objective). Take the higher objective if X2 is required to be west of Chipps Island
44	D1641	SJ River Inflow	Pulse Vernalis minimum monthly average flow rate in cfs. Take the higher objective if X2 is required to be west of Chipps Island
45	D1641	SJ River Inflow	Pulse - up to an additional 28 TAF pulse/attraction flow to bring flows up to a monthly average of 2000 cfs except for a critical year following a critical year. Time period based on real-time monitoring and determined by CalFed Op's group

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
46	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, in cfs, for 21-day continuous period. Start date depends on beginning of chinook salmon smolt out-migration from SJ basin. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days. Daily mean combined pumping at Tracy, Banks, and Contra Costa pumping plants shall be ≤1500 cfs. All pumping restrictions are to be split equally between CVP and SWP. Total annual maximum of 150 TAF for the two salmon flows (these and fall attraction flows) from the SJ Basin reservoirs
47	Draft D1630	SJ River Inflow	SJ River at Vernalis. Function = chinook salmon. Minimum daily flow, for 14-day continuous period. Start date depends upon beginning of chinook salmon adult spawning migration. Attraction flow shall be provided only if water is avaiable from the 150 TAF alloted for the two salmon flows. During this time, water right holders on Mokelumne and Calaveras rivers shall bypass all inflows for 5 consecutive days.
48	CDFG	SJ River Inflow	Source: SJR Salmon Model V.1.6 (CDFG 2009), DFG Exhibit 3 (Flows needed in the Delta to restore anadromous salmonid passage from the SJ River at Vernalis to Chipps Island) - Table 10 - South Delta (Vernalis) flows needed to double smolt production at Chipps Island (by water year type), and CDFG closing comments. Flows to support smolt outmigration.
49	CSPA / C-WIN	SJ River Inflow	CSPA and C-WIN Closing Comments - CSPA Table 2. Based on WRINT-DFG Exhibit 8 (1992) and C. Mesick 2010 (C-Win Exh 19). Pulse flows in all years to attract adult spawning salmonids, Oct 20-29, SJR at Vernalis. To the tributary flows (each measured at their confluence with SJ Riv mainstem (see Mesick 2010), C-WIN / CSPA added in a flow of the SJ Riv below Millerton Lake reflecting that river's fair share unimpaired flow, as well as accretions and other inflows. Combined valley flows at Vernalis assumes tributaries (Mer, Stan, Tuol) are 67.06% of total SJ River flow at Vernalis. Spring - pulse flows for temperature regulation, migration cues, habitat inundation. Oct - pulse flows to attract adult salmonids.
50	TBI / NRDC	SJ River Inflow	TBI Exhibit 3 - Delta Inflows (Table 1, p.28), TBI / NRDC closing comments (Table 3b). Flows >5000 cfs to maintain minimum temperature (≤ 65F) for migrating salmonids in April and May. Flows >20000 to trigger floodplain inundation. Year-round flows should exceed 2000 cfs to alleviate potential for DO problems in DWSC.
51	AR / NHI	SJ River Inflow	AR_NHI_Exh1 (testimony of Cain, Opperman, and Tompkins) and AR_NHI_closing comments (Table 2). SJ River flows to benefit salmon rearing habitat and smolt out-migration (increase flow velocities and turbidity), with focus on temperature (maintain temp at or below 65F) and floodplain inundation. Criteria recommended to be in addition to those stipulated in D1641.
52	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Based upon investigations for the SJ River DO TMDL, minimum instream flows at the Stockton DWSC should be maintained in excess of 1,800 cfs during Sept and Oct of each year. Low DO in the lower SJ River has been found to impede upstream salmon migration (NMFS 2009, p.74). Studies by Hallock (1970) indicate that low DO at Stockton delay upmigration and straying rates.
53	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Flows during November should correspond to current minimum Federal Energy Regulatory Commission (FERC) spawning flow requirements from the Stanislaus, Tuolumne, Merced, and upper San Joaquin rivers.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
54	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.47-49). Salmonid spawning attraction flows in excess if 3500 cfs at Vernalis should be provided for 10-14 days during October, using coordinated releases from the SJ River and tributaries. For remainder of fall, Delta inflows would be determined by the minimum instream flow requirements of the SJ River basin and east side tributaries. Upstream flow levels would likely be increased to meet the Delta outflow recommendations.
55	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54). "Although USFWS (1995) previously recommended spring Delta inflows ranging from 4,050 cfs to 15,750 cfs at Vernalis based upon of regression models of Chinook salmon smolt survival. The current D-1641 flow minimums range from 3,110 cfs to 8,620 cfs (Table 1-5), depending upon water year type, have never been fully implemented. In addition to baseline flows, for the benefit of rearing Chinook salmon and other native fishes, floodplain activation flows should be provided..."
56	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.51-52). Winter Inflows - Minimum flows at Vernalis and the eastside tributaries should be coordinated to maintain net seaward flows at Jersey Point of 1000 cfs in Critical and Dry years, 2000 cfs in Below and Above Normal years, and 3000 cfs in Wet years (USFWS 1995 3-Xe-19). Net seaward flows for benefit of outmigrating juvenile salmon.
57	EDF / Stillwater	SJ River Inflow	EDF / Stillwater Exh 1 (focal species approach, pp.54-55). For the benefit of rearing chinook salmon and other native fishes, floodplain activation flows should be provided of 14800 cfs in the lower SJ River in Above Normal and Wet water year types. A series of pulse flows instead of a single extended high flow event might also be used to achieve the desired target of continuous days of inundated floodplain. Goal for combined winter and spring floodplain activation flows is to maintain inundated seasonal floodplain habitat conditions (or the potential for such conditions in sites where floodplain restoration actions may be undertaken in the future) in the lower SJ River during Jan through Apr for a minimum of 21 and 35 consecutive days in Above Normal and Wet water year types, respectively. For the purposes of this assessment, Stillwater allocated the Delta inflows for floodplain inundation to February and March. Also discusses inundation of Cosumnes River floodplain.
58	USFWS	SJ River Inflow	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 56-57 and 25. Quote in table from p.56-57. "The Anadromous Fish Restoration Program has developed estimates of flow levels needed at Vernalis to achieve a 53% increase (page 9) and a doubling (page 10) in predicted Chinook salmon production for the basin (USFWS, 2005). These Vernalis flow criteria vary by water year type and by month between February and May. We recommend these flows as starting point for establishing minimum and maximum volume of flow for increasing juvenile salmon and steelhead survival in the San Joaquin basin." (p.25).
59	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP). Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Salmon doubling - total average flow (Stanislaus, Tuolumne, Merced) that would be expected to double the total predicted Chinook salmon production for the basin.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
60	AFRP	SJ River Inflow	Anadromous Fish Restoration Program (ARFP) - Recommended streamflow schedules to meet the AFRP Doubling Goal in the San Joaquin River Basin (USFWS, 27 Sept 2005). Total average flow (Stanislaus, Tuolumne, Merced) that would be expected to achieve a 53% increase in total predicted Chinook salmon production for the basin.
61	NMFS	SJ River Inflow	NMFS OCAP Bio Opinion, Action IV.2.1 (pp.641-644) San Joaquin River Inflow to Export Ratio - both interim (2010-2011) and long-term (beginning in 2012) requirements are stipulated. Interim flows are based on maintaining a minimum status quo for SJ River basin salmonid populations. Long term flow schedules for the SJ River are expected to result from SWRCB proceedings on SJ River flows. Export limitations and flows are also described on pp. 642-644
62	NMFS	SJ River Inflow	NMFS_Exh9 (from AFRP 1995) - Sturgeon (Green and White), mean monthly flows - ensure suitable conditions for sturgeon to migrate and spawn and for progeny to survive.
63	UCDavis - Delta Solutions Group	SJ River Inflow	Functional Flows 3a - transport juvenile salmon (references USFWS Exhibit 31, 1987; Newman and Rice 2002; Williams 2006) - wet years - 20000 cfs, Apr-Jun (2 out of 10 years); AN years - 15000 cfs, April - Jun 15 (4 out of 10 years); BN years - 10000 cfs, Apr-May (6 out of 10 years); Dry years - 7000 cfs, Apr-May 15 (8 out of 10 years); and Critical years - 5000 cfs, Apr (10 out of 10 years). Functional Flows 3c - adult salmon recruitment (reference USFWS Exhibit 31, 1987) - 2000 cfs year round (10 out of 10 years) (flows were not experienced in unimpaired conditions, but likely result from the disturbed conditions). Functional Flows 3b - Improve DO conditions in DWSC (2000 cfs, July-Oct, all years) (Lehman et al 2004, Jassby and VanNieuwenhuyse 2005).
64	D1641	OMR	Export/Inflow ratio - the maximum percent Delta inflow diverted for Feb may vary depending on the Jan 8RI (see D1641)
65	D1641	OMR	SWP/CVP Export Limit - All water year types, Apr 15 - May 15, the greater of 1500 cfs or 100% of 3-day avg. Vernalis flow. Maximum 3-day average of combined export rate (cfs), which includes Tracy Pumping Plant and Clifton Court Forebay Inflow less Byron-Bethany pumping. The time period may need to be adjusted to coincide with fish migration. Maximum export rate may be varied by CalFed Ops Group.
66	Draft D1630	OMR	Reverse flow restrictions for all year types are relaxed when combined CVP and SWP exports are < 2000 cfs. Export pumping restriction is relaxed for all year types when Delta outflow > 50000 cfs, except for the export pumping restriction during the SJ River pulse period. July 1 - Jan 31 - 14-day running average flow (as calculated in DAYFLOW), these restrictions do not apply whenever the EC at the Mallard Slough monitoring station is < 3 mmhos/cm. QWEST standards in 1630 discussed in DOI submittal, p.53, section concerning reverse flows.
67	CSPA / C-WIN	OMR	CSPA closing comments, C-WIN closing comments, CSPA_Exh1_Jennings. Combined export rates would be 0 cfs in all years from March 16 through June 30. Prevent entrainment and keep migration corridors open to maximize salmon juvenile and smolt survival. Facilitate SJ River salmonid migration down Old River.
68	CSPA / C-WIN	OMR	CSPA and C-WIN closing comments - flow direction, entrainment protection and provision of migration corridors

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
69	CSPA / C-WIN	OMR	SJ River at Jersey Point flow recommendations (positive 14-day mean flows). Source: CSPA_exh1_Jennings_test; CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p.11, flows at Jersey Pt from Apr 1 through June 30, salmon); AFRP Working Paper, 1995, p. 3-Xe-19 (salmon). Function maintain positive flow for salmonid smolt outmigration and protect Delta smelt, originally two separate recommendations. DS - Feb 1 - Jun 30, Salmon - Oct 1 - Jun 30, only difference between flow recommendations where overlap occurred was DS in AN years = 2500 cfs, salmon in AN years = 2000. For this table, recommendations merged and 2500 cfs used for AN years (+DFG Exh 8 recommends 2500 cfs in AN years)
70	TBI / NRDC	OMR	TBI/NRDC closing comments (Table 4). The hydrodynamic recommendations expressed as Vernalis flow and/or export to inflow ratios in TBI/NRDC Exh4 (Delta Hydrodynamics, p.30) were converted to OMR flows, using the San Joaquin flow recommendations as described in TBI/NRDC Exh 3 (Delta Inflows), for inclusion in Table 4. Note: recommended OMR flows assume SJ River flows recommended in TBI Exhibit 3 are also implemented. (*) - when the previous longin smelt FMWT index <500, OMR flows in Jan-Mar are >0. This corrects a typographical error in the table on p.30 of TBI Exhibit 4
71	AFRP	OMR	Anadromous Fish Restoration Program (ARFP) (Working Paper on Restoration Needs, Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California, Volume 3, 1995, p. 3-Xe-19). Action 3 - Maintain positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in Critical and Dry years, 2000 cfs in below- and above normal years, and 3000 cfs in wet years from Oct 1 through June 30. Objective - Increase survival of smolts migrating down the mainstem rivers, decrease the number of smolts diverted into the central Delta, increase the survival of smolts diverted into the central Delta, and provide attraction flows for San Joaquin Basin adults (Oct - Dec).
72	NMFS	OMR	NMFS OCAP Bio Opinion, Action IV.2.3 - Old and Middle River Flow Management (pp. 648-652). See action triggers on pp. 648-650. Actions will be taken in coordination with USFWS RPA for Delta Smelt and State-listed longfin smelt 2081 incidental take permit. During the Jan 1 - Jun 15 period, the most restrictive export reduction shall be implemented.
73	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 50, 53, and 24-25 (references USFWS 1992; AFRP Working Paper p.3-Xe-19, USFWS 2005, Restoration Action #3; D-1630, pp44-47). "Based on the scientific information we reviewed, the Board should develop reverse flow criteria that would maintain the Old and Middle river flow positive during key months (January through June) of the year to protect important public trust resources in the Delta" (p.53).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
74	USFWS	OMR	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 24,25, and 53. "In a previous Board exhibit (USFWS, 1992), we showed a positive relationship between temperature corrected juvenile survival indices and flow at Jersey Point for marked fish released at Jersey Point (QWEST) (USFWS, 1992, p.21). In addition, the AFRP Working Paper (USFWS, 1995) Restoration Action #3 calls for maintaining positive QWEST flows, or an equivalent measure of net seaward flows at Jersey Point, of 1000 cfs in critical and dry years, 2000 cfs in below- and above-normal years, and 3000 cfs in wet years from Oct 1 through June 30. Higher flow at Jersey Point has been provided during the VAMP period (mid-April to mid-May) with the adoption of VAMP flows and exports. We encourage the Board to retain or expand this
74 cont	USFWS	OMR	type of action to assure the contribution of downstream flow from the San Joaquin Basin to Delta outflow for the protection of juvenile and adult salmonids migrating from the San Joaquin basin."
75	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 1 - Adults (Dec - Mar) - Action 1 (protect upmigrating delta smelt) - once turbidity or salvage trigger has been met, -2000 cfs OMR for 14 days to reduce flows towards the pumps. Action 2 (protect delta smelt after migration prior to spawning) - OMR range between -1250 and -5000 cfs determined using adaptive process until spawning detected. pp.280-282
76	USFWS	OMR	USFWS OCAP Bio Opinion - RPA re: OMR flows. Component 2 - Larvae/Juveniles - action starts once temperatures hit 12 degrees C at three delta monitoring stations or when spent female is caught. OMR range between -1250 and -5000 cfs determined using adaptive process. OMR flows continue until June 30 or when Delta water temperatures reach 25 degrees C, whichever comes first. pp. 280-282
77	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 9-10, Condition 5.1. This Condition is not likely to occur in many years. To protect adult longfin smelt migration and spawning during December through February period, the Smelt Working Group (SWG) or DFG SWG personnel staff shall provide OMR flow advice to the Water Operations Management Team (WOMT) and to Director of DFG weekly. The SWG will provide the advice when either: 1) the cumulative salvage index (defined as the total longfin smelt salvage at the CVP and SWP in the December through February period divided by the immediately previous FMWT longfin smelt annual abundance index) exceeds five (5); or 2) when a review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt indicate OMR flow advise is warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average is no more negative than -5000 cfs and the initial 5-day running average is not more negative than -6250 cfs. During any time OMR flow restrictions for
77 cont	CDFG	OMR	the FWS's 2008 Biological Opinion for delta smelt are being implemented, this condition (5.1) shall not result in additional OMR flow requirements for protection of adult longfin smelt. Once spawning has been detected in the system, this Condition terminates and 5.2 begins. Condition 5.1 is not required or would cease if previously required when river flows are 1) > 55000 cfs in the Sac River at Rio Vista; or 2) > 8000 cfs in the SJ River at Vernalis. If flows go below 40000 cfs in the Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the OMR flow in Condition 5.1 shall resume if triggered previously. Review of survey data and other pertinent biological factors that influence the entrainment risk of adult longfin smelt may result in a recommendation to relax or cease an OMR flow requirement.

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
78	CDFG	OMR	Longfin Smelt Incidental Take Permit (2009), p. 10-11, Condition 5.2. To protect larval and juvenile longfin smelt during Jan-June period, the SWG or DFG SWG personnel shall provide OMR flow advice to the WOMT and the DFG Director weekly. The OMR flow advice shall be an OMR flow between -1250 and -5000 cfs and be based on review of survey data, including all of the distributional and abundance data, and other pertinent biological factors that influence the entrainment risk of larval and juvenile longfin smelt. When a single Smelt Larval Survey (SLS) or 20 mm Survey sampling period results in: 1) longfin smelt larvae or juveniles found in 8 or more of the 12 SLS or 20mm stations in the central and south Delta (Stations 809, 812, 901, 910, 912, 918, 919) or, 2) catch per tow exceeds 15 longfin smelt larvae or juveniles in 4 or more of the 12 survey stations listed above, OMR flow advice shall be warranted. Permittee shall ensure the OMR flow requirement is met by maintaining the OMR flow 14-day running average no more negative than the required OMR flow and the 5-day running average is within 25% of the
78 cont	CDFG	OMR	required OMR. This Conditions OMR flow requirement is likely to vary throughout Jan through June. Based on prior analysis, DFG has identified three likely scenarios that illustrate the typical entrainment risk level and protective measures for larval smelt over the period: High Entrainment Risk Period: Jan - Mar OMR range from -1250 to -5000 cfs; Medium Entrainment Risk Period: April and May OMR range from -2000 to -5000 cfs, and Low Entrainment Risk Period: June OMR -5000 cfs. When river flows are: 1) greater than 55000 cfs in the Sac River at Rio Vista; or 2) greater than 8000 cfs in the SJ River at Vernalis, the Condition would not trigger or would be relaxed if triggered previously. Should flows go below 40000 cfs in Sac River at Rio Vista or 5000 cfs in the SJ River at Vernalis, the Condition shall resume if triggered previously. In addition to river flows, the SWG or DFG SWG personnel review of all abundance and distribution survey data and other pertinent biological factors that influence the entrainment risk of longfin smelt may result in a recommendation by DFG to WOMT to relax or cease an OMR flow requirement.
79	CDFG	Floodplain	DFG_Closing: DFG Exhibit 1, Page 13. Sacramento Splittail - floodplain inundation (habitat) - incubation, early rearing, egg and larval habitat and survival
80	USFWS	Floodplain	USFWS testimony concerning scientific information used to determine flow criteria. Source: U.S. Department Of the Interior - Comments Regarding the California State Water Resources Control Board's Notice of Public Informational Proceeding to Develop Delta Flow Criteria for the Delta Ecosystem Necessary to Protect Public Trust Resources, Sections II and III, pages 28 and 54. "The Board should consider the importance of more frequent floodplain inundation (especially Yolo Bypass flows) when determining the Delta outflows needed to restore the Delta ecosystem pursuant to the Board’s public trust responsibilities" (p.28). "The Yolo Bypass floods via the Fremont Weir when flows on the Sacramento River exceed approximately 70,000 cfs, which it currently does in about 60% of years (Feyrer, et al. 2006). Flows on the Sacramento River should therefore exceed 70,000 cfs in at least six out of ten years. Recent historical floodplain inundation events are shown in Figure 4 (Sommer et al., 2001)" (p.54).

Appendix A, Table 7. Notes for Tables 1 through 6.

No.	Entity	Type	Notes (excerpts from source documents)
81	NMFS	Floodplain	NMFS OCAP Bio Opinion, Action I.6.1 - Restoration of Floodplain Rearing Habitat. p.608. " Objective: To restore floodplain rearing habitat for juvenile winter-run, spring-run, and CV steelhead in the lower Sacramento River basin. This objective may be achieved at the Yolo Bypass, and/or through actions in other suitable areas of the lower Sacramento River. Action: In cooperation with CDFG, USFWS, NMFS, and Corps, Reclamation and DWR shall, to the maximum extent of their authorities, provide significantly increased acreage of seasonal floodplain rearing habitat, with biologically appropriate durations and magnitudes, from December through April, in the lower Sacramento River basin, on a return rate of approximately one to three years, depending on water year type. In the event this action conflicts with Shasta Operations Actions I.2.1 to I.2.3., the Shasta Operations Actions shall prevail." By December 31, 2011, Reclamation and DWR shall submit to NMFS a plan to implement this action.
82	NMFS	Floodplain	NMFS - Public Draft Recovery Plan for the ESUs of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the DPS of Central Valley Steelhead (October 2009), Section 1.5.5, p.157. "Enhance the Yolo Bypass by re-configuring Fremont and Sacramento weirs to: (1) all for fish passage through Fremont Weir for multiple species; (2) enhance lower Putah Creek floodplain habitat; (3) improve fish passage along the toe drain/Lisbon weir; (4) enhance floodplain habitat along the toe drain; and (5) eliminate stranding events;and (6) create annual spring inundation of at least 8000 cfs to fully activate the Yolo Bypass floodplain."
83	D1641	DCC	For the May 21 - June 15 period, close the Delta Cross Channel gates for a total of 14 days per CALFED Ops Group. During the period the DCC gates may close 4 consecutive days each week, excluding weekends
84	Draft D1630	DCC	When monitoring indicates that significant numbers of salmon smolts or striped bass eggs and larvae are present or suspected to be present, the Executive Director (ED) or his designee shall order USBR to close the gates. The ED, with advice from other agencies, will develop specific monitoring and density criteria for closing and opening the gates.
85	CSPA / C-WIN	DCC	CSPA_Exh1_Jennings, C-WIN closing comments. Source CDFG_1992_WRINT-DFG-Exhibit #8, Alt C (p10). Function: reduce entrainment of Sacramento salmon smolts into the interior Delta
86	NMFS	DCC	NMFS OCAP Bio Opinion, Action Suite IV.1 (pp. 631-640)
87	EDF / Stillwater	Ouflow	EDF_Closing Comments (Table 1) - Mean Historical Delta Outflow Volumes (TAF) for 1956-2003 by month and water year type. Historical and unimpaired flow values are based on Water Years 1956-2003 using California Central Valley Unimpaired Flow Data, 4th ed. (CDWR 2007). In instances where there was a difference between Dry and Critically Dry years, the value for Critically Dry years was selected. Originally reported as volume (TAF). Conversion calculated as follows: (TAF/month)(1000 AF/TAF)(43560 ft3/AF)(month/X days)(day/86400 sec)

Appendix B: Enacting Legislation

California Water Code, Division 35 (Sacramento-San Joaquin Delta Reform Act of 2009), Part 2 (Early Actions), Section 85086

(a) The board shall establish an effective system of Delta watershed diversion data collection and public reporting by December 31, 2010.

(b) It is the intent of the Legislature to establish an accelerated process to determine instream flow needs of the Delta for the purposes of facilitating the planning decisions that are required to achieve the objectives of the Delta Plan.

(c)

> (1) For the purpose of informing planning decisions for the Delta Plan and the Bay Delta Conservation Plan, the board shall, pursuant to its public trust obligations, develop new flow criteria for the Delta ecosystem necessary to protect public trust resources. In carrying out this section, the board shall review existing water quality objectives and use the best available scientific information. The flow criteria for the Delta ecosystem shall include the volume, quality, and timing of water necessary for the Delta ecosystem under different conditions. The flow criteria shall be developed in a public process by the board within nine months of the enactment of this division. The public process shall be in the form of an informational proceeding conducted pursuant to Article 3 (commencing with Section 649) of Chapter 1.5 of Division 3 of Title 23 of the California Code of Regulations, and shall provide an opportunity for all interested persons to participate. The flow criteria shall not be considered predecisional with regard to any subsequent board consideration of a permit, including any permit in connection with a final BDCP.
>
> (2) Any order approving a change in the point of diversion of the State Water Project or the federal Central Valley Project from the southern Delta to a point on the Sacramento River shall include appropriate Delta flow criteria and shall be informed by the analysis conducted pursuant to this section. The flow criteria shall be subject to modification over time based on a science-based adaptive management program that integrates scientific and monitoring results, including the contribution of habitat and other conservation measures, into ongoing Delta water management.
>
> (3) Nothing in this section amends or otherwise affects the application of the board's authority under Part 2 (commencing with Section 1200) of Division 2 to include terms and conditions in permits that in its judgment will best develop, conserve, and utilize in the public interest the water sought to be appropriated.

(d) The board shall enter into an agreement with the State Water Project contractors and the federal Central Valley Project contractors, who rely on water exported from the Sacramento River watershed, or a joint powers authority comprised of those contractors, for reimbursement of the costs of the analysis conducted pursuant to this section.

(e) The board shall submit its flow criteria determinations pursuant to this section to the council for its information within 30 days of completing the determinations.

Going with the flow: the distribution, biomass and grazing rate of *Potamocorbula* and *Corbicula* with varying freshwater flow (May and October 2009-2011).

J. Thompson[1], K. Gehrts[2], F. Parchaso[1], H. Fuller[2]

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Summary of findings:

Spatially intensive benthic samples from >200 stations were analyzed for bivalve biomass, filtration rate, grazing rate, and water column turnover rate for three Octobers (2009-2011) to determine if the increased freshwater flow in fall 2011 would decrease the bivalve grazing in the low salinity zone in fall. Relative to the previous two dry years, the biomass of bivalves was decreased in the shallow portions of Grizzly and Honker Bays and in Western Suisun Marsh (including Montezuma and Suisun Slough) in 2011. The reduction in biomass was sufficient to limit the potential for bivalves to control phytoplankton biomass accumulation in fall. It is likely they could decrease the phytoplankton biomass by their feeding, but they did not have a sufficient grazing rate to exceed the phytoplankton growth rate during fall 2011, if the phytoplankton growth rate is assumed to be similar to that observed by Kimmerer et al. (2012) in 2006-2007.

Introduction

The POD conceptual model recognizes that food limitation may be contributing to the decline of Delta Smelt (Baxter et al. 2008). The questions of how food has changed during the POD years and the factors responsible for those changes have not been resolved. We know that the variability in salinity decreased in late summer and fall during the POD and that Delta Smelt are mostly in the low salinity zone (LSZ) during this period. There are several components of the LSZ food web that might be affected by this change in salinity. We discuss here the response of the benthic bivalves and how their change in biomass in space and time might reduce phytoplankton, copepods, bacteria, and possibly microzooplankton.

The distributions of *Potamocorbula amurensis* (*Potamocorbula* hereafter) and *Corbicula fluminea* (*Corbicula* hereafter) are dependent on the salinity distribution at the time their larvae are available for settlement, the number of adults present in the area of settlement, and the environmental stresses on the population after settlement. Field data shows that these bivalves overlap within the LSZ region which is consistent with laboratory studies on the juvenile/larval salinity tolerances for both species (Nicolini and Penry 2000, McMahon 1999). Based on data collected for the Environmental Monitoring Program Benthic Program we know that *Potamocorbula* is more persistent and is a larger presence in the LSZ than is *Corbicula*. We have also observed that the pattern is reversed upriver of the LSZ where the freshwater clam, *Corbicula*, becomes the dominant form. It is important to understand the dynamics of both clams as previous field (Thompson et al 2008, Lopez et al. 2006) and modeling (Lucas et al 2002, Lucas et al 2009) work has shown that both bivalves can limit phytoplankton biomass in the bay and delta. In addition, experimental work has shown zooplankton nauplii and ciliates can be filtered out of the water column by *Potamocorbula* in the bay (Kimmerer et al 1994, Greene et al 2011). *Corbicula* can filter fast-moving ciliates (Scherwass et al 2001) and glochidia (Scherwass et al 2005) but there have been no experiments on their ability to filter copepod nauplii. Thus, *Potamocorbula* may limit food supplies in the LSZ and both *Potamocorbula* and *Corbicula* may consume phytoplankton and zooplankton as it is transported towards the LSZ although *Corbicula* are likely to dominate in this upstream habitat in most years.

Because Delta Smelt feed on zooplankton (mostly calanoid copepods, Nobriga 2002) throughout their lives, any direct reduction in zooplankton through filtration by bivalves or indirect reduction in zooplankton due to food limitation needs to be examined. Thus, this project concentrated on the magnitude of bivalve grazing within the LSZ, within the tidal dispersion zone of the LSZ, and upstream of the LSZ during the fall periods.

Bivalve conceptual models

The distribution and dynamics of *Potamocorbula* and *Corbicula* are based on their physiological salinity limits and their life history characteristics. As explained below, *Potamocorbula* is the dominant grazer within the LSZ and *Corbicula* is the dominant grazer upstream of X2. As X2 and the LSZ moves up- and down-bay, the overlapping region of *Corbicula* and *Potamocorbula* moves with it so we will always have to consider both species when we examine foodweb dynamics in the LSZ. In addition, declines in phytoplankton biomass can not be assumed to be due to local grazing due to the tidal dispersion of pelagic particles and thus grazing must be assessed in regions within the tidal dispersion sphere of influence. The major difference in *Potamocorbula* and *Corbicula* other than their salinity tolerance is their method and season of reproduction that determines their distribution within their salinity range and their response to the fall increase in salinity intrusion.

Potamocorbula

Potamocorbula is a dioecious (sexes are separate), fecund (45,000-220,000 oocytes), broadcast spawning bivalve with external fertilization, a short lived non swimming trochophore larvae and a motile suspension feeding veliger larvae. Both larval stages have a broad salinity tolerance (2-30). The larvae settle at day 17-19 and thus can be moved by the currents for substantial distances before settling.

Potamocorbula recruitment usually occurs in the western Delta in fall and in the northern estuary in early spring through fall (Parchaso and Thompson 2002). Thus larvae have been available to respond to the recent fall periods of increasing salinity. We observed an increase in the biomass and abundance of *Potamocorbula* at Chipps Island in late 1999 and early 2000 (USGS unpublished data). We hypothesize that the increasing salinity in fall that began in 1999 allows fall larvae to settle further upstream. The high salinity may also allow *Potamocorbula* that settles in previously marginal salinity zones to persist, because individuals have grown sufficiently large in fall to become more tolerant of environmental stresses during the following winter.

The antidote to this fall incursion of bivalves is a large outflow event such as was seen in spring 2006. The mass mortality in spring 2006, observed as a drop in abundance and biomass of *Potamocorbula* to near zero at a Chipps Island station (USGS unpublished data), was short lived. The recruitment and subsequent biomass was very high in the fall of 2006 at that location because there were no adults to interfere with the larvae, and the salinity was high enough for a long enough period to allow the recruits to grow and persist. The elevated fall 2006 biomass then carried into the spring of the following year when Delta outflow was again low. We hypothesize that the effect of the recent increases in fall salinity was an increase in recruitment of *Potamocorbula* in traditionally lower salinity areas. The corollary to this hypothesis is that if these animals are given sufficient time to grow they become more resistant to osmotic and physical stresses during the winter peaks in Delta outflow which results in higher grazing rates in the following spring than we might expect with normal fall salinity distributions.

Corbicula

Corbicula is a simultaneous hermaphrodite (Kraemer and Galloway 1986) thereby making it possible for one individual to establish a population. Adults hold unfertilized eggs until there is sufficient food at which time they produce sperm and the eggs are fertilized. The larvae (pediveligers) develop in 3-5 days, are brooded in the gills of the adult before release, cannot swim but are found in the plankton for their first 48 hours, and are limited to salinities ≤2. They depend on their small size (200 µm) and mass (0.1 mg dry weight) to allow currents to re-suspend and transport them after settling (Aldridge and McMahon 1978). As a freshwater bivalve, this strategy is good for moving larvae downstream with the currents but may be less effective at widening their distribution throughout the system. It is not surprising that *Corbicula*, as a freshwater bivalve, would have an opposite reproductive seasonality to that of *Potamocorbula*. Eng (1979) and Heinsohn (1958) found a large spawning peak in the spring followed by a smaller fall peak in the Delta. If this reproductive seasonality persists today then *Corbicula* is most likely to expand down river and down-bay in the spring but its expansion into new down bay areas is likely to be limited in fall by the increasing salinity.

Methods

The DWR EMP program sampled 175 benthic stations (single sample at each location with a $0.05m^2$ bottom grab) throughout the Delta and northern bay in one week in May and October from 2007-2011 (Figure 1). The sampling design (generalized random tessellated stratified design) allows for a random selection of stations in various strata which DWR defined as habitat type (lake, large river, river, slough, bay, large bay). The station locations changed each year for all but 50 stations (the annual panal) which were sampled throughout the program. Twenty two additional stations were added beginning in October 2009 to establish channel-shoal pairings at some locations to determine if shallow locations had significantly different bivalve populations than their adjacent channel stations. In order to focus on the low salinity zone and it’s nearby habitat, we further parsed the strata into the following regions (Figure 2): Grizzly/Honker Bays (≤4m), Shallow Suisun Bay (not in channel and <7m), Channel Suisun Bay, Lake (Big Break and Sherman Lake with adjoining sloughs), Western Suisun Marsh (Suisun Slough, Montezuma Slough west of Nurse Slough), Eastern Suisun Marsh (Montezuma Slough east of Nurse Slough), and Confluence (Sacramento River up to Browns Island, San Joaquin River to False River out of Franks Tract).

Samples were sieved through 0.5mm screens, preserved in 10% formalin in the field, and changed to 70% alcohol at 1-2 weeks. Samples of live bivalves were collected at annual panel stations to estimate weight as a function of length; clams were measured, dried, weighed, ashed, and reweighed to determine ash-free dry weight (AFDW). Samples were sorted by a contractor (Hydrozoology) and returned to DWR. Bivalves from all samples were measured using an image analyzer or hand calipers and length of each animal in each sample was converted to AFDW using the live animal length to weight conversions calculated at the annual panel stations. Biomass at a station was estimated by summing these values.

Consumption rate was estimated two ways. The first rate, the filtration rate, is the highest consumption rate that we would expect. Filtration rate is the product of bivalve biomass and species specific pumping rates (PR's) which were adjusted for temperature. *Potamocorbula* pumping rates have been estimated at two temperatures to be ≈400 L $(gAFDW)^{-1}d^{-1}$ at temperatures ≥15°C and 270 L $(gAFDW)^{-1}d^{-1}$ at temperatures <15°C (Cole et al. 1992). *Corbicula* pumping rate was determined at four temperatures by Foe and Knight 1986) and data were fitted to an exponential model which was then used to determine temperature specific pumping rates. Filtration rates assume no depletion boundary layer (the local reduction in food concentration when vertical mixing rate is too low to compensate for the loss due to consumption at the bed) and that animals filter all of the time. The second rate, the grazing rate, incorporates a concentration boundary layer and is smaller than the filtration rate when there are large populations. Filtration rates were converted to grazing rates by reducing the pumping rates to adjust for the presence of a concentration boundary layer. This adjustment was based on O'Riordan's (1995, Figure 7b) refiltration relationship, $n_{max} = F_c/(s/d_o)$, where $n_{\max}$ is the maximum refiltration proportion (ie the proportion of water previously filtered), F_c is a species specific refiltration factor determined in the laboratory for *Potamocorbula* (2.5) and *Venerupis* (3.0, similar to *Corbicula* in size and habit), s is the distance between siphon pairs, and d_0 is the diameter of the excurrent siphon. The diameter of the excurrent siphon was changed throughout each year to reflect the change in average size of animals as the year progressed, and the distance between siphon pairs was based on density of animals observed in our benthic sampling assuming equidistant spacing within the 0.05 m^2 grab. The use of maximum refiltration proportion maximizes the effect of the concentration boundary layer resulting in a conservative grazing rate estimate. The combined use of filtration rate and grazing rate should give a reasonable range of possible consumption rates. We assumed all bivalves grazed continuously.

Data and Approach

Biomass, filtration rate, grazing rate and grazing rate water column turnover rate have been calculated for each region and are summarized in Tables 1-4. Water column turnover rate is a method of normalizing grazing and filtration rates by depth of the water column. The resulting number is more intuitive of the bivalves effect on pelagic particles (biologic and refractory) than grazing rate because it reflects the number of times in a day that a population could filter the overlying water column if the water was stationary. With this value, the importance of water depth becomes apparent; if it is assumed that the same population lived on the bottom of a 1m vs a 10m water column, the bivalves would filter the 1 m water column ten times the rate at which they filter the deeper water column.

The data are not normally distributed and regions have unequal number of samples so non-parametric measures of statistical significance (Kruskal-Wallis) have been used to compare regions and time periods. As with most benthic data, the median value is shown in plots because it is the best way to eliminate the influence of one very high or very low value in a region.

Findings

General Distribution Patterns

When the entire sampling domain with the data from all three years is combined, there are several observations that can be made about persistent patterns that don't seem to be affected by water year type (Figures 3 and 4a). First *Potamocorbula* has a larger presence, and thus larger filtration rate in fall than spring, and the opposite is true of *Corbicula*. Second, *Potamocorbula* have very low filtration rates in the spring in the shallows of Grizzly and Honker Bays for all three years. Third, filtration rates for both bivalves in the lower reaches of Sacramento and San Joaquin Rivers (just upstream of confluence) are consistently lower than the surrounding areas and there appears to be less seasonality in this region than in the rest of the system.

These persistent distribution patterns become even more apparent when we narrow the focus to the LSZ (Figure 4b). We can also see that the area where the two bivalve species overlaps can be described as within and just upstream of the confluence and on the eastern end of Montezuma Slough (east of Nurse Slough). When the distributions are plotted separately for each year (Figure 5a) and compared for May and October we see that the zone of overlap in May is within the range of X2 over the previous 6 months with a few exceptions in 2009-2010. In 2011 *Potamocorbula* were consistently upstream of the maximum X2 in the previous 6 months. This pattern persists into fall 2011 with *Potamocorbula* being observed upstream of the X2 maximum in all years (Figure 5b). Unlike May 2011, the October 2011 distribution showed some *Corbicula* within the X2 range.

Differences between years in regions (Fall 2009-2011)

When the filtration rates, grazing rates, and water column turnover rates are compared between years within the regions, only the values in the Grizzly/Honker Bay shallows and the Western Suisun Marsh showed a statistically significant difference between years (Kruskal-Wallis, $p<0.05$). Grizzly/Honker bay biomass, filtration, grazing, and turnover rates were all similar in 2009 and 2010 but were significantly less in 2011 than in 2010 (Figure 6a, 6b). The western Suisun Slough rates were similar in 2009 and 2010 but the 2011 rates were different from both the 2009 and 2010 rates (Figure 7a, 7b). The location of these decreased grazing rates is important as we might expect pelagic primary producers to do best in the shallows of Grizzly and Honker Bays and we might expect that marsh production would have a better chance of reaching other consumers when the bivalve grazers were greatly reduced as seen in 2011.

Differences between areas in years (Fall 2009-2011)

Because we are most interested in the effect that the bivalve grazers have on the system, we will show grazing turnover rates in this section (data for other parameters are in tables 1-4). The pattern and values for grazing turnover rate were similar in 2009 and 2010 with the shallow regions, Grizzly/Honker Bay, Suisun Bay Shallow, and West Suisun Marsh, having much higher values than the remaining areas that are mostly upstream or deeper than these stations (Figures 8 and 9). The bimodal distribution of values highlights the significant differences in these groups. The Confluence region had significantly lower turnover rates than those observed in Grizzly/Honker Bay and in the West Suisun Marsh in both 2009 and 2010. The West Suisun Marsh also had significantly higher rates than were observed in Suisun Channel in 2009 and 2010. In addition the Confluence rates were significantly lower than the Grizzly/Honker Bay rates and the West Suisun Marsh rates were significantly higher than the rates in the Lakes region in 2010 Figure 9).

Grazing turnover rates in 2011were lower and the bimodal distribution of values was less pronounced. There were no significant differences between the regions with the median values fell between 0.1 and 0.5 d^{-1} (Figure 10).

Time Series in Grizzly/Honker Bay Shallows

Figures 11 and 12 show the full time series (May 2009-October 2011) for all parameters for the Grizzly/Honker Bay region. Because the shallow areas are the presumed source of locally grown phytoplankton, grazing in this region is the most likely to have an effect on net phytoplankton growth.

Biomass, filtration rate, grazing rate, and grazing rate turnover rate all show the same strong seasonal pattern which is expected since all values are derived from biomass. In this region, where the bivalves are almost all *Potamocorbula*, filtration rate is derived from biomass with one conversion factor. It should be noted that in other regions, where *Corbicula* and *Potamocorbula* occur together the conversions are less linearly related to biomass.

Spring filtration rates (medians of 0.2-0.3 m d^{-1}) are about an order of magnitude less than fall filtration rates (2, 4, and 1 m d^{-1}). Grazing rates showed a similar pattern with spring rates (0.2, 0.3, and 0.1 m d^{-1}) an order of magnitude less than fall rates (2, 3, 1 m d^{-1}). Grazing water column turnover rate was very low with populations needing 10-20 days to totally turnover the water column in spring (0.1, 0.1, 0.05 d^{-1}). Fall grazing turnover rates were much higher with populations turning over the water column every 1-2 days (0.6, 1, 0.4 d^{-1}). If we assume a spring phytoplankton growth rate of 0.5-0.6 d^{-1} (Kimmerer et al in press) we can state that the bivalves were unlikely to be a controlling factor on spring phytoplankton biomass accumulation in any year. Fall phytoplankton growth rates have not been recently measured but summer rates (0.7-1.0 d^{-1}) would be about equivalent to the loss rates by bivalves in 2009-2010 but not in 2011 when bivalve turnover rates (0.4 d^{-1}) were unlikely to limit a bloom from developing in the shallow water.

Significance of Findings

We saw a decline in bivalve biomass and therefore grazing rate during and following the increased freshwater flow in spring and fall 2011. In examining the shallow Grizzly and Honker Bay data we found that bivalve grazing was unlikely to have an impact on net phytoplankton growth in spring during any of the years examined (2009-2011). We also found that the fall grazing rates were sufficient to potentially limit phytoplankton biomass accumulation in 2009-2010 but not in 2011.

The reduction in bivalve biomass and therefore grazing in 2011 could be due to recruitment losses in spring or fall and our ongoing work with the monitoring station samples should help delineate the cause. We were surprised by the persistence of *Potamocorbula* in the confluence area in 2011 despite the down bay position of X2. Our present working hypothesis is that it is the salinity gradient and therefore change in salinity over short periods of time that is important in determining the distribution of both species rather than the absolute salinity at a location. If true, this hypothesis would support the presence of *Potamocorbula* upstream of X2 in spring 2011.

Next Steps

Fall Study: We will measure bivalves and calculate biomass, filtration rate and grazing rate of the bivalves in the May and October 2012 GRTS samples when the samples have been sorted. We are presently measuring bivalves in the monitoring stations to better determine the seasonality of recruitment of both species and to determine if there are interannual and spatial differences in recruitment. Recruitment patterns are a critical component in our understanding of why bivalves have limited success in some areas and during some periods. We are submitting abstracts for two posters for the Bay-Delta conference that will highlight what we learn about recruitment for each species.

HSG Study: We are finishing the analyses of the May 2011 data and when that is complete we will repeat the analysis done here on the samples from throughout the study domain. The values reported will include biomass, grazing and filtration rates, and recruit abundance and the analysis will include the effect of depth on these rates for each species.

The combination of analyses in both studies will give us an opportunity to examine if and when populations that settle in the fall are still present in spring and if these "carry-over" populations are adding a new dimension to the bivalve community seasonal patterns.

Literature Cited

Aldridge DW, and McMahon RF 1978. Growth, fecundity, and bioenergetics in a natural population of the freshwater clam, *C. fluminea malinensis* Philippi, from north central Texas. Journal of Molluscan Studies 44: 49-70.

Baxter R, Breuer R, Brown L, Chotkowski M, Feyrer F, Gingras M, Herbold B, Mueller-Solger A, Nobriga M, Sommer T, Souza K (2008) Pelagic Organism Decline Progress Report: 2007 Synthesis of Results, Sacramento

Cole BE, Cloern JE (1984) Significance of biomass and light availability to phytoplankton productivity in San Francisco Bay. Mar Ecol Prog Ser 17:15-24.

Eng LL. 1979. Population dynamics of the Asiatic clam, *C. fluminea fluminea* (Muller) in the concrete-lined Delta-Mendota Canal of central California. p. 39–168 in J. C. Britton (ed.), First International *C. fluminea* Symposium, Fort Worth, TX, Texas Christian University Research Foundation

Foe, C. and A. Knight. 1986. A thermal energy budget for juvenile Corbicula fluminea American Malacological Bulletin, Special Edition No. 2:143-150.

Greene VE, Sullivan LJ, Thompson JK, Kimmerer W. 2011. Grazing impact of the invasive clam *Corbula amurensis* on the microplankton assemblage of the northern San Francisco Estuary. Marine Ecology Progress Series, 431:183-193.

Heinsohn GE. 1958. Life history and ecology of the freshwater clam, *C. fluminea fluminea*. Santa Barbara, CA, University of California: 64.

Kimmerer WJ, Gartside E, Orsi JJ. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Mar Eco Prog Ser 324:207-218

Kimmerer WJ, Parker AE, Lidstrom UE, Carpenter EJ. 2012. Short-term and interannual variability in primary production in the low-salinity zone of San Francisco Estuary. Estuaries and Coasts. In press.

Kraemer L R and Galloway ML. 1986. Larval development of *C. fluminea fluminea* (Muller) (Bivalvia: C. flumineacea): an appraisal of its heterochrony. American Malacological Bulletin 4: 61-79.

Lopez CB, Cloern JE, Schraga TS, Little AJ, Lucas LV, Thompson JK, and Burau JR, 2006, Ecological values of shallow-water habitats: implications for restoration of disturbed ecosystems , Ecosystems 9: 422-440

Lucas LV, Cloern JE, Thompson JK, and Monsen NE, 2002, Functional variability of habitats in the Sacramento-San Joaquin Delta: restoration implications: Ecological Applications, v.12, no. 5, p. 1528-1547

Lucas LV, Thompson JK, Brown LR. 2009. Why are diverse relationships observed between phytoplankton biomass and transport time?. Limnol. Oceanog. 54(1):381-390

McMahon RF. 1999. Invasive characteristics of the freshwater bivalve *C. fluminea fluminea*. Nonindigenous Freshwater Organisms: Vectors, Biology, and Impacts. R. Claudi and J. H. Leach. New York, Lewis Publishers: 315-346.

McManus GB, York JK, Kimmerer WJ 2008. Microzooplankton dynamics in the low salinity zone of the San Francisco Estuary. Verh Internat Verein Limnol 30:196-202

Nicolini MH, Penry DL, 2000. Spawning, fertilization, and larval development of *Potamocorbula amurensis* (Mollusca: Bivalvia) from San Francisco Bay, California. Pacific Science, 54:377-388.

Nobriga ML 2002. Larval delta smelt diet composition and feeding incidence: environmental and ontogenetic influences. Calif Fish Game 88:149-164

O'Riordan, C.A., Monismith, S.G., Koseff, J.R., 1995. The effect of bivalve excurrent jet dynamics on mass transfer in a benthic boundary layer. Limnology and Oceanography 40 (2), 330-344.

Parchaso F, Thompson JK. 2002. The influence of hydrologic processes on reproduction of the introduced bivalve *Potamocorbula amurensis* in northern San Francisco Bay, California. Pacific Science, 56(3):329-345.

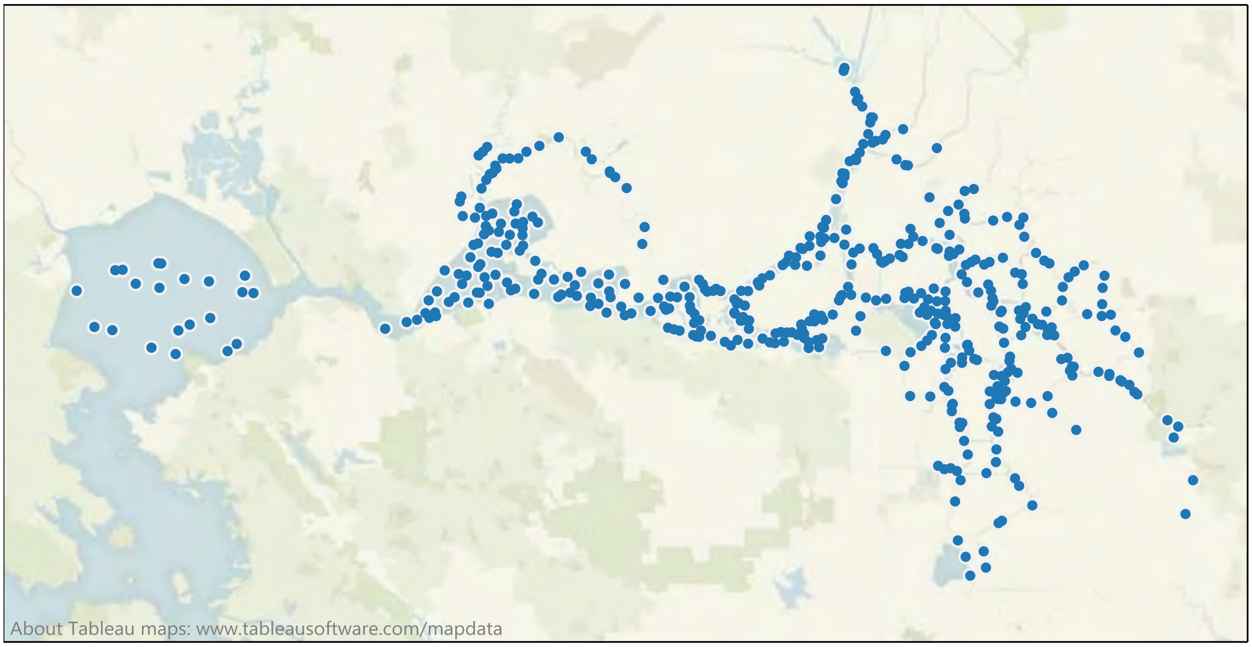
Scherwass A, Eimer A, and Arndt, H. 2001. Selective influence of filter-feeding benthic bivalves (*C. fluminea* sp., *Mytilus* sp.) on planktonic ciliates. Verh. Int. Verein. theor. angew. Limnol.: 27, 3315-3318.

Scherwass, A., Arndt, H. 2005. Structure, dynamics and control of the ciliate fauna in the potamoplankton of the river Rhine. Archiv für Hydrobiologie: 164(3), 287-307

Schlekat DW, Lee BG, Luoma SN, 2002. Assimilation of selenium from phytoplankton by three benthic invertebrates: effect of phytoplankton species. Mar Eco Prog Ser 237:79-85

Thompson JK, Koseff JR, Monismith SG, Lucas LV, 2008. Shallow water processes govern system-wide phytoplankton bloom dynamics: A field study. J Mar Syst 74:153-166

Werner I, Hollibaugh, JT, 1993. *Potamocorbula amurensis*: comparison of clearance rates and assimilation efficiencies for phytoplankton and bacterioplankton. Limnol Oceanogr 38:949-964.



ma

Map based on average of long and lat. The data is filtered on year, Panel and Strata. The year filter has multiple members selected. The Panel filte has multiple members selected. The Strata filter has multiple members selected

Figure 1. Composite (2007-2011) of all stations sampled by DWR in the GRTS benthic study.

Grizzly/Honker Bay

West Suisun
Sheet 3

Map based on long and lat. Color shows details about year. The data is filtered on Strata, Location and Sub habitat. The Strata filter keeps Bay and Slough. The Locatio
of Nurse Sl.. The view is filtered on year and Exclusions (lat,long,year). The year filter has multiple members selected. The Exclusions (lat,long,year) filter specifies a set

year

🟥 2009
🟧 2010
🟦 2011

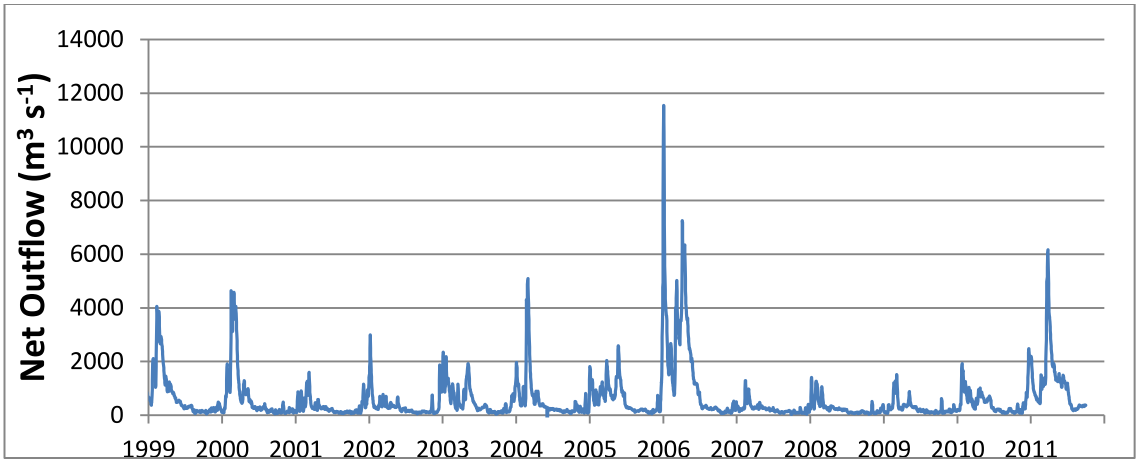


Figure 3. Net Delta Outflow for pelagic organism decline (1999- present). Note the years of the benthic study encompass a dry-below normal year (2009), a dry-above normal year (2010), and a wet year(2011).

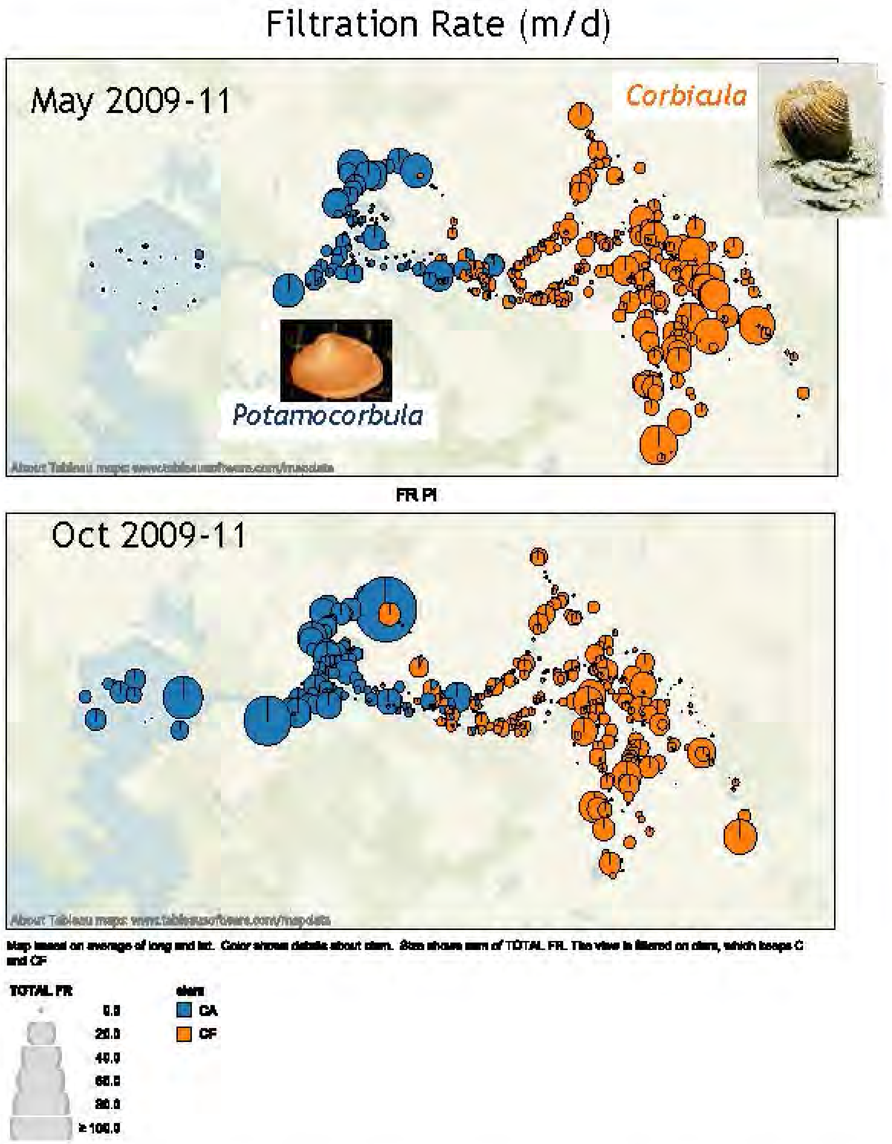


Figure 4a. Filtration rate for *Potamocorbula* (blue) and *Corbicula* for May and October of 2009-2011. The combination of data sets allows us to see persistent patterns that were not influenced by freshwater inflow during these three years.

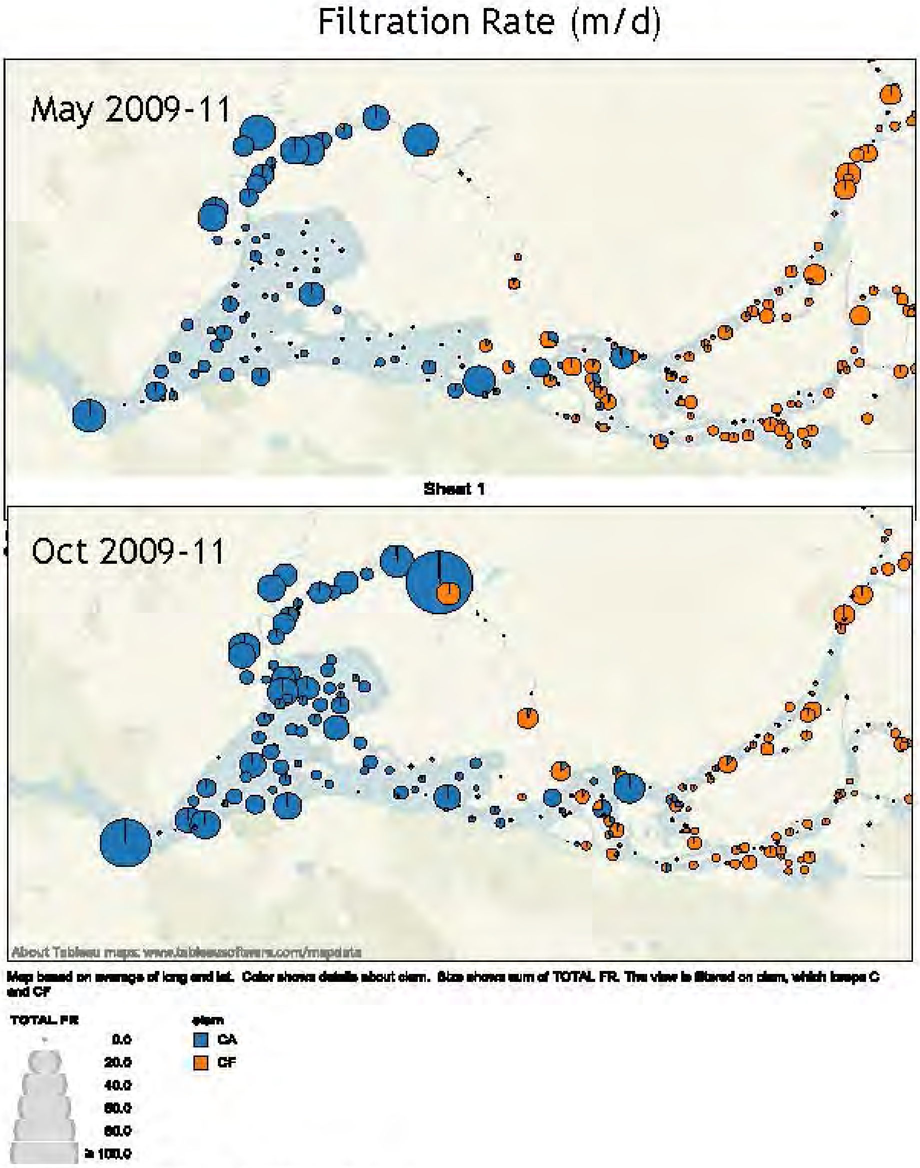


Figure 4b A close-up of the LSZ region in Figure 4a

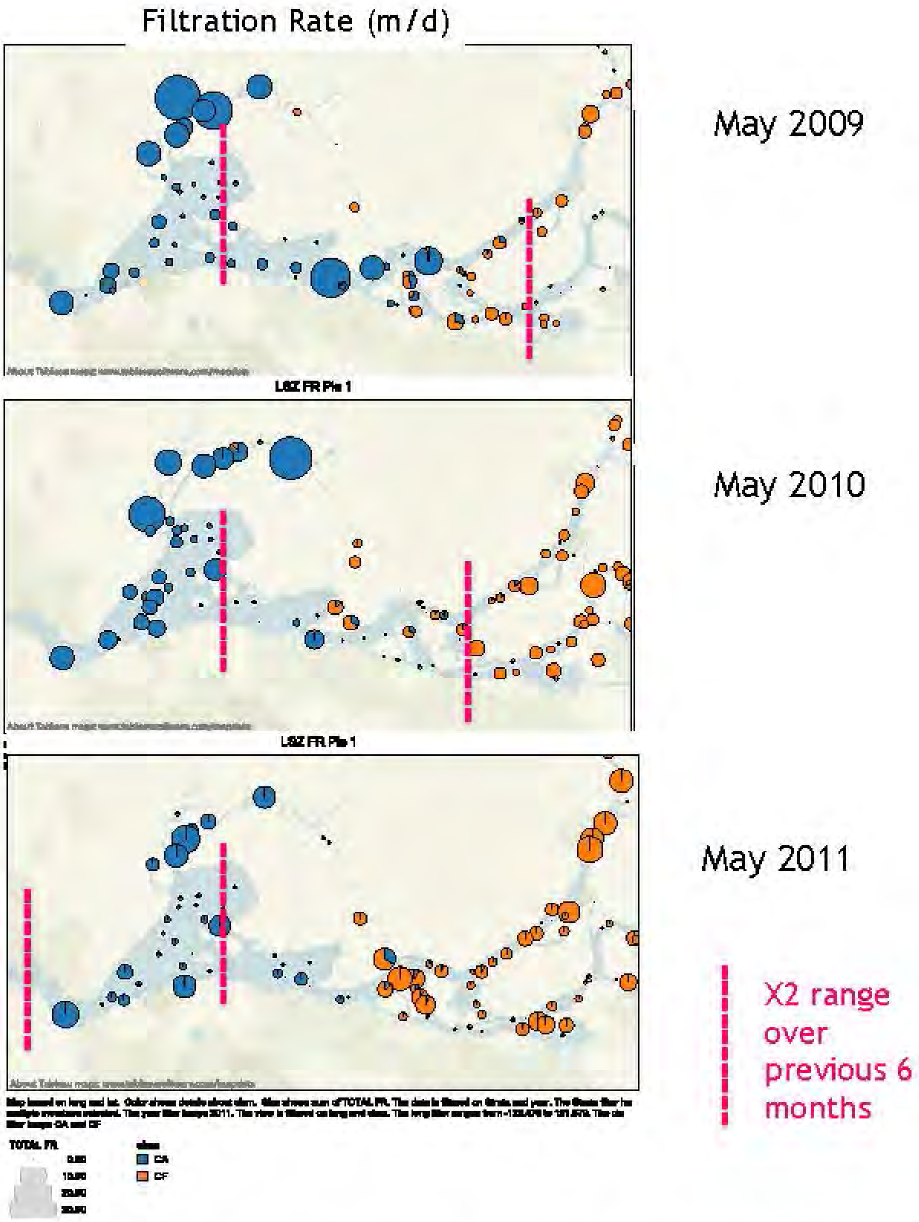
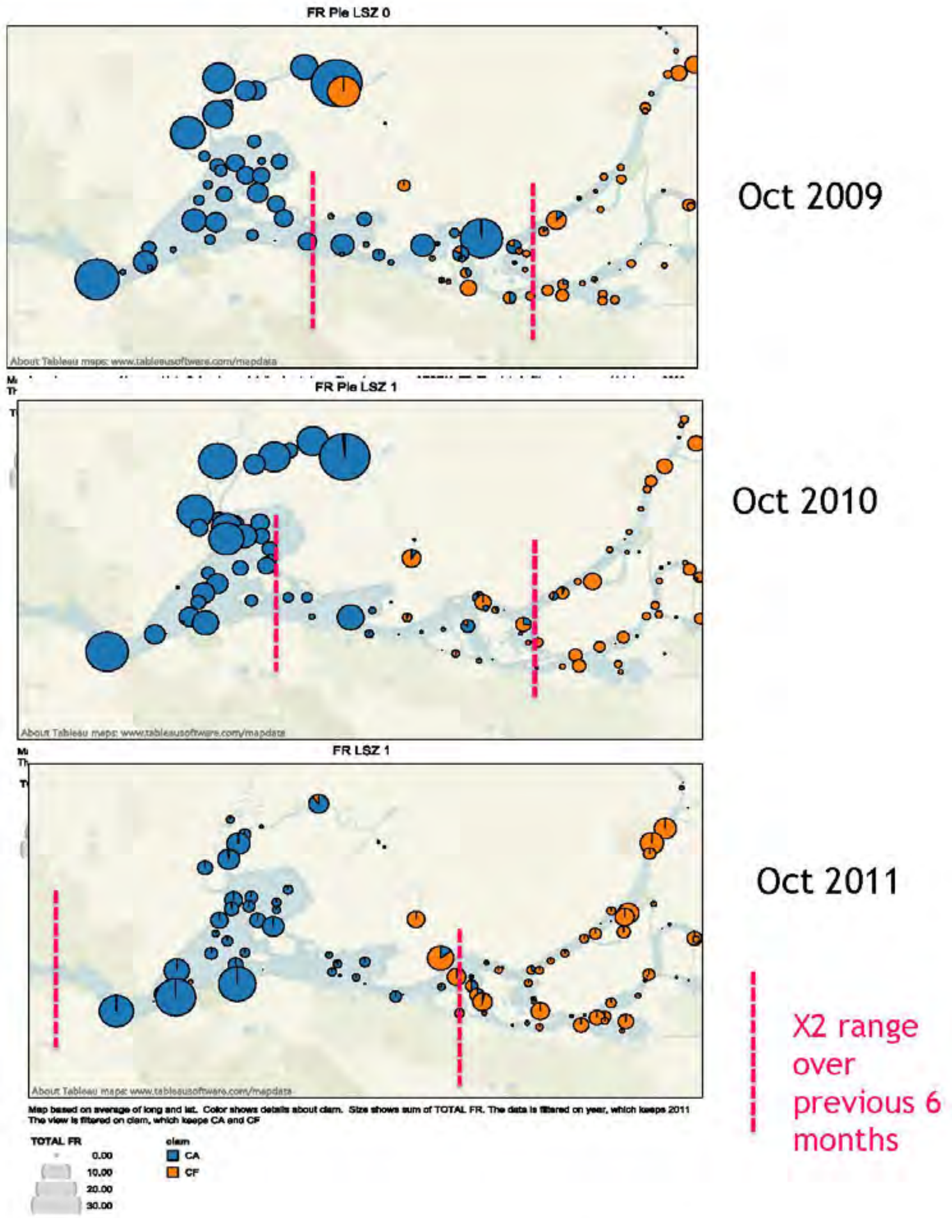


Figure 5a. Filtration rate for both bivalves in May 2009, 2010, and 2011. Range of X2 over previous 6 months shown on map as range where bivalves were expected to overlap.



Map based on average of long and lat. Color shows details about clam. Size shows sum of TOTAL FR. The data is filtered on year, which keeps 2011
The view is filtered on clam, which keeps CA and CF

Figure 5b. Filtrattion rate for both bivalves in October 2009,2010, and 2011. Range of X2 over previous 6 months shown on map as range where bivalves were expected to overlap.

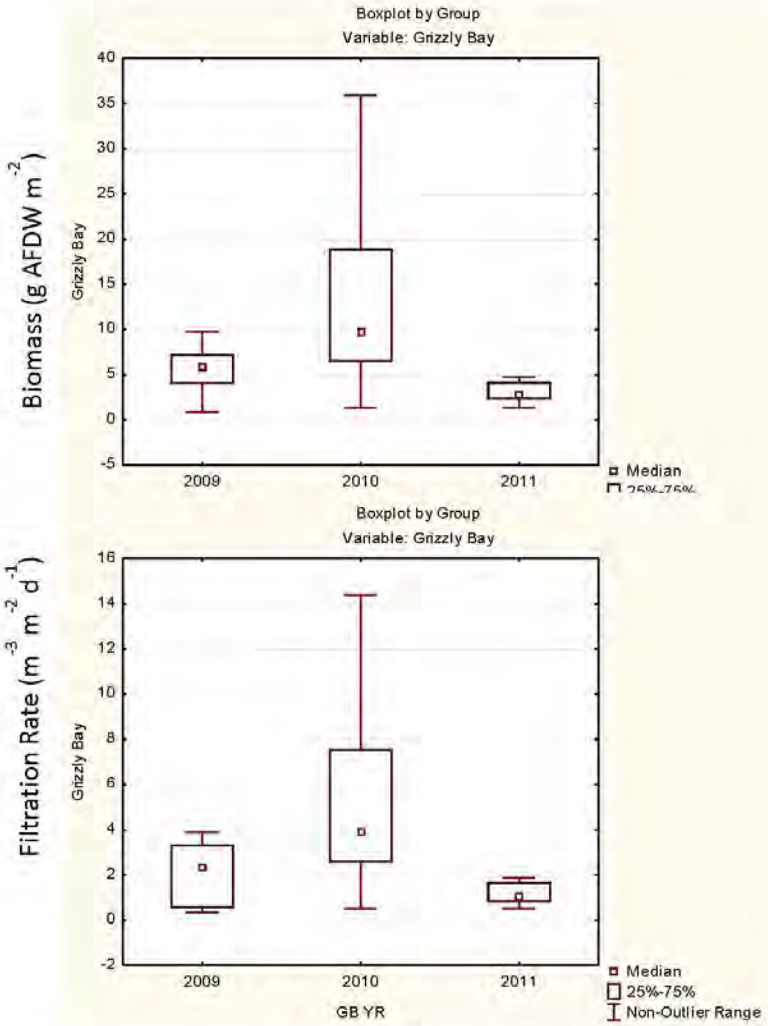


Figure 6a. Biomass and filtration rate during the October sampling periods in Grizzly/Honker Bay shallows. All values (biomass, filtration rate, grazing rate, and turnover rate) for Grizzly/Honker Bay clams were not significantly different between 2009 and 2010 but were significantly different for 2010 and 2011.

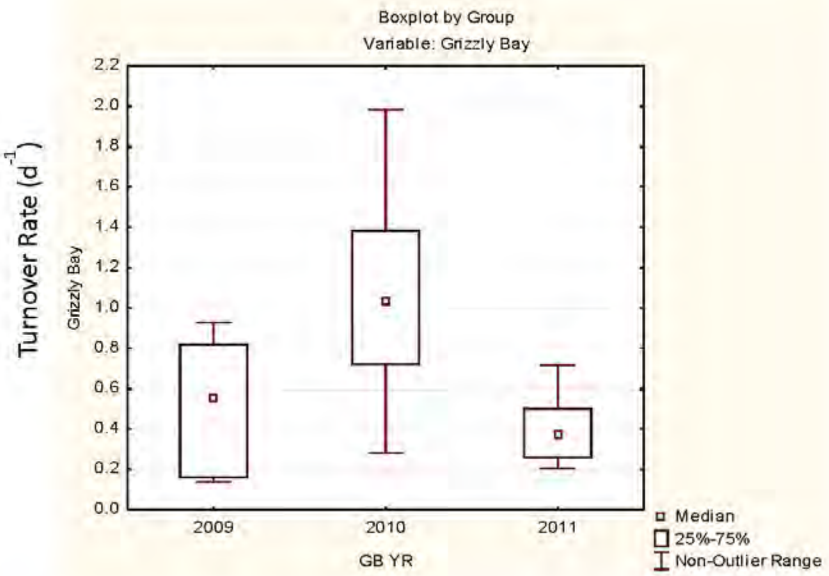


Figure 6b. Grazing rate normalized by water depth in Grizzly/Honker Bay shallows estimates water column turnover rate, the more conservative of the two calculated turnover rates.

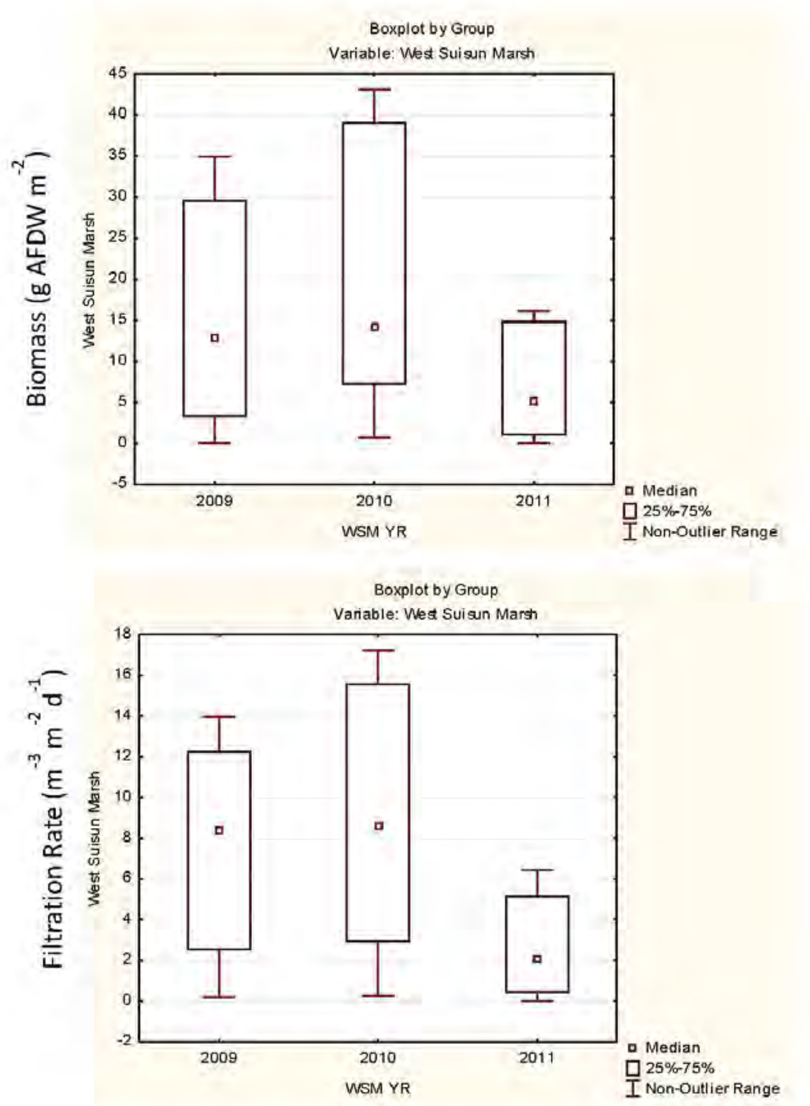


Figure 7a. Biomass and filtration rate during the October sampling periods in West Suisun Marsh region. All values (biomass, filtration rate, grazing rate, and turnover rate) for West Suisun Marsh clams were not significantly different between 2009 and 2010 but were significantly different for 2010 and 2011.

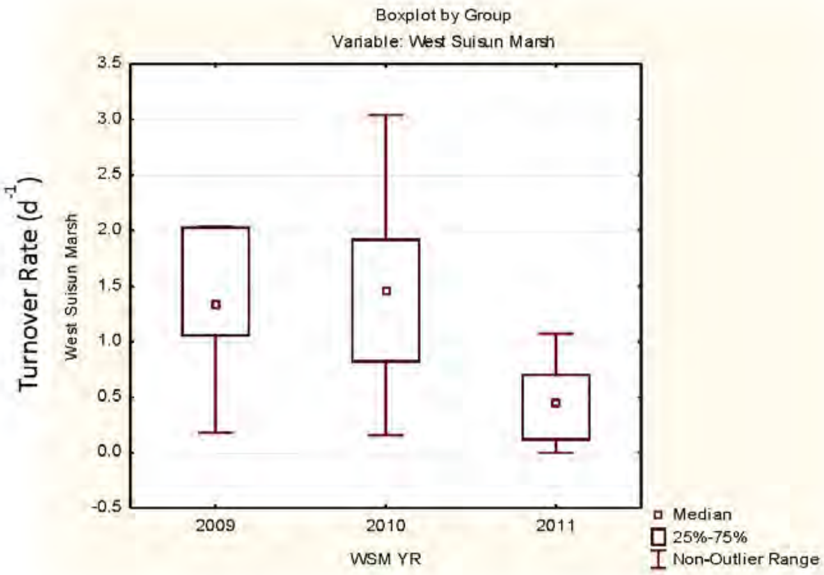
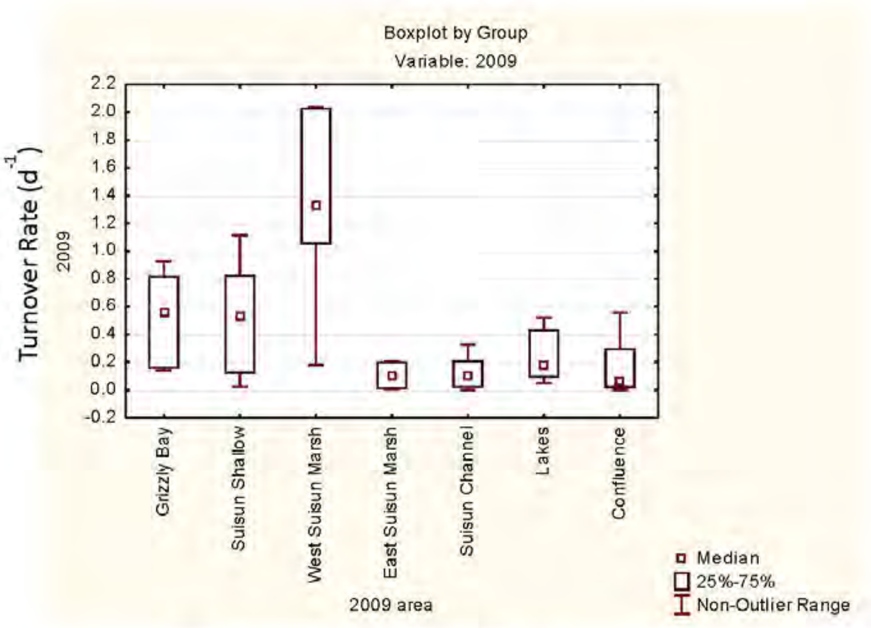
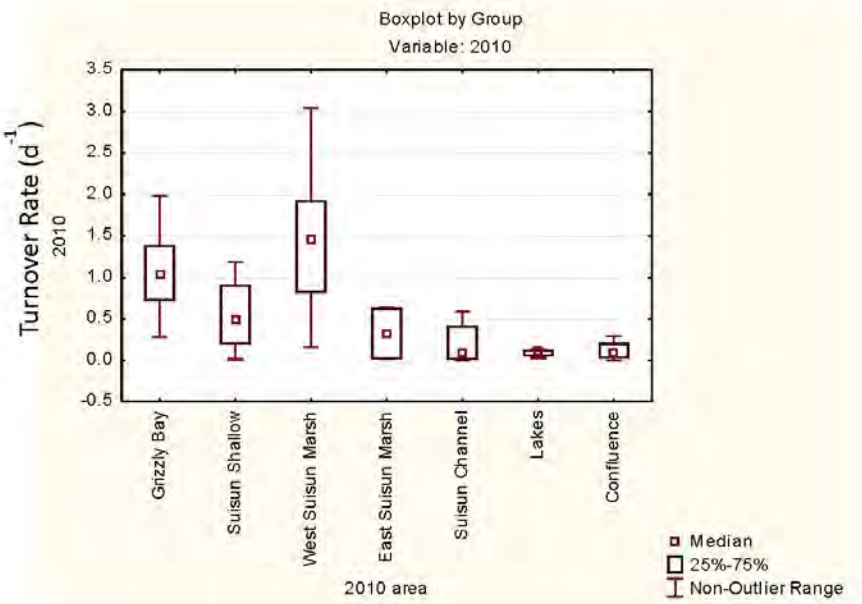


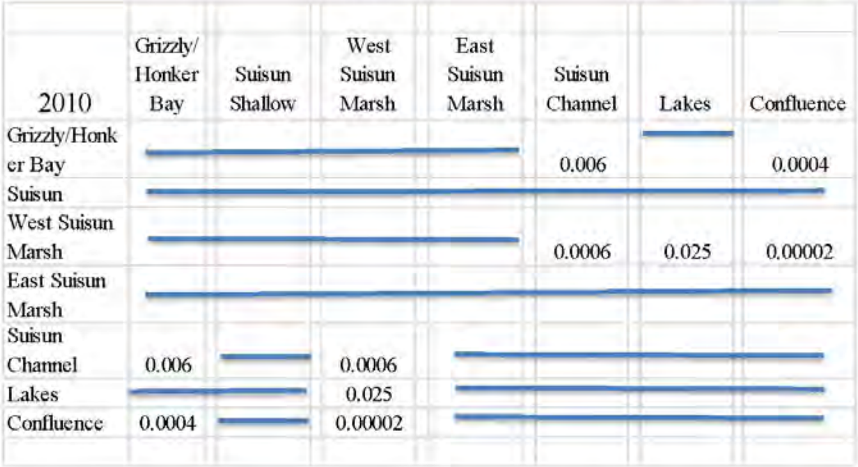
Figure 7b. Grazing rate normalized by water depth in West Suisun Marsh estimates water column turnover rate, the more conservative of the two calculated turnover rates.



2009	Grizzly/ Honker Bay	Suisun Shallow	West Suisun Marsh	East Suisun Marsh	Suisun Channel	Lakes	Confluence
Grizzly/Honker Bay	—	—	—	—	—	—	0.049
Suisun Shallow	—	—	—	—	—	—	—
West Suisun Marsh	—	—	—	—	0.00006	—	0.000004
East Suisun Marsh	—	—	—	—	—	—	—
Suisun Channel	—	—	0.00006	—	—	—	—
Lakes	—	—	—	—	—	—	—
Confluence	0.0492	—	0.000004	—	—	—	—

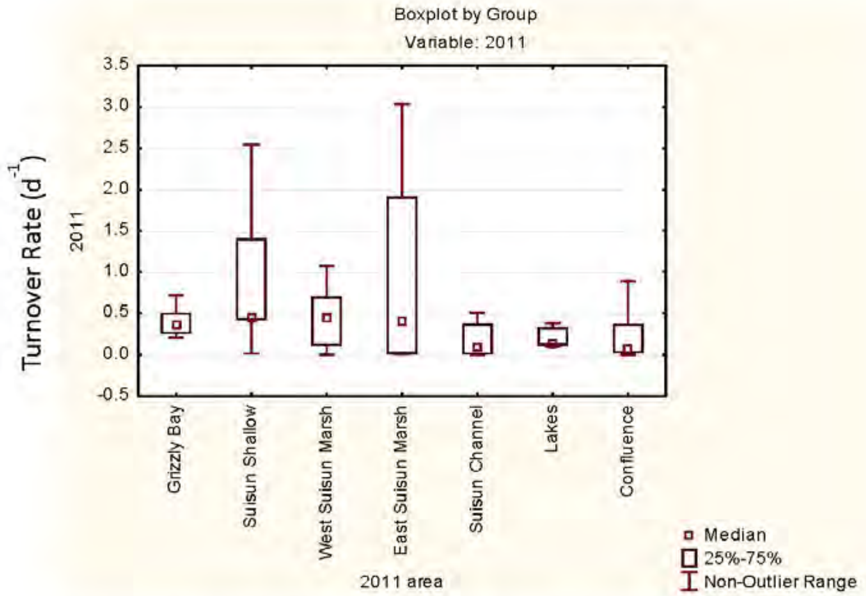
Figure 8. Grazing turnover rates for all regions in 2009. Table shows regions that had similar values (line) and those significantly different at p≤0.05 (Kruskal-Wallis test).





2010	Grizzly/ Honker Bay	Suisun Shallow	West Suisun Marsh	East Suisun Marsh	Suisun Channel	Lakes	Confluence
Grizzly/Honker Bay	—	—	—	—	0.006	—	0.0004
Suisun	—	—	—	—	—	—	—
West Suisun Marsh	—	—	—	—	0.0006	0.025	0.00002
East Suisun Marsh	—	—	—	—	—	—	—
Suisun Channel	0.006	—	0.0006	—	—	—	—
Lakes	—	—	0.025	—	—	—	—
Confluence	0.0004	—	0.00002	—	—	—	—

Figure 9. Grazing turnover rates for all regions in 2010. Table shows regions that had similar values (line) and those significantly different at p≤0.05 (Kruskal-Wallis test).



2011	Grizzly/ Honker Bay	Suisun Shallow	West Suisun Marsh	East Suisun Marsh	Suisun Channel	Lakes	Confluence
Grizzly/Honker Bay	—	—	—	—	—	—	—
Suisun Shallow	—	—	—	—	—	—	—
West Suisun Marsh	—	—	—	—	—	—	—
East Suisun Marsh	—	—	—	—	—	—	—
Suisun Channel	—	—	—	—	—	—	—
Lakes	—	—	—	—	—	—	—
Confluence	—	—	—	—	—	—	—

Figure 10. Grazing turnover rates for all regions in 2011. Table shows all regions had statistically similar values (line) at $p \leq 0.05$ (Kruskal-Wallis test).

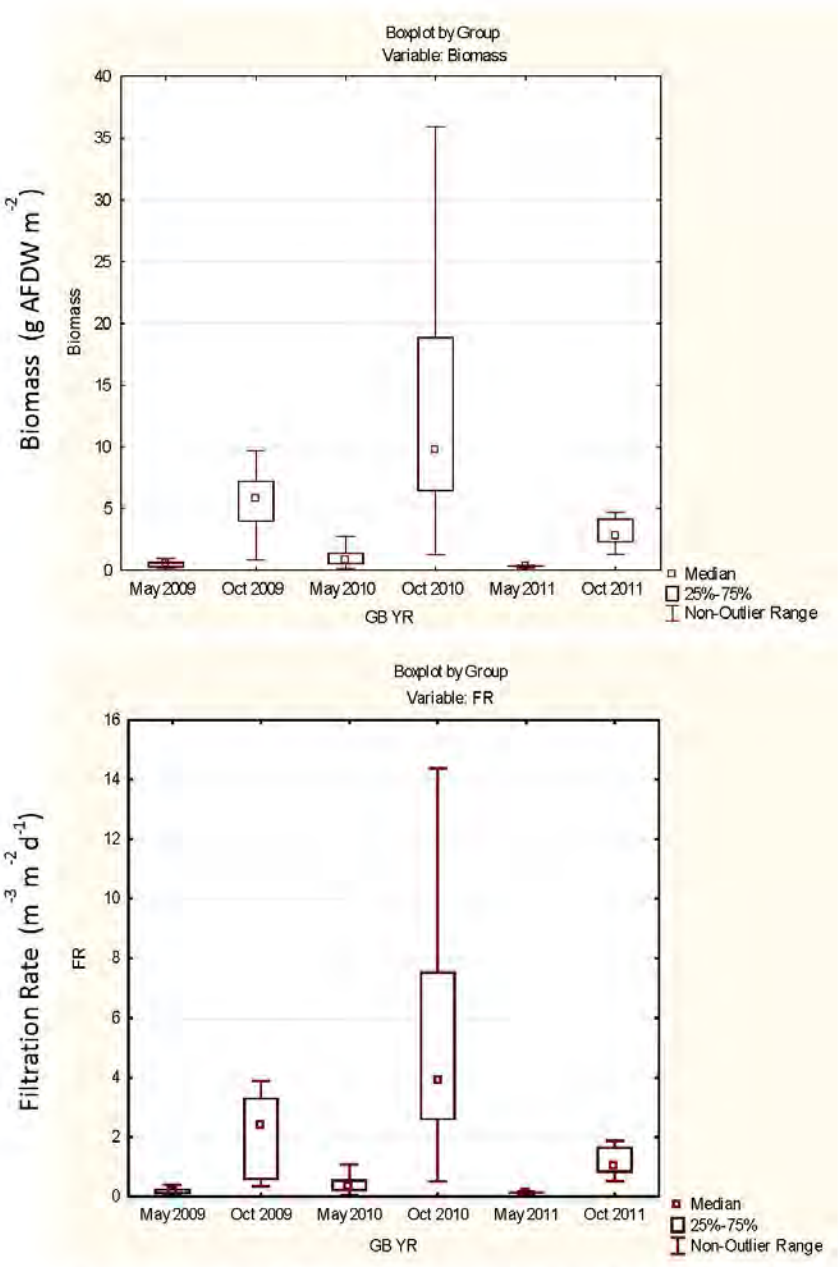


Figure 11. Biomass and filtration rate of bivalves in the shallow habitat of Grizzly and Honker Bays in May 2009-October 2011.

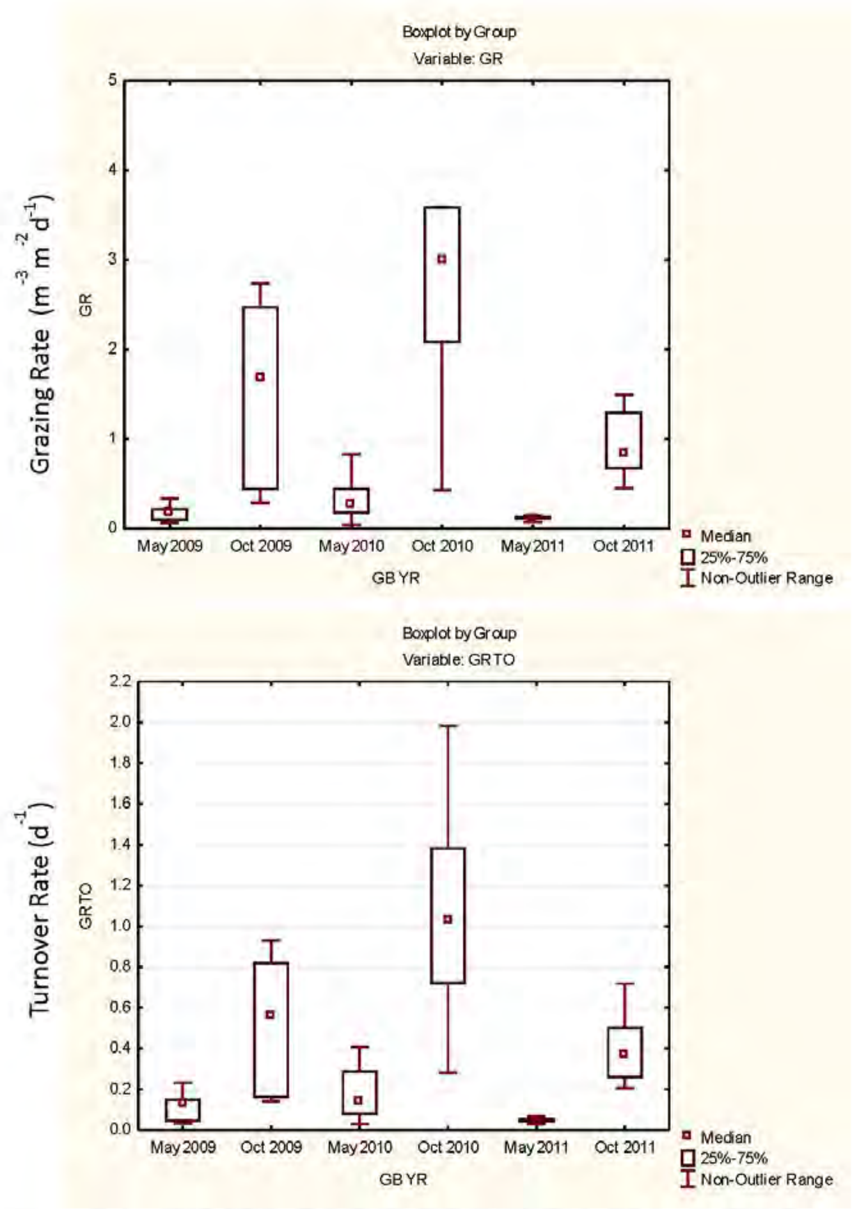


Figure 12. Grazing rate and water column turnover rate of bivalves in the shallow habitat of Grizzly and Honker Bays in May 2009-October 2011.

Table 1. Biomass (g AFDW m^{-2}) (N: sample number, CL: confidence limit)

Region	N	Mean	-95% CL	+95%CL	Median	Min	Max
2009							
Grizzly/Honker Bay	11	5.3	3.5	7.1	5.8	0.9	9.7
Suisun Shallows	10	8.4	3.6	13.2	8.4	0.3	17.2
Suisun Channel	16	7.3	0.1	14.6	3.3	0.0	56.4
East Suisun Marsh	2	11.7	-135.8	159.2	11.7	0.1	23.3
West Suisun Marsh	11	16.0	7.3	24.6	12.9	0.0	34.9
Confluence	28	11.9	5.8	17.9	5.9	0.0	57.4
Lakes	7	8.1	4.2	12.0	7.9	2.0	12.8
2010							
Grizzly/Honker Bay	9	13.6	4.8	22.4	9.8	1.3	35.9
Suisun Shallows	11	7.2	2.0	12.4	4.2	0.0	21.1
Suisun Channel	12	9.0	-0.5	18.5	3.3	0.0	53.5
East Suisun Marsh	2	27.5	-310.2	365.3	27.5	0.9	54.1
West Suisun Marsh	11	25.6	8.2	42.9	14.3	0.7	90.6
Confluence	25	10.4	5.4	15.3	5.5	0.0	43.9
Lakes	6	7.2	-4.5	19.0	3.3	0.9	30.0
2011							
Grizzly/Honker Bay	9	3.6	1.8	5.3	2.8	1.3	9.1
Suisun Shallows	9	13.3	-0.7	27.3	4.0	1.7	49.2
Suisun Channel	16	9.0	2.0	16.0	3.4	0.0	42.6
East Suisun Marsh	4	28.9	-29.1	87.0	19.3	0.4	76.7
West Suisun Marsh	8	7.3	1.5	13.1	5.2	0.0	16.1
Confluence	30	12.1	6.9	17.2	7.7	0.0	50.7
Lakes	5	4.9	1.6	8.3	3.1	3.0	8.7

Table 2. Filtration Rate ($m^{-3}m^{-2}d^{-1}$)

Region	N	Mean	-95% CL	+95%CL	Median	Min	Max
2009							
Grizzly/Honker Bay	11	2.2	1.3	3.0	2.4	0.4	3.9
Suisun Shallows	10	3.4	1.4	5.3	3.4	0.1	6.9
Suisun Channel	16	3.1	0.2	6.1	1.3	0.0	22.5
East Suisun Marsh	2	0.8			0.8	0.0	1.6
West Suisun Marsh	11	11.6	0.9	22.2	8.4	0.2	57.2
Confluence	28	1.6	0.1	3.2	0.4	0.0	20.7
Lakes	7	0.6	0.3	0.8	0.5	0.2	0.9
2010							
Grizzly/Honker Bay	9	5.4	1.9	9.0	3.9	0.5	14.4
Suisun Shallows	11	2.9	0.8	5.0	1.7	0.0	8.4
Suisun Channel	14	3.2	-0.1	6.4	0.8	0.0	21.4
East Suisun Marsh	2	2.1			2.1	0.1	4.0
West Suisun Marsh	10	13.0	1.0	25.1	8.6	0.3	58.0
Confluence	25	0.9	0.5	1.2	0.6	0.0	3.0
Lakes	6	0.6	-0.4	1.6	0.2	0.1	2.6
2011							
Grizzly/Honker Bay	9	1.4	0.6	2.1	1.0	0.5	3.6
Suisun Shallows	9	3.9	-0.8	8.6	1.6	0.6	19.7
Suisun Channel	16	3.6	0.8	6.4	1.4	0.0	17.0
East Suisun Marsh	4	3.0	-3.2	9.2	1.9	0.0	8.3
West Suisun Marsh	8	2.7	0.6	4.9	2.1	0.0	6.4
Confluence	30	1.1	0.6	1.6	0.6	0.0	4.5
Lakes	5	0.4	0.1	0.7	0.3	0.2	0.7

Table 3. Grazing Rate ($m^{-3}m^{-2}d^{-1}$)

Region	N	Mean	-95% CL	+95%CL	Median	Min	Max
2009							
Grizzly/Honker Bay	11	1.6	0.9	2.2	1.7	0.3	2.7
Suisun Shallows	10	2.4	1.1	3.8	2.4	0.1	4.8
Suisun Channel	16	2.1	0.5	3.6	1.1	0.0	11.7
East Suisun Marsh	2	0.6			0.6	0.0	1.3
West Suisun Marsh	11	8.0	1.2	14.7	6.5	0.2	36.5
Confluence	28	1.2	0.2	2.3	0.4	0.0	13.8
Lakes	7	0.5	0.3	0.7	0.5	0.1	0.7
2010							
Grizzly/Honker Bay	9	3.6	1.5	5.6	3.0	0.4	8.7
Suisun Shallows	11	2.1	0.7	3.6	1.4	0.0	6.4
Suisun Channel	14	2.1	0.2	3.9	0.7	0.0	11.9
East Suisun Marsh	2	1.7			1.7	0.1	3.3
West Suisun Marsh	11	8.4	1.5	15.4	4.3	0.2	37.1
Confluence	26	0.7	0.4	0.9	0.5	0.0	2.1
Lakes	6	0.4	-0.1	0.9	0.2	0.1	1.3
2011							
Grizzly/Honker Bay	9	1.1	0.6	1.6	0.8	0.4	2.7
Suisun Shallows	8	3.1	-0.4	6.6	1.6	0.6	13.2
Suisun Channel	16	2.6	0.7	4.6	1.1	0. 0	11.8
East Suisun Marsh	4	2.1	-2.1	6.4	1.5	0.0	5.6
West Suisun Marsh	9	1.9	0.5	3.3	1.3	0.0	4.9
Confluence	30	0.9	0.5	1.2	0.6	0.0	3.3
Lakes	5	0.4	0.1	0.6	0.3	0.2	0.6

Table 4. Grazing Turnover Rate (d^{-1})

Region	N	Mean	-95% CL	+95%CL	Median	Min	Max
2009							
Grizzly/Honker Bay	11	0.5	0.3	0.7	0.6	0.1	0.9
Suisun Shallows	10	0.5	0.2	0.8	0.5	0.0	1.1
Suisun Channel	16	0.2	0.1	0.3	0.1	0.0	0.6
East Suisun Marsh	2	0.1			0.1	0.0	0.2
West Suisun Marsh	11	2.1	0.6	3.6	1.3	0.2	8.2
Confluence	28	0.3	0.0	0.5	0.1	0.0	2.7
Lakes	7	0.3	0.1	0.4	0.2	0.0	0.5
2010							
Grizzly/Honker Bay	9	1.1	0.6	1.5	1.0	0.3	2.0
Suisun Shallows	11	0.5	0.2	0.8	0.5	0.0	1.2
Suisun Channel	14	0.2	0.1	0.3	0.1	0.0	0.6
East Suisun Marsh	2	0.3			0.3	0.0	0.6
West Suisun Marsh	11	1.5	0.9	2.1	1.5	0.2	3.0
Confluence	25	0.1	0.1	0.2	0.1	0.0	0.6
Lakes	6	0.1	0.0	0.3	0.1	0.0	0.4
2011							
Grizzly/Honker Bay	9	0.4	0.3	0.6	0.4	0.2	0.7
Suisun Shallows	9	0.9	0.2	1.6	0.5	0.0	2.6
Suisun Channel	16	0.2	0.1	0.4	0.1	0.0	1.0
East Suisun Marsh	4	1.0	0	3.2	0.4	0.0	3.0
West Suisun Marsh	8	0.4	0.1	0.8	0.4	0.0	1.1
Confluence	30	0.3	0.1	0.5	0.1	0.0	1.9
Lakes	5	0.2	0.0	0.4	0.1	0.1	0.4

Delta Chinook Final Report

Curry Cunningham, Noble Hendrix, Eva Dusek-Jennings, Robert Lessard and Ray Hilborn

EXECUTIVE SUMMARY

This project developed a stage-structured life history model of summer, spring and winter run Chinook salmon, fitted this model to available data on salmon stock abundance and environmental conditions, and estimated the impact of the environmental conditions on survival of the different stocks of Chinook salmon. This model was then used to forecast how differences in future climate change, marine conditions or productivity, and water exports would affect the survival of the different stocks of Chinook salmon.

We used several statistical techniques to evaluate the relative importance of environmental variables on the survival including both information theoretic approaches and Bayesian approaches. Due to the large number of potential explanatory covariates (59) and the inability to fit all combinations of these covariates, we used Akaike Information Criterion for small sample size (AICc) and a novel method for exploring the model space. The approach used a forward stepwise model building with AICc as the selection criteria. The steps were: 1) fit a null model without any covariate effects to the available data; 2) construct a proposal model by selecting a covariate at random from amongst the set of 59 possible covariates; 3) fit the proposed model to the data; 4) compare the proposal model to the null model; 5) keep proposal model if reduction in AICc value is greater than 2 units; 6) repeat sampling covariates without replacement, fitting the model to data, and evaluating AICc i.e. until all covariates have been tested.

Using the information theoretic approaches we found support for environmental impacts of 14 variables including flow, temperature, sediment concentration, export inflow ratios, exports, ocean upwelling, curl and PDO. The top three environmental drivers affecting fall run were export to inflow ratio, spring upwelling south of the Farallon Islands, and the delta gross channel depletion. The top three drivers affecting spring run were size at Chipps Island, export levels, and sediment concentration at Freemont. The three main factors affecting winter-run were minimum flow during fry rearing, temperatures during egg incubation, and spring upwelling south of the Farallon Islands. We then conducted a Bayesian analysis using these 14 variables to calculate the posterior distribution of the impact of these variables on survival.

We conducted forward simulations under four different export regimes to understand how management of exports would affect each of the races. Furthermore, we evaluated export management under two different climate scenarios and two ocean productivity scenarios to understand how climate variability and ocean productivity may act in concert with management of exports to affect the three Chinook runs. We developed a harvest model that reflected current management of the Central Valley Chinook stocks in which low levels of winter run escapement can reduce fall run harvest.

We found that both climate and exports affected projected survival and the potential recruits per spawner for wild populations. Under current export levels all stocks of spring run would increase across all climate scenarios tested. Winter run would increase except under the most pessimistic of the four climate conditions we evaluated. Mainstem Fall run would have recruits per spawner greater than 1 under the two optimistic climate scenarios and less than 1 under the two pessimistic climate scenarios although the future trend in mainstem fall chinook could be heavily influenced by straying from hatcheries and thus hard to predict. A 30% increase in exports decreased spring and fall stock survival to the point where they would all decline regardless of the climate scenario. A 30% decrease in exports improved survival and recruits per spawner for all stocks.

We found spring Chinook stocks to be most sensitive to exports and less sensitive to climate conditions, whereas winter Chinook were more sensitive to climate conditions than exports.

We did not evaluate alternative ocean harvest scenarios, although reduction or elimination of ocean harvest would increase survival to spawning and thus contribute to rebuilding in the same way as better climate or reduced exports.

INTRODUCTION

Salmon populations in the Sacramento River are far below historical numbers. Fisheries closures have been implemented to protect spring-run Chinook (SRC), winter-run Chinook (WRC), and even fall-run Chinook (FRC), which until 2005, had been considered a healthy stock. The FRC was the staple of the California salmon fishery, has been closed in several years. The FRC have been the most heavily subsidized with hatchery fish. The impact on commercial and recreational fisheries has been dramatic. A variety of reasons in both freshwater and marine environments have been cited as causes of the decline, but it appears that salmon have been subjected to something of a “perfect storm” of deleterious effects, both natural and anthropogenic in origin.

Historically both WRC and SRC used the upstream, higher altitude tributaries of the Sacramento River, but the current extent of accessible freshwater habitat differs greatly and their lower abundances have led to concern and listing by both state and federal agencies (Yoshiyama et al. 1998, 2000, Lindley et al. 2004). WRC and SRC were separated both temporally and geographically in their spawning habitat. Winter-run historically used the headwater springs, spawned in the early summer, emerged from the gravel in late summer, emigrated over the winter, and entered the ocean the following spring (Lindley et al. 2004). Development of eggs was dependent on relatively constant flow and cool temperatures of the spring fed streams. Currently, WRC are confined to spawning in the Sacramento River. SRC used the high spring flows to reach the upper tributaries of the Sacramento in summer and waited out the summer in high elevation pools. Spawning commenced in the fall and juveniles emerged the following spring. Stream residency varied and could last over a year. Out-migration occurred in both spring and fall depending upon time of residency. There are currently several extant subpopulations of SRC. Lindley et al. (2004) suggest that there are four principle groupings that might form the basis of a meta-population structure: 1. Winter-run, 2. Butte Creek spring-run, 3.

Deer and Mill Creek spring-run, 4. Fall-run, late fall-run and Feather/Yuba spring-run. Since several of these runs overlap in their usage of stream and mainstem habitat, it is reasonable to consider that they may compete for resources and therefore a modeling approach that accounts for these overlaps could improve the precision of population predictions. Additionally, variation in survival of one population can provide additional statistical ability to the estimation of environmental effects that influence both populations.

Over the past several decades, substantial resources have been devoted to the management of water resources, fisheries, and habitat in the San Francisco Bay-Sacramento River Delta (Bay-Delta) ecosystem in general, with particular attention being given to resident Chinook salmon runs. There has been increasing concern for species in decline, with the listing of WRC and SRC in the Central Valley (CV) under both federal (Endangered Species Act, ESA) and state laws. The exceedingly low return of FRC in 2008 led to a complete closure of salmon fisheries. Many studies have been conducted in an attempt to explain sources of mortality in freshwater and in the ocean. Tagging studies have shown extremely low survival in freshwater. Wells et al. (2007) showed strong associations between survival and ocean climate indices, providing evidence for a linkage between survival and primary productivity during the marine portion of the life cycle.

Fish interact with natural and anthropogenic aspects of their environment and there can be significant variation in such externalities. Decisions regarding fisheries management, water management and research direction should account for all significant and predictable sources of variation in those externalities where they have a measurable effect on survival. What is lacking is an integrative model that can provide a level of detail in water resource management and fishery management that accounts for interactions between salmon populations, both in the wild as well implicitly captured in the mechanics of fisheries policy.

Although mathematical models of salmon species have been developed both at the individual (e.g., Kimmerer 2001, Jager and Rose 2003) and the population (e.g., Botsford and Brittnacher 1998) level, management and research direction have been based primarily on qualitative compilations of what is known about individual salmon runs. Management would benefit from models that more closely link environmental conditions to biological response. Lessard et al. (*submitted manuscript*) built upon the general principle that survival could be broken down into life history stages so that the relevant environmental factors in each stage could be factored into the estimation of the productivity and capacity parameters that predict density dependence in survival rates. A series of competing models were compared using a statistical modeling and population dynamics platform (OBAN), each reconstructing population dynamics and estimating the relative effects of environmental conditions in freshwater and ocean stages. The study found that temperature, flow and exports explained most of the variation in freshwater. Historically, gate positions of bypasses and cross channels have explained some of the variation in survival, however, water management agencies have responded to biological needs and have in recent years adjusted the timing and magnitude of water redirection activities to mitigate negative effects on salmon. Wind stress curl, a primary productivity surrogate (Wells et al. 2008), was the leading factor explaining variation in ocean survival, although indices such as the Pacific Decadal Oscillation (Mantua et al. 1997) and sea surface temperature also explained variation in ocean survival, although not throughout enough of the timeframe of the study to be statistically competitive in model selection.

For the population dynamics portion of the project, we developed a multi-stock model of the three Central Valley Chinook salmon species-at-risk (WRC, SRC and FRC) that incorporates mortality in all phases of salmon life history, and includes the effects of uncertainty in assessing population status. The approach involves several categories of models: (1) the population dynamics models, (2) the parameter estimation model, (3) the growth model, and (4) the fisheries management model that calibrates fishing effort to the predicted runs of the individual populations.

PART I FITTING A STATISTICAL MODEL

METHODS; MODEL DESCRIPTION

The goal of this project was evaluate the environmental drivers of survival for Chinook salmon populations spawning in the Sacramento River, CA watershed, in a statistically rigorous manner. More generally, our purpose was to test a range of hypotheses describing the putative factors facilitating or limiting survival, factors both natural and anthropogenic in origin and describing both biotic and abiotic processes. To achieve this goal we have created a stage-structured population dynamics model, which estimates the direction and magnitude of influence that a range of these factors, or environmental covariates, have on survival through specific portions of the Chinook life cycle, when fit to available juvenile and adult spawning abundance data. The population dynamics model is currently used to explore the environmental drivers of survival for four fall-run populations including: 1) Mainstem Sacramento wild-spawning Chinook, 2) Battle Creek Coleman National Fish Hatchery produced Chinook, 3) Feather River Hatchery produced Chinook, and 4) American River Nimbus Hatchery produced Chinook, as well as three spring-run populations including: 1) Deer Creek, 2) Mill Creek, and 3) Butte Creek, wild-spawning Chinook.

The stage-structured population dynamics model described in this document compliments and expands upon previous analyses of interactions between environmental factors and survival of Chinook salmon populations of the Sacramento River watershed in several ways. First, while many previous analyses have modeled the survival or productivity of single components of the Sacramento River Chinook stock complex (i.e. (Newman and Rice 2002, Lindley and Mohr 2003, Newman and Brandes 2010, Zeug et al. 2012), fall-run (Newman and Rice 2002), late-fall-run (Newman and Brandes 2010), winter-run (Lindley and Mohr 2003, Zeug et al. 2012)) in isolation, the current population dynamics model is applied to multiple populations of both spring-run and fall-run Chinook and evaluates interactions between these populations at points in the life cycle where co-rearing and co-migration occurs. Second, the current population dynamics model approximates both wild and hatchery type life histories, utilizing historical records of hatchery releases from the Coleman National Fish Hatchery on Battle Creek, the Feather River Hatchery, and the Nimbus Fish Hatchery on the American River compiled by Huber and Carlson (in review). Third, we have utilized estimates of stray rates between hatcheries and wild populations of fall-run Chinook available from the proportional coded wire tagging program (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013), to reconstruct spawning abundance data in the presence of straying, prior to fitting the estimation model. Fourth, while previous analyses have primarily evaluated survival variation in either the freshwater or marine portions of the Chinook life cycle, we have created a population dynamics model with both marine and freshwater stages, permitting the testing of competing hypotheses for putative survival influences in all habitats utilized by Sacramento River Chinook. Fifth, while previous stage-structured population dynamics models used to evaluate the interaction between environmental factors and the survival of Sacramento Chinook including Zeug et al. (2012) have defined these interactions based upon a priori information or findings from other systems or laboratory experimentation, the population dynamics model we have created is statistical in nature, estimating the effect of the hypothesized environmental drivers of survival based upon historical variation observed in adult and juvenile abundance. The result is a flexible multi-stock, stage-structured, statistical, population dynamics model that estimates the influence of natural and anthropogenic environmental factors on survival of Chinook salmon throughout their life cycle, using both Bayesian and Maximum Likelihood methods.

The Data

In order to estimate the effect of various environmental covariates as well as basal productivity and capacity for the seven populations in specific life stages, the estimation model is conditioned on different types of data available for the Sacramento River system. The first type of data that are required by the estimation model are time-series of explanatory environmental covariates. For each environmental covariate being evaluated for its influence on Chinook survival, it is necessary to provide, a historical record of its value over time as a model input. Covariate data are z-standardized (Zar 2010) based upon the mean and standard deviation of the time-series (Eq. I.1).

(I.1) $$X_{t,i} = \frac{x_{t,i} - \sum_{t=1}^{Nt} x_{t,i} / Nt}{\sigma_i}$$

In this way, the ith covariate at time t ($x_{t,i}$) is transformed into units of standard deviations from the time-series mean, rather than untransformed values that span many orders of magnitude among covariates. By transforming covariate data into the same units, the magnitude of subsequently estimated coefficients describing the influence of individual covariates are more readily comparable and estimable.

Potential covariates were chosen for evaluation within the estimation model based upon first principals and a valid biological rationale for why each might be expected to influence either survival rate or stage-specific capacity. Covariates were developed came from a wide range of sources, including a review of the pertinent literature and expert opinion, and were created using data from the period of time throughout the year over which they were expected to exhibit the greatest influence (Table I.1).

TABLE I.1. Environmental covariates

Hypothesis Number	Covariate	Covariate Description	Location	Populations
1	fall.sac.mainstem - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Fall Sacramento Mainstem Wild
2	fall.sac.mainstem - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Fall Sacramento Mainstem Wild
3	fall.sac.mainstem - keswick.discharge	Average January - March water discharge (cfs) at Keswick Dam	Keswick Dam	Fall Sacramento Mainstem Wild
4	.1.2.3.4-verona.peak.streamflow	Peak (maximum) streamflow on the Sacramento River mainstem at Verona, CA (January - May)	Verona, Sacramento River	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
5	.1.2.3.4-yolo.wood.peak.streamflow	Peak (maximum) streamflow into Yolo Bypass at Woodland, CA (January - May)	Into Yolo Bypass at Woodland, CA	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
6	.1.2.3.4-freeport.sed.conc	Average February - April monthly sediment concentration (mg/L)	Freeport, Sacramento River	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
7	.1.2.3.4-bass.cpue	Index of Striped Bass abundance as number of striped bass kept	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
8	.1.2.3.4-fall.dayflow.geo	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO). February - March average	Sacramento - San Joaquin Delta at the Delta Cross Channel and Georgiana Slough	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
9	.1.2.3.4-fall.dayflow.export	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS). March - May average	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
10	.1.2.3.4-fall.dayflow.expin	Dayflow: Export/Inflow Ratio (EXPIN). March - May average	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
11	.1.2.3.4-fall.dayflow.cd	Dayflow: Net Channel Depletion (QCD). March - May average	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
12	.1.2.3.4-fall.size.chipps	Average size of fall-run Chinook at ocean entry from Chipps Island Trawl	Chipps Island Trawl	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
13	.1.2.3.4-fall.farallon.temp.early	Average temperature at the Farallon Islands, CA (37° 41.8' N, 122° 59.9' W) during the SPRING months (February - April) BEFORE Chinook ocean entry	Nearshore Region, Farallon Islands, CA	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
14	.1.2.3.4-fall.farallon.temp.late	Average temperature at the Farallon Islands, CA (37° 41.8' N, 122° 59.9' W) during the SUMMER months (May - July) AFTER Chinook ocean entry	Nearshore Region, Farallon Islands, CA	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
15	.1.2.3.4-upwelling.north.early	NOAA Index for upwelling at Northern Location (39 N, 125 W), average of SPRING months (April - June)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
16	.1.2.3.4-upwelling.north.late	NOAA Index for upwelling at Northern Location (39 N, 125 W), average of FALL months (July - December)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
17	.1.2.3.4-upwelling.south.early	NOAA Index for upwelling at Southern Location (36 N, 122 W), average of SPRING months (April - June)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
18	.1.2.3.4-upwelling.south.late	NOAA Index for upwelling at Southern Location (36 N, 122 W), average of FALL months (July - December)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
19	.1.2.3.4.5.6.7-curl.early	NOAA Wind Stress Curl Index for upwelling at Northern Location (39 N, 125 W), average of SUMMER months (April -June)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek
20	.1.2.3.4.5.6.7-curl.late	NOAA Wind Stress Curl for upwelling at Northern Location (39 N, 125 W), average of FALL months (July - December)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek
21	.1.2.3.4.5.6.7-pdo.early	Pacific Decadal Oscillation (PDO), average of January - May monthly indices during first year of mearine residence	Ocean	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek
22	.1.2.3.4.5.6.7-pdo.late	Pacific Decadal Oscillation (PDO), average of October - December monthly indices during first year of mearine residence	Ocean	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek

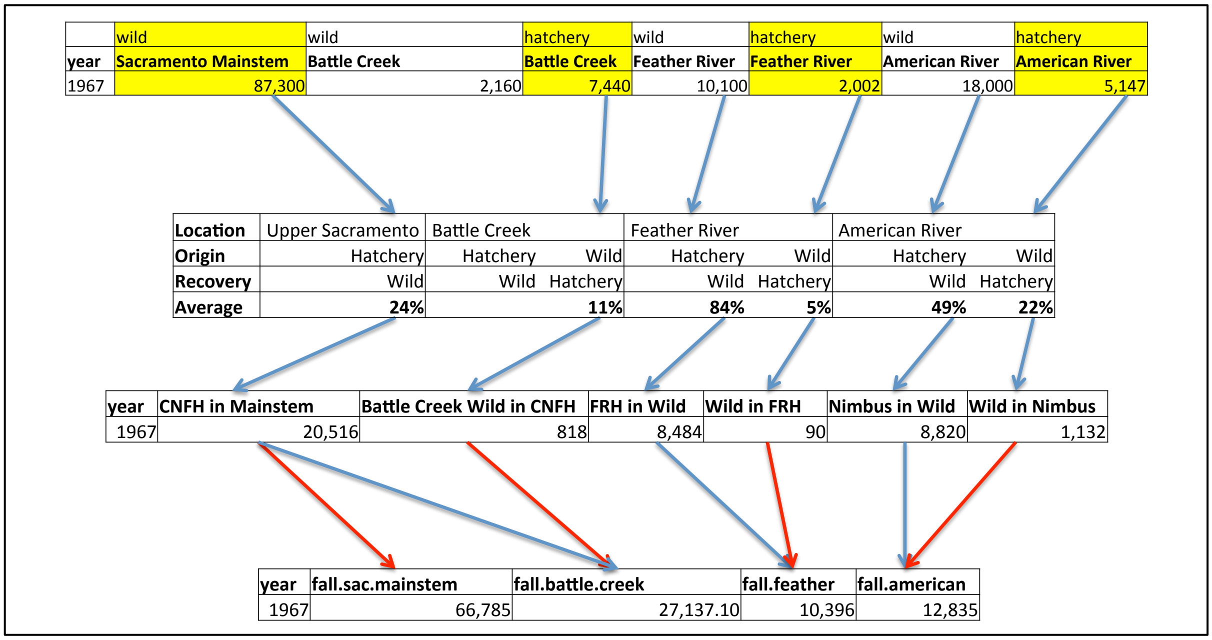
Hypothesis Number	Covariate	Covariate Description	Location	Populations
23	fall.battle.creek - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Fall Battle Creek (CNFH) Hatchery
24	fall.battle.creek - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Fall Battle Creek (CNFH) Hatchery
25	fall.battle.creek - keswick.discharge	Average January - March water discharge (cfs) at Keswick Dam	Keswick Dam	Fall Battle Creek (CNFH) Hatchery
26	fall.battle.creek - battle.discharge	Average January - March water discharge (cfs) on Battle Creek	Cottonwood, Battle Creek	Fall Battle Creek (CNFH) Hatchery
27	fall.battle.creek - battle.peak.gage.ht	Battle Creek peak guage height November - December of brood year	Cottonwood, Battle Creek	Fall Battle Creek (CNFH) Hatchery
28	fall.feather - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Fall Feather River Hatchery
29	fall.feather - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Fall Feather River Hatchery
30	fall.feather - keswick.discharge	Average January - March water discharge (cfs) at Keswick Dam	Keswick Dam	Fall Feather River Hatchery
31	fall.feather - feather.oronville.discharge	Average January - March water discharge (cfs) on the Feather River	Oronville, Feather River	Fall Feather River Hatchery
32	fall.american - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Fall American River (Nimbus) Hatchery
33	fall.american - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Fall American River (Nimbus) Hatchery
34	fall.american - keswick.discharge	Average January - March water discharge (cfs) at Keswick Dam	Keswick Dam	Fall American River (Nimbus) Hatchery
35	fall.american - american.discharge	Average January - March water discharge (cfs) on the American River	Fair Oaks, American River	Fall American River (Nimbus) Hatchery
36	spring.deer - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Spring Deer Creek
37	spring.deer - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Spring Deer Creek
38	.5.6.7-verona.peak.streamflow	Peak (maximum) streamflow on the Sacramento River mainstem at Verona, CA (January - May)	Verona, Sacramento River	Spring Deer Creek Spring Mill Creek Spring Butte Creek
39	.5.6.7-yolo.wood.peak.streamflow	Peak (maximum) streamflow into Yolo Bypass at Woodland, CA (January - May)	Into Yolo Bypass at Woodland, CA	Spring Deer Creek Spring Mill Creek Spring Butte Creek
40	.5.6.7-freeport.sed.conc	Average February - April monthly sediment concentration (mg/L)	Freeport, Sacramento River	Spring Deer Creek Spring Mill Creek Spring Butte Creek
41	.5.6.7-bass.cpue	Index of Striped Bass abundance as number of striped bass kept	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
42	.5.6.7-upwelling.north.early	NOAA Index for upwelling at Northern Location (39 N, 125 W), average of SPRING months (April - June)	Nearshore Region	Spring Deer Creek Spring Mill Creek Spring Butte Creek
43	.5.6.7-upwelling.north.late	NOAA Index for upwelling at Northern Location (39 N, 125 W), average of FALL months (July - December)	Nearshore Region	Spring Deer Creek Spring Mill Creek Spring Butte Creek
44	.5.6.7-upwelling.south.early	NOAA Index for upwelling at Southern Location (36 N, 122 W), average of SPRING months (April - June)	Nearshore Region	Spring Deer Creek Spring Mill Creek Spring Butte Creek
45	.5.6.7-upwelling.south.late	NOAA Index for upwelling at Southern Location (36 N, 122 W), average of FALL months (July - December)	Nearshore Region	Spring Deer Creek Spring Mill Creek Spring Butte Creek
46	spring.deer - deer.discharge	Average October - December water discharge (cfs) at Deer Creek	Vinna, Deer Creek	SpringDeer Creek
47	.5.6.7-spring.dayflow.geo	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO). January - March average	Sacramento - San Joaquin Delta at the Delta Cross Channel and Georgiana Slough	Spring Deer Creek Spring Mill Creek Spring Butte Creek
48	.5.6.7-spring.dayflow.export	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS). February - April average	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
49	.5.6.7-spring.dayflow.expin	Dayflow: Export/Inflow Ratio (EXPIN). February - April average	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
50	.5.6.7-spring.dayflow.cd	Dayflow: Net Channel Depletion (QCD). February - April average	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
51	.5.6.7-spring.size.chipps	Average size of spring-run Chinook at ocean entry from Chipps Island Trawl	Chipps Island Trawl	Spring Deer Creek Spring Mill Creek Spring Butte Creek
52	.5.6.7-spring.farallon.temp.early	Temperature at the Farallon Islands, CA (37° 41.8' N, 122° 59.9' W) during the SPRING months (January - March) BEFORE Chinook ocean entry	Nearshore Region	Spring Deer Creek Spring Mill Creek Spring Butte Creek
53	.5.6.7-spring.farallon.temp.late	Temperature at the Farallon Islands, CA (37° 41.8' N, 122° 59.9' W) during the SUMMER months (April - June) AFTER Chinook ocean entry	Nearshore Region, Farallon Islands, CA	Spring Deer Creek Spring Mill Creek Spring Butte Creek
54	spring.mill - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Spring Mill Creek
55	spring.mill - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Spring Mill Creek
56	spring.mill - mill.discharge	Average October - December water discharge (cfs) on Mill Creek	Molinos, Mill Creek	Spring Mill Creek
57	spring.butte - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Sacramento, CA	Spring Butte Creek
58	spring.butte - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Sacramento, CA	Spring Butte Creek
59	spring.butte - butte.discharge	Average October - December water discharge (cfs) on Butte Creek	Chico, Butte Creek	Spring Butte Creek

The second type of data required are time-series of abundance data for the populations included in the multi-stock population dynamics model. Estimates of the number of adult Chinook returning to natural spawning grounds and hatcheries are available from the GrandTab database (CDF&W 2014) for all seven populations evaluated as part of this study. However, since the Central Valley Constant Fractional Marking Program (CFM) was initiated in 2007, it has been possible to estimate the contribution of hatchery-origin Chinook to the spawning abundance observed on wild spawning grounds and the contribution of wild-origin Chinook production to observed returns to regional hatcheries (Kormos et al. 2012). Historical abundances for the seven Chinook populations were reconstructed to account for straying between hatcheries and natural spawning grounds, using the average of the estimated proportion of observed adult Chinook straying in 2010 (Kormos et al. 2012) and 2011 (Palmer-Zwahlen and Kormos 2013). Average (2010-2011) proportions of observed adult abundance that were comprised of hatchery and wild individuals in each population (Table I.2), were used to reconstruct historical abundances for the fall-run spawning populations.

Location	Origin	Recovery	2010	2011	Average
Upper Sacramento	Hatchery	Wild	20%	27%	**24%**
Battle Creek	Hatchery	Wild			
	Wild	Hatchery	11%	11%	**11%**
Feather River	Hatchery	Wild	78%	90%	**84%**
	Wild	Hatchery	5%	4%	**5%**
American River	Hatchery	Wild	32%	66%	**49%**
	Wild	Hatchery	21%	23%	**22%**

Table I.2. Proportion of observed adult abundance by location estimated from CWT recoveries to be of wild or hatchery origin in 2010 and 2011, and the average used to reconstruct historical abundances.

For example, in order to reconstruct the fall-run wild Sacramento mainstem population spawning abundance, each year 24% of the observed spawning abundance was remove and reallocated to the Coleman National Fish Hatchery (Battle Creek) adult abundance, while 11% of the observed Battle Creek hatchery (CNFH) abundance was removed as wild migrants into the hatchery (Fig. I.1).



	wild	wild	hatchery	wild	hatchery	wild	hatchery
year	**Sacramento Mainstem**	**Battle Creek**	**Battle Creek**	**Feather River**	**Feather River**	**American River**	**American River**
1967	87,300	2,160	7,440	10,100	2,002	18,000	5,147

Location	Upper Sacramento	Battle Creek		Feather River		American River	
Origin	Hatchery	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
Recovery	Wild	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery
Average	**24%**		**11%**	**84%**	**5%**	**49%**	**22%**

year	**CNFH in Mainstem**	**Battle Creek Wild in CNFH**	**FRH in Wild**	**Wild in FRH**	**Nimbus in Wild**	**Wild in Nimbus**
1967	20,516	818	8,484	90	8,820	1,132

year	**fall.sac.mainstem**	**fall.battle.creek**	**fall.feather**	**fall.american**
1967	66,785	27,137.10	10,396	12,835

Figure I.1. Empirical schematic showing how the historical abundance of the 1967 population for the four fall-run Chinook populations were reconstructed through additional or removal of the abundance of other stocks.

Adult abundances for the four fall-run Chinook populations were reconstructed using the methods detailed above for years 1967 – 2010 (Fig. I.2). Existing adult abundance estimates reported by CDF&W (2014) for the spring-run populations included in our analyses (i.e. Deer, Mill, and Butte Creeks) were assumed to be minimally impacted by hatchery straying and therefore unaltered (Fig. I.2).

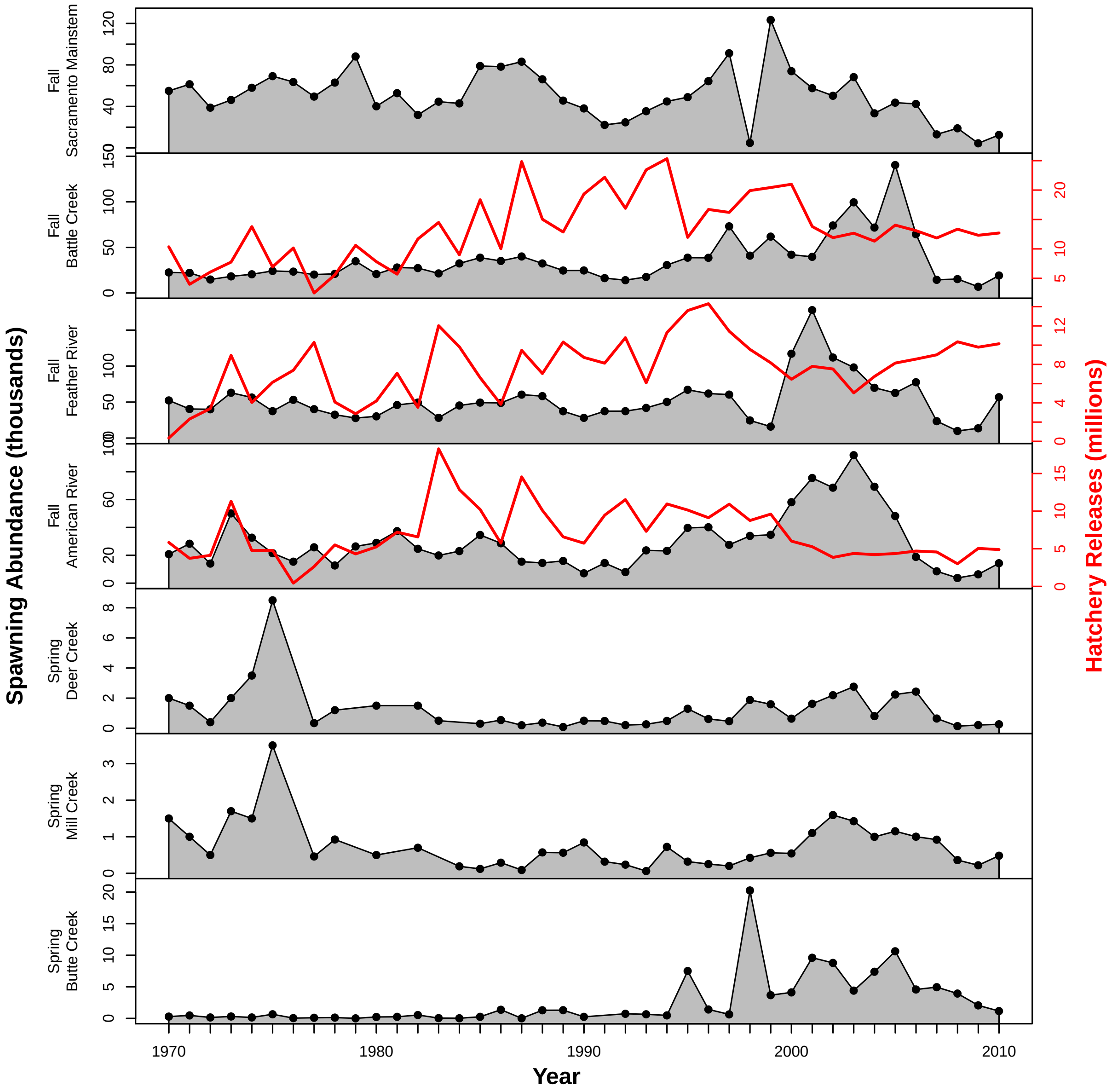


Figure I.2. Adult abundance (grey area plot) and hatchery release (red line) data for Sacramento River Chinook. Fall-run abundances are reconstructed based upon hatchery-wild stray rate estimates, while spring-run abundances are as reported in GrandTab 2014.

Estimates of juvenile Chinook abundance in Sacramento River system were also used to inform estimates of model parameters. The inclusion of additional abundance indices to which the estimation model is fit, confers a greater ability to partition mortality between life stages and more precise estimation of the strength and magnitude of influence from environmental covariates. Poytress et al. (2014) have used available trap efficiency information to calculate absolute abundance indices for juvenile Chinook passing Red Bluff Diversion Dam, partitioned by race. Fall-run juvenile Chinook abundance estimates from 2002 forward were assumed to be comprised predominantly of two populations, the wild Sacramento Mainstem population and the Battle Creek (CNFH) Hatchery population. Therefore, model estimates of the combined abundance of these two populations were compared to the estimates provided by Poytress et al. (2014) in likelihood calculations.

The third type of data required by the estimation model are historical hatchery releases. As constructed, the estimation model allows for specification of the wild or hatchery life-history type for each population. Three of the seven populations currently in included in our analysis are of hatchery origin, therefore annual hatchery release numbers were required for the Battle Creek (CNFH) Hatchery, Feather River Hatchery, and American River (Nimbus) Hatchery populations. Huber and Carlson (in review) have expended significant time and effort to digitize and render historical hatchery reports in an easily accessible and usable format. For the three hatchery population included in our analysis, we have used these hatchery release data to in place of the functional relationship between spawning abundance and fecundity assumed for the wild spawning populations. Figure I.2 shows hatchery release numbers from Huber and Carlson (in review) for each of the three fall-run hatchery populations.

Hatchery release practices have historically differed amongst facilities and over time, with on-sight releases, releases in the Sacramento-San Joaquin delta, releases in San Francisco Bay, and many locations in between (Huber and Carlson in review). At this time, hatchery release location was not specifically considered. However, for populations whose release strategies allow fish to bypass the mortality incurred in the upriver stage, this should manifest as a reduction in the estimated influence of covariates linked to the upriver stage. In this way, although we do not specifically adjust the model stage pathway depending on hatchery release location in each year, this should not be expected to introduce any significant bias in our estimates of coefficients describing the influence of environmental covariates.

The fourth type of data required for these analyses were annual estimates of harvest rate by population. Harvest rate estimates are available from the U.S. Fish and Wildlife Chinookprod database. For each population of interest, this database uses both the abundance estimates from the Grandtab (CDF&W 2014) database and ocean harvest numbers from the Pacific Fishery Management Council (PFMC) to calculate harvest rates in the marine and in-river regions. For our purposes, we have calculated the total harvest rate by stock and year as the sum of ocean ($C_{t,p}^{ocean}$) and in-river catch ($C_{t,p}^{in-river}$), divided by the total abundance including observed escapement ($E_{t,p}$) and catches for that population (p) in that year (t) (Eq. I.2).

(I.2) $$hr_{t,p} = \frac{C_{t,p}^{ocean} + C_{t,p}^{in-river}}{E_{t,p} + C_{t,p}^{ocean} + C_{t,p}^{in-river}}$$

Estimation model structure

The purpose of our analysis is to test the various hypotheses regarding what natural and anthropogenic factors have influenced Sacramento River Chinook salmon survival historically, during both the freshwater and marine portions of the Chinook life cycle. Furthermore, we wish to use estimates of the drivers of Chinook survival to generate robust predictions for future abundance under a range of alternative climate change, oceanographic, and water management scenarios. In order to achieve this objective we have created a population dynamics model that estimates the influence of environmental covariates as well as population-specific basal productivity (maximum survival) rates and rearing capacities for different stages in the life cycle.

The statistical population dynamics model is stage-structured, simulating the entire Chinook life cycle from egg to spawning adult, and partitioning mortality events between those separate spatio-temporal stages. For the freshwater portion of the life cycle, these stages are defined by the migration pathways exhibited by the various Chinook populations and the availability of two data types. First, freshwater life stages are defined in accordance with the availability of environmental covariate data, so as to accurately reflect the point in time and location within Sacramento River network where the Chinook have the most substantial exposure to the environmental covariates. Second, model stages are structured to correspond with juvenile indices of abundance at Red Bluff, CA (Poytress et al. 2014). The estimation model contains six stages, three associated with juvenile rearing in freshwater and nearshore regions, and three associated with the marine component of the life cycle (Fig. I.3). The first stage represents rearing of juveniles in tributaries and upper reaches of the Sacramento River mainstem. The second model stage represents the area within the Sacramento River watershed including the Sacramento-San Joaquin Delta through Chipps Island. The third stage represents juvenile rearing in the nearshore region from San Francisco Bay and the Gulf of Farallones. Stages 4-6 represent the years spent in the marine environment, with associated probability of maturation and potential for ocean harvest.

Figure I.3. Map of estimation model stage structure.

The population dynamics model tracks cohorts of Chinook from specific brood years forward in time across sequential model stages. Chinook abundance is represented by $N_{y,s,p}$ or the number of individuals from brood year y, surviving to stage s, of population p. The abundance of Chinook of brood year y and population p, surviving to the end of the current stage (s) is dependent upon the year, stage, and population specific survival rate $SR_{y,s,p}$ in Equation I.3.

(I.3) $$N_{y,s,p} = N_{y,s-1,p} * SR_{y,s,p}$$

Survival though the spatio-temporally explicit life stages is described by a Beverton-Holt transition function (Moussalli and Hilborn 1986). The Beverton-Holt equation, while traditionally used in the evaluation of spawner-recruit data (Beverton and Holt 1957), provides a useful approximation for survival of individuals from one model stage to the next, as influenced by two factors: 1) the productivity rate $p_{y,s,p}$, and 2) the rearing capacity $K_{y,s,p}$ of each stage (Eq. I.4).

(I.4) $$SR_{y,s,p} = \frac{p_{y,s,p}}{1 + \frac{p_{y,s,p} * \sum_{i=1}^{Npop} \alpha_{p,i,s} * N_{y,s-1,i}}{K_{y,s,p}}}$$

In this formulation (Eq. I.4) the year, stage, and population-specific productivity ($p_{y,s,p}$) represents the maximum survival rate in the absence of density-dependent compensation.

Conversely, the year, stage, and population-specific capacity ($K_{y,s,p}$) describes the total number of individuals that can potential survive through the model stage. However, given that we are evaluating multiple co-migrating and co-rearing populations, equation I.4 also includes an interaction effect ($\alpha_{p,i,s}$) which describes how many individuals of the focal population p are displaced with respect to the stage capacity ($K_{y,s,p}$) for each individual of population i. In this way no interaction effect for a stage may be specified with a zero value for all elements of $\alpha_{p,i,s}$ except $\alpha_{p,i=p,s}$. Positive, non-zero values indicate that the abundance of other populations (i) results in a reduction in overall rearing capacity for the focal population (p), and therefore reduced survival at high abundance levels which approach the stage-specific capacity ($K_{y,s,p}$). Specifying $\alpha_{p,i,s}$ elements equal to one create a situation where capacity is shared across populations with symmetric impacts on capacity.

In our current analysis we have identified the Sacramento-San Joaquin Delta stage (2nd) and nearshore stage (3rd) as points of possible competition and therefore capacity interactions within the model. Fall-run and spring-run juvenile Chinook are assumed to compete with members of their own race within these two stages of the life cycle and therefore shared capacities are assumed, with symmetric interactions (i.e. $\alpha_{p,i,s}$ elements equal to 1).

The productivity ($p_{y,s,p}$) capacity ($K_{y,s,p}$) parameters in the population dynamics model are time varying and assumed to change in response to inter-annual variation in the environmental covariates under evaluation. The productivity parameter for population p, of brood year y, in stage s is a function of the basal productivity $\beta_{s,p,0}$, or the average survival for members of that population in the current stage, as well as the sum of environmental covariate c values at time t ($X_{t,c}$) multiplied by their respective coefficients ($\beta_{s,p,c}$) which describe the influence of each covariate on stage and population-specific productivity $p_{y,s,p}$ (Eq. I.5).

$$p_{y,s,p} = \frac{1}{1 + \exp\left(-\beta_{s,p,0} - \sum_{c=1}^{Nc_{s,p}} \beta_{s,p,c} * X_{t,c}\right)} \qquad \text{(I.5)}$$

$$t = y + \delta_c$$

δ_c is the covariate-specific temporal reference which is the difference between the brood year y and the year in which the cohort will interact with that covariate, and is used as a pointer to ensure that the covariate value for the correct year is used when tracking each cohort forward in time, and $Nc_{s,p}$ is the number of productivity covariates linked to each population in each stage. The overall productivity parameter value ($p_{y,s,p}$) is a logit transformation of the additive effects of the basal productivity rate and covariate effects, which ensures that its value is smoothly scaled between 0 and 1 (Eq. I.5).

The capacity parameter for each population's brood year specific cohort in each stage ($K_{y,s,p}$) is likewise a function of a basal, or average, stage and population specific capacity across years ($\gamma_{s,p.0}$) and the additive effects of capacity-related covariates ($Y_{t,k}$) and the population-specific coefficients ($\gamma_{s,p.k}$) describing the magnitude and direction of influence each holds (Eq. I.6).

(I.6)
$$K_{y,s,p} = \exp\left(\gamma_{s,p,0} + \sum_{k=1}^{Nk_{s,p}} \gamma_{s,p,k} * Y_{t,k}\right)$$
$$t = y + \delta_k$$

The capacity parameter ($K_{y,s,p}$) is described in natural log space for ease of estimation and to ensure it is bounded within the set of positive values, where k is the covariate reference number and δ_k is the temporal reference for the offset from the brood year for each covariate, indicating when the population interacts with each specific covariate in the life cycle.

However, for populations of Chinook occupying the same habitats and subject to the same environmental covariates, it may be reasonable to assume that a common response in survival to a particular covariate is exhibited. For this reason we have further allowed for a coefficient describing the effect of a particular covariate to be shared across populations. In this way several productivity ($\beta_{s,c}$) capacity ($\gamma_{s.k}$) coefficients may be common across a subset of populations. This reduces model complexity, increases parsimony, and improves the ability to estimate of coefficient values for which a common survival response is biologically defensible.

The basal capacity parameters for a population ($\gamma_{s,p.0}$, see Eq. I.6), or group of interacting populations for which $\alpha_{p,i,s} > 0$ (see Eq. I.4), represent the maximum rearing capacity for that population in that stage over time in the absence of influence from environmental covariates. For populations that are currently well below historical abundance levels, or for populations without subsequent juvenile abundance estimates, it is often difficult to estimate these basal stage capacity values. However, auxiliary information may be used to inform these stage-specific capacities. Recent work by Noble Hendrix, in collaboration with researchers at NOAA, has resulted in monthly juvenile Chinook salmon capacity estimates for the Sacramento River mainstem and the Sacramento-San Joaquin Delta (Hendrix et al. 2014). In place of estimating stage capacities for: 1) Sacramento River mainstem-spawning wild fall-run Chinook in the upstream stage (1st), 2) mainstem-spawning wild, Battle Creek (CNFH) hatchery, Feather River Hatchery, and American River (Nimbus) Hatchery, populations in the Sacramento-San Joaquin Delta stage (2nd), and 3) Deer, Mill, and Butte Creek populations in the Sacramento-San Joaquin Delta stage (2nd), we have used capacity estimates available from NOAA in-stream Chinook capacity modelling (see Appendix A - Delta Submodel). The average of estimated monthly capacities in the Sacramento Mainstem for the period between January and April in each year, was used for as the input capacity for mainstem-spawning wild fall-run population. The average of estimated monthly Sacramento – San Joaquin Delta rearing capacities for the March – May and February – April periods, were used as the input capacities for the fall-run and spring-run populations in that stage, respectively.

Capacity estimates for the Sacramento-San Joaquin Delta from NOAA in-stream Chinook habitat capacity modelling were only available after 1980 (Hendrix et al. 2014). Given that our population dynamics model begins in year 1967, it was necessary to assume a fixed capacity for the period prior to 1980. NOAA Delta capacity estimates correlate most directly with water year type, therefore the average of estimated capacities for the fall-run and spring-run populations by water year type were calculated and used in place of actual capacity estimates prior to 1980. These average capacities by water year type and Chinook run type were used in years prior to 1980 based on the reported water year.

Survival for cohorts of Chinook is tracked forward in time across spatio-temporal model stages in the same manner (Eq. I.4, I.5, I.6) independent of whether the stage is in the freshwater or marine portion of the life cycle and independent of the ontogenetic status of individuals. However, for the final three model stages representing the 1st, 2nd, and 3rd year in the ocean, it is necessary to account for both the maturation process and marine harvest when tracking the number of individuals entering the next stage. Harvest mortality is assumed to occur after the annual mortality event, but prior to maturation. Catch by year, population, and stage ($C_{t,p,s}$) is the number of surviving individuals multiplied by the population specific harvest rate observed in each year ($hr_{t,p}$), scaled by the stage (i.e. ocean age) specific catchability coefficient (ε_s) (Eq. I.7).

(I.7)
$$\begin{gathered} C_{t,p,s} = N_{y,s,p} * SR_{y,s,p} * \left(hr_{t,p} / \varepsilon_s \right) \\ t = y + \rho_s \\ \varepsilon_s = \{0, 0, 0, 0, 1.54, 1.0\} \end{gathered}$$

In equation I.7, ρ_s is the temporal offset for model stages that indicates the difference between the brood year and the calendar year, so that the proper annual harvest rate may be referenced. Annual harvest rate estimates were obtained from the Pacific Fishery Management Council (PFMC).

For the three ocean life-stages, the number of individuals of a cohort moving to the next stage is governed by the survival rate ($SR_{y,s,p}$), annual catch estimate ($C_{t,p,s}$), and the maturation probability (ϕ_s) (Eq. I.8).

(I.8)
$$\begin{gathered} N_{y,s+1,p} = \left(N_{y,s,p} * SR_{y,s,p} - C_{t,p,s} \right) * \left(1 - \phi_s \right) \\ \phi_s = \{0, 0, 0, 0.1, 0.942, 1\} \\ t = y + \rho_s \end{gathered}$$

While the cohort specific survival rate varies over time, the maturation probability (ϕ_s) is assumed to be temporally invariant. So then, the number of individuals of a cohort advancing to the next ocean stage is the number in the previous stage ($N_{y,s,p}$) that have survived, less the proportion that matures and begins homeward migration (Eq. I.8). The return abundance ($R_{y,s,p}$) is the number of individuals from a cohort that survived marine and harvest mortality, and have initiated the maturation process and return to freshwater to spawn (Eq. I.9).

(I.9)
$$R_{y,s,p} = \left(N_{y,s,p} * SR_{y,s,p} - C_{t,p,s} \right) * \phi_s$$

The predicted number of spawning adults of each population in each year ($\hat{A}_{t,p}$) is the sum of returning individuals ($R_{y,s,p}$) across stages or equivalently ocean age classes (Eq. I.10).

(I.10) $$\hat{A}_{t,p} = \sum_{s=1}^{Nstage} R_{y,s,p}$$
$$t = y + \rho_s$$

Depending on whether a wild-type or hatchery-type life history is assumed for each population the next cohort ($N_{y,s=1,p}$) will be created either based on the predicted number of spawning adults and an assumed fecundity value of 2000 eggs/individuals (Eq. I.11) or based upon recorded releases from hatchery facilities (Eq. I.12).

(I.11) $$N_{y,s=1,p} = \hat{A}_{t=y,p} * fec$$

(I.12) $$N_{y,s=1,p} = RH_{t=y,p}$$

In order to estimate the value for model parameters including basal productivities ($\beta_{s,p,0}$) and capacities ($\gamma_{s,p.0}$) for each population in each stage, and coefficients describing the direction and magnitude of influence each environmental covariate has on either productivity ($\beta_{s,p,c}$) or capacity ($\gamma_{s,p.k}$) for individual populations or shared amongst populations ($\beta_{s,c}$ and $\gamma_{s,k}$), the model must be fit to available abundance data. We employ a maximum likelihood approach to compare abundance predictions with available data and estimate model parameter values (Hilborn and Mangel 1997). Predicted adult spawning abundances are calculated (Eq. I.10) as part of the population dynamics model. Absolute abundance estimates for juveniles are available for Chinook passing Red Bluff Diversion Dam (Poytress et al. 2014), and we assume that the mainstem Sacramento wild population and Battle Creek hatchery (CNFH) population comprise the majority of the juvenile fall-run Chinook sampled at this location, so the juvenile abundance estimate is calculated as the sum of these two populations (Eq. I.13)

(I.13) $$\hat{J}_t = \sum_{p=1}^{2} N_{y,s=1,p}$$
$$t = y + \rho_{s=1}$$

Model predicted adult spawning abundances are compared to empirical data, and model parameters are estimated by minimizing the negative log-likelihood of the model given the observed data (Eq. I.14).

(I.14) $$L_A\left(\Theta \mid A_{t,p}\right) = \prod_{t=1}^{n} \frac{1}{\hat{\sigma}_p\sqrt{2\pi}} \exp\left[-\frac{\left(\ln(A_{t,p}) - \ln(\hat{A}_{t,p})\right)^2}{2\hat{\sigma}_p^2}\right]$$

The likelihood of the model parameters, given the spawning abundance data, assume a that observation error in log transformed abundances are normally distributed, with the standard deviation of the observation error distribution ($\hat{\sigma}_p$) equal to the maximum likelihood estimate (Eq. I.15).

(I.15) $$\hat{\sigma}_p = \sqrt{\sum_{t=1}^{n} \frac{\left(\ln(A_{t,p}) - \ln(\hat{A}_{t,p})\right)^2}{n}}$$

Under the same assumptions the observation error likelihood of the model parameters given juvenile abundance data (Eq. I.13) was calculated (Eq. I.16)

(I.16) $$L_J\left(\Theta \mid J_t\right) = \prod_{t=1}^{n} \frac{1}{\hat{\sigma}_J \sqrt{2\pi}} \exp\left[-\frac{\left(\ln(J_t) - \ln(\hat{J}_t)\right)^2}{2\hat{\sigma}_J^2}\right]$$

using the maximum likelihood estimate for the standard deviation of the normal observation error distribution from the juvenile data (Eq. I.17).

(I.17) $$\hat{\sigma}_J = \sqrt{\sum_{t=1}^{n} \frac{\left(\ln(J_t) - \ln(\hat{J}_t)\right)^2}{n}}$$

The total data likelihood (Eq. I.18) is the sum of the negative log of the likelihood from the juvenile and adult abundance data.

(I.18) $$LL_T = -\ln\left(L_A\right) - \ln\left(L_J\right)$$

Model parameter values that minimized the total negative log likelihood (LL_T) were found using AD Model Builder (Fournier et al. 2012). AD Model Builder (ADMB) is a software platform allowing complex non-linear minimizations for models containing a large number of parameters while also permitting profile likelihoods or posterior distributions for parameters of interest to be estimated. ADMB was selected as the software design platform for this project because of its flexibility, computational efficiency and ability to reliably sample a complex multivariate likelihood surface. In addition to its benefits as a fast and stable optimization tool for fitting statistical models to data, ADMB also estimates uncertainty in and correlations between model parameters based on their derivative structure.

When fit to available abundance data the ADMB stage-structured population dynamics model provides estimates of model parameters, uncertainty in those parameter estimates, and the hessian matrix for model parameters from which the parameter covariance matrix may be derived. However, with 37 separate environmental covariates to be tested as competing hypotheses it was necessary to define metrics for model fit and parsimony. We use the Akaike Information Criterion corrected for small sample sizes (AICc) (Burnham and Anderson 2002) as a metric for model parsimony (Eq. I.19).

(I.19) $$AICc = 2LL_T + 2p + \frac{2p\left(p+1\right)}{n-p-1}$$

AICc balances the degree to which a model is able to explain the variability in data (LL_T) against the number of parameters estimated (p) and number of data used in estimation (n), and provides a basis for model selection. The second statistic used to evaluate model fit is the mean absolute percent error in model predictions (Eq. I.20).

$$\text{(I.20)} \quad MAPE_p = \frac{\sum_{t=1}^{n} \left| \frac{\hat{A}_{t,p} - A_{t,p}}{A_{t,p}} \right|}{n}$$

The method we have employed in the Sacramento for modelling the anadromous salmonid life cycle as a series of sequential, spatially-explicit, stage-specific Beverton-Holt transition functions that relate density-dependent survival to habitat covariates is similar to those successfully used to address conservation questions regarding other Chinook salmon populations along the West Coast. The Shiraz model developed by Scheuerell et al. (2006), employed to evaluate anthropogenic and habitat effects on production of Chinook in the Snohomish River basin of Puget Sound, Washington, was one of the first to specify interactions between habitat variables and the productivity and capacity parameters of the Beverton-Holt functions describing survival though life stages. Subsequently, Battin et al. (2007) and Honea et al. (2009) employed stage-structured models governed by linked Beverton-Holt transition functions to evaluate the influence of climate change, hydrologic variability, and habitat restoration on populations of Chinook salmon in the Columbia River basin. All three of these analyses used a Shiraz-type approach by linking habitat and climate covariates to stage-specific survival.

However, the model we have designed for evaluating the environmental drivers of survival for Chinook salmon in the Sacramento River differs from the Shiraz-type models described above (Scheuerell et al. 2006, Battin et al. 2007, Honea et al. 2009) in several fundamental ways. First, the model used in these analyses is statistical in nature. Whereas Scheuerell et al. (2006), Honea et al. (2009), and Battin et al. (2007), all specify the relationships between environmental covariates and the productivity and capacity parameters of the Beverton-Holt function for each stage, based upon *in situ* observations, laboratory experiments, or expert opinion, the estimation framework we have created for the analysis of the drivers of Sacramento River Chinook survival estimates these relationships directly from the abundance data. Second, estimation of the relationships between environmental covariates and the Beverton-Holt productivity and capacity parameters, will not only provide point estimates of the effect of each covariate, but also estimates of uncertainty. By estimating both the value for coefficients describing covariate effects, as well as their uncertainty, we are not only be able to discern which covariates have the largest influence, but also which covariates have had a consistent influence historically. Finally, by estimating the value of coefficients describing the magnitude and direction of influence each environmental covariate has on stage-specific productivity or capacity, our method allows for the propagation of estimation uncertainty in those relationships forward when those model parameters are used to predict future abundance trends under alternative climate, marine productivity, or water use scenarios.

METHODS UNCERTAINTY – AICC SELECTIONS AND MCMC METHODS

In order to test a range of hypotheses regarding which environmental covariates influence the survival of seven populations of Sacramento River Chinook, we constructed a stage-structured statistical population dynamics model. When fit to available adult and juvenile abundance data, this model estimates the magnitude and direction of influence that a set of environmental covariates has on two components of Chinook survival, namely life-stage specific productivity (maximum survival) rates and capacities. In the process of fitting population dynamics models to data as part of our analysis, there were two sources of uncertainty that we considered directly. The first was structural uncertainty, or uncertainty in the subset of environmental covariates that best represent the processes driving changes in abundance over time. The second is estimation uncertainty, or uncertainty in our ability to identify the true direction and magnitude of the effect each environmental covariate imposes on Chinook survival. To address structural uncertainty in our analysis, we used a process of forward stepwise model building, based upon an AICc criteria, with replication to ensure complete evaluation of model space, or the range of potential models that may be used to describe trends in abundance over time. This process allowed us to define the “best” model or subset of potential environmental covariates (hypotheses) for describing observed population dynamics. To address the second type of uncertainty in our analysis, estimation uncertainty, we employed Markov Chain Monte-Carlo estimation methods to quantify the probability distributions for the coefficients describing the effect of each environmental covariate on survival.

Stepwise AICc Model Selection

In total 37 separate environmental covariates were identified by the study team as potential drivers of interannual variation in Sacramento Chinook survival. Describing the effects of these 37 environmental covariates on separate populations in the form of either population-specific effects or common influences on groups of populations, resulted in a total 59 covariate-by-population effects, whose influence on survival may be estimated based on their ability to explain observed Chinook abundance data. Each of these 59 covariate-by-population effects represents an alternative hypothesis to be tested in our analysis.

Hypotheses for covariate-by-population effects on Chinook survival may be compared to a “null” model that attempts to explain variation in the time-series’ of observed juvenile and adult abundance data based on only observed ocean harvest rates, hatchery release numbers, estimated productivities (maximum survival rates) for populations in the first life-stage, and annual capacities specified by the juvenile capacity modelling (Hendrix et al. 2014). The null model represents the base case, without any influence from environmental covariates. However, in order to define the model with the best potential to provide accurate predictions for population responses to future environmental, climate, and water management scenarios it was necessary to find the most parsimonious model, or subset of explanatory covariates. Model parsimony is defined by the balance between the ability to accurately explain variation in observed data, while estimating the fewest parameters possible. The Akaike information criterion, corrected for small sample sizes (AICc, Eq. I.19), quantifies model parsimony and provides a metric for selecting amongst competing models (Burnham and Anderson 2002). Competing models incorporating alternative combinations of covariate effects were compared based on their AICc values in order to define a “best-fit” model for generating predictions for future abundance trends.

With a total of 59 independent covariate-by-population effects to be tested for their ability to explain variation in historical Sacramento Chinook survival, the number of possible combinations of these effects, or potential models, is quite large. It becomes unrealistic to fit every possible model permutation to the available data and compare AICc values. Therefore we used a method for exploring the model space, or the range of potential models incorporating different combinations of these effects, which involved a forward stepwise model building with AICc as the selection criteria. Forward stepwise model building begins first by fitting the null model, without any covariate effects, to the available data. Second, a covariate is selected at random from amongst the set of 59 possible covariate-by-population effects and included in the model, and this model is subsequently fit to the data. Third, the AICc value for this new model is compared to that of the null model. If a reduction in AICc value for the model including the additional covariate of greater than 2 units is observed ($\Delta\text{AICc} \leq 2$), when the old model is compared to the model incorporating the new covariate, that covariate is kept, otherwise it is removed from the model. Moving forward, this process of randomly sampling covariates without replacement, fitting the model to data, and evaluating $\Delta AICc$, (i.e. steps two and three) are repeated until all covariates have been tested for their ability to improve model parsimony (see Fig. I.4).

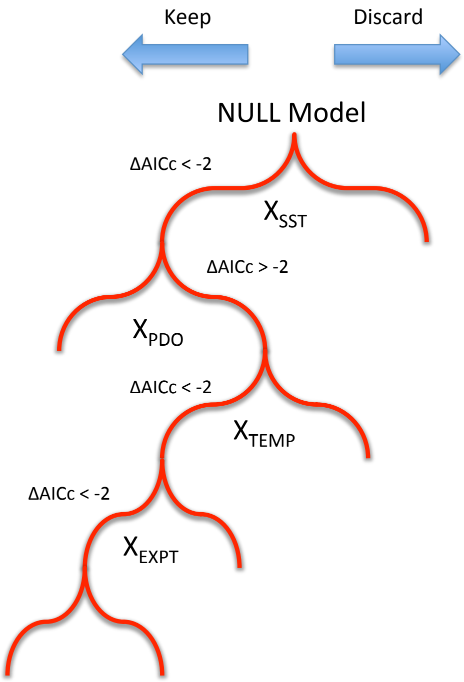


Figure I.4. Diagram of forward stepwise AICc model building process. Starting from the null model, covariates (X_{TEMP}, X_{PDO} etc.) are sampled at random without replacement from the set of 59 possible hypotheses and included in the statistical model. The model is then fit to abundance data and the difference in AICc values between the old and new models dictates whether that covariate is kept or discarded, and the next iteration begins.

The result of one round of forward stepwise AICc model building, or fitting the null model and 59 alternative models sequentially, is one realization of a best-fit model based upon the AICc criteria. However, experience indicates that given even small correlations among some environmental covariates, the order in which covariates are introduced has a subtle influence on the resulting model. Therefore, in order to more fully explore the uncertainty in model selection, we repeated the forward stepwise AICc process 1,000 times. By evaluating the frequency with which specific covariates appear in best-fit models across these 1,000 realizations, it is possible to determine which covariates are most important in explaining historical variation in Chinook survival. Furthermore, by repeating the stepwise AICc process 1,000 times, we are thoroughly exploring the model space and among these independently built models can determine the single model that has the lowest AICc among the candidate best-fit models.

Markov Chain Monte-Carlo Estimation Methods

The second critical piece of uncertainty in our analysis is estimation uncertainty. Estimation uncertainty describes variation in the estimated value of model parameters, and is a function of how well model parameters are informed by the available data. In order to quantify the level of estimation uncertainty in our analyses, particularly as it pertains to estimates of the coefficients describing the influence of environmental covariates on Chinook survival, we employed Bayesian estimation methods in addition to the maximum likelihood approach described above. Bayes' Theorem (Eq. I.21) describes the probability of a hypothesis θ, in our case a set of parameter values, given the data, which in our case are both adult spawning abundance ($A_{t,p}$) and juvenile abundance (J_t) observations.

(I.21) $$P(\theta \mid data) = \frac{P(data \mid \theta) P(\theta)}{\int P(data \mid \theta) P(\theta)}$$

The prior probability on logit transformed coefficients was normal with a mean of zero and standard deviation equal to 2.5, as per recommendations by King et al. (2010). Bounded uniform priors were assumed for all other estimated model parameters. Estimated initial (log) abundances 1967-1969 were bounded on the (0, 100) interval, basal stage productivities ($\beta_{s,p,0}$) were bounded on the (-25, 25) interval, and basal stage capacities ($\gamma_{s,p.0}$) bounded on the (-100, 100) interval. Bayesian estimation methods allow the posterior probability distribution for derived and estimated parameters to be calculated, and from it the full range of parameter uncertainty. The posterior probability distribution for model parameter i (θ_i) describes the probability that the true value of that parameter is equal to a specific value. Based upon the posterior probability distributions for model parameters, we are able to calculate the expected values for model parameters as well the uncertainty in those parameter estimates.

Markov Chain Monte-Carlo (MCMC) methods are commonly used numerical algorithms employed to draw samples from the posterior distributions for parameters in Bayesian models (Gelman et al. 2004). We employed the Random Walk Metropolis-Hastings (RW-MH) MCMC algorithm implemented in AD Model Builder (Fournier et al. 2012) to draw samples from posterior distributions of parameters in population dynamics model. The RW-MH MCMC algorithm is a widely applicable MCMC algorithm that accounts for correlations among model parameters. As implemented in ADMB, the RW-MH MCMC algorithm begins by finding the parameter values that maximize the complete data likelihood, or posterior modes, and then uses the estimated covariance matrix for model parameters to create a multivariate proposal distribution. Based upon this multivariate proposal distribution randomly drawn parameter sets, or MCMC jumps, are proposed and either accepted or rejected based upon comparison of the ratio of the proposed posterior density to that of the current state, with a random uniform (0,1) deviate. In this way, the RW-MH MCMC algorithm in ADMB begins as the posterior mode and samples the joint posterior.

MCMC chains were run for 5,000,000 iterations with a thinning rate of 1/1,000 to reduce posterior correlation. The first 30% of the chain was removed as a burn-in period, during which the chain approached the stationary distribution for model parameters. To ensure MCMC results converged to their stationary distribution, three independent chains were run simultaneously. Model convergence was tested in three separate ways. First, traceplots of MCMC samples were evaluated for the presence of discernable trends that would indicate a lack of convergence to the true stationary distribution. Second, posterior correlations at differing lags were calculated, wherein significant correlation would indicating a lack of convergence. Finally, Gelman and Rubin’s convergence diagnostic (Gelman and Rubin 1992, Brooks and Gelman 1998) was used to compare within and among chain variance to determine if all three chains had indeed converged to the same stationary distribution.

RESULTS MODEL FITS

Model Selection Results

In order to define the set of environmental covariates that best explains historical patterns in abundance for the seven populations of Sacramento Chinook, we employed a process of iterative forward stepwise AICc model selection. This process was meant to test the full range of alternative hypotheses for drivers of Sacramento Chinook survival, and define the most coherent set of covariates with the greatest explanatory power and predictive potential. Each iteration of model selection results in a candidate best-fit model, however it in order to fully explore model space it was necessary to repeat this process many times with a randomized order of covariate proposal in each iteration. By comparing the percent of times any particular covariate appeared across the 1,000 candidate best-fit models, we are able to determine which covariates or hypotheses have the greatest support from the data. Table I.3, describes the percentage of candidate best-fit models that incorporated each specific covariate.

Hypothesis	Covariate	Sum	Percent
58	spring.butte - sacAirTemp.spring	998	100%
51	.5.6.7-spring.size.chipps	945	95%
17	.1.2.3.4-upwelling.south.early	783	78%
21	.1.2.3.4.5.6.7-pdo.early	657	66%
57	spring.butte - sacAirTemp.summer	571	57%
48	.5.6.7-spring.dayflow.export	541	54%
9	.1.2.3.4-fall.dayflow.export	484	48%
10	.1.2.3.4-fall.dayflow.expin	374	37%
41	.5.6.7-bass.cpue	362	36%
36	spring.deer - sacAirTemp.summer	359	36%
55	spring.mill - sacAirTemp.spring	316	32%
46	spring.deer - deer.discharge	282	28%
20	.1.2.3.4.5.6.7-curl.late	275	28%
44	.5.6.7-upwelling.south.early	222	22%
50	.5.6.7-spring.dayflow.cd	220	22%
18	.1.2.3.4-upwelling.south.late	205	21%
53	.5.6.7-spring.farallon.temp.late	202	20%
42	.5.6.7-upwelling.north.early	199	20%
47	.5.6.7-spring.dayflow.geo	194	19%
19	.1.2.3.4.5.6.7-curl.early	193	19%
37	spring.deer - sacAirTemp.spring	186	19%
40	.5.6.7-freeport.sed.conc	185	19%
11	.1.2.3.4-fall.dayflow.cd	182	18%
15	.1.2.3.4-upwelling.north.early	169	17%
6	.1.2.3.4-freeport.sed.conc	159	16%
56	spring.mill - mill.discharge	131	13%
7	.1.2.3.4-bass.cpue	107	11%
38	.5.6.7-verona.peak.streamflow	96	10%
49	.5.6.7-spring.dayflow.expin	95	10%
43	.5.6.7-upwelling.north.late	94	9%
4	.1.2.3.4-verona.peak.streamflow	87	9%
3	fall.sac.mainstem - keswick.discharge	85	9%
2	fall.sac.mainstem - sacAirTemp.spring	83	8%
29	fall.feather - sacAirTemp.spring	77	8%
52	.5.6.7-spring.farallon.temp.early	62	6%
45	.5.6.7-upwelling.south.late	48	5%
39	.5.6.7-yolo.wood.peak.streamflow	46	5%
1	fall.sac.mainstem - sacAirTemp.summer	45	5%
12	.1.2.3.4-fall.size.chipps	36	4%
8	.1.2.3.4-fall.dayflow.geo	17	2%
22	.1.2.3.4.5.6.7-pdo.late	11	1%
24	fall.battle.creek - sacAirTemp.spring	11	1%
14	.1.2.3.4-fall.farallon.temp.late	9	1%
31	fall.feather - feather.oronville.discharge	9	1%
59	spring.butte - butte.discharge	8	1%
13	.1.2.3.4-fall.farallon.temp.early	7	1%
5	.1.2.3.4-yolo.wood.peak.streamflow	3	0%
16	.1.2.3.4-upwelling.north.late	2	0%
23	fall.battle.creek - sacAirTemp.summer	2	0%
54	spring.mill - sacAirTemp.summer	2	0%
25	fall.battle.creek - keswick.discharge	1	0%
26	fall.battle.creek - battle.discharge	1	0%
27	fall.battle.creek - battle.peak.gage.ht	0	0%
28	fall.feather - sacAirTemp.summer	0	0%
30	fall.feather - keswick.discharge	0	0%
32	fall.american - sacAirTemp.summer	0	0%
33	fall.american - sacAirTemp.spring	0	0%
34	fall.american - keswick.discharge	0	0%
35	fall.american - american.discharge	0	0%

Table I.3. **Model selection results. Percent inclusion rate for environmental covariate effects across 1,000 candidate best-fit models, each resulting from one round of forward stepwise-AICc model building. Note the covariate name includes the single population name, or the numbers for multiple populations upon whose survival the effect of the environmental covariate is shared. For reference population numbers are: 1) fall-run mainstem Sacramento wild-run Chinook, 2) fall-run Battle Creek Coleman National Fish Hatchery produced Chinook, 3) fall-run Feather River Hatchery produced Chinook, 4) fall-run American River Nimbus Hatchery produced Chinook, 5) spring-run Deer Creek wild Chinook, 6) spring-run Mill Creek wild Chinook, and 7) spring-run Butte Creek wild Chinook.**

Results of the iterative forward stepwise-AICc model selection (Table I.3) indicate that the set of environmental covariates (hypotheses) which best describe historical variation in Sacramento Chinook abundance encompass a wide range of locations within the life cycle, populations, and ecological processes. A higher inclusion rate across best-fit models for a specific covariate by population(s) effect may be interpreted as greater weight of evidence from the data that this covariate explains variation in survival and therefore may be of ecological importance (Table I.3). Foremost, it should be noted that the influence of spring air temperature at the city of Sacramento on survival of the Butte Creek population (spring.butte – sacAirTemp.spring) was included as an AICc-selected covariate in 998 of 1,000 best-fit models. This covariate represents air temperature during juvenile rearing (January – March) at the city of Sacramento, and is included as a surrogate for Butte Creek stream temperature. Additional covariates which were represented in 60% or greater of iteratively built models include: 1) the combined influence of the size of out-migrating spring-run juveniles on the survival of Deer, Mill and Butte Creek spring-run populations (.5.6.7-spring.size.chipps), 2) the combined influence of near-shore upwelling during the period of ocean entry (April – June) upon the survival of the four fall-run populations (.1.2.3.4-upwelling.south.early), and 3) the combined influence of the Pacific Decadal Oscillation during winter (January – May average) of the first year of marine residence (.1.2.3.4.5.6.7-pdo.early) on the survival of all four fall-run and three spring-run populations. The 5th most frequently included covariate was the effect of summer (July – September) air temperature at Sacramento during the brood year, on survival of Butte Creek spring-run Chinook (spring.butte-sacAirTemp.summer). This covariate was included to test hypothesis that high over-summer water temperatures may have a negative impact on the survival and successful spawning of adult spring-run Chinook holding in tributaries.

With respect to the representation of anthropogenic drivers of Chinook survival across the 1,000 forward-AICc built models, covariates describing the influence of water exports on spring and fall-run survival were the 6th, 7th, and 8th most often included. The combined effect of average water exports from the Sacramento – San Joaquin Delta between February and April quantified by the Dayflow QEXPORTS metric on survival of spring-run Chinook (.5.6.7-spring.dayflow.export), appeared in 54% of forward stepwise-AICc built models. Similarly, the covariate representing the combined effect of March – May average Sacramento – San Joaquin water exports on the survival of the four fall-run Chinook populations (.1.2.3.4-fall.dayflow.export) was included in 48% of stepwise-AICc built models, with the ratio of water exports to total Delta water inflow (Dayflow: EXPIN) during this same period (.1.2.3.4-fall.dayflow.expin) following closely with a 37% inclusion rate. Other covariates highlighting the influence of water routing and supply in the Sacramento – San Joaquin Delta were included in a smaller subset of stepwise-AICc built models. The influence of average net channel depletion (Dayflow: QCD) between February and April on the grouped spring-run Chinook populations (.5.6.7-spring.dayflow.cd) was included in 22% of the 1,000 stepwise-AICc built models. In addition, the combined influence of the average flow into Georgiana Slough and the Delta Cross Channel (Dayflow: QXGEO) February – April on the spring-run populations (.5.6.7-spring.dayflow.geo) was included in 19% of candidate best-fit models.

While the inclusion rate of specific covariate-by-population effects across the 1,000 stepwise-AICc built models provides an indication of the relative weight of evidence from the data, that each covariate holds some ability to explain historical patterns in survival, we consider the model with the lowest AICc value to have the best predictive ability. The single model with the lowest AICc value represents the most parsimonious fit to the data, explaining the greatest amount of observed variation in adult and juvenile abundance, while estimating the fewest parameters. This lowest AICc or "final" model provides the best basis for predicting future trends in abundance under alternative climate, marine production, and water management scenarios. The final model included 14 covariate-by-population effects, spanning both the freshwater and marine portions of the life cycle (Table I.4). In addition, the effects incorporated in the final model include both single-population effects as well as shared effects of environmental covariates across multiple populations. In total five of the covariates included in the final (lowest AICc) model were related to survival in the 1st (upriver) stage, six were related to the 2nd stage representing environmental effects on survival through the Sacramento – San Joaquin Delta, two were related to the 3rd stage influencing survival in the nearshore environment, and only one covariate was related to survival during subsequent years of marine residence.

Hypothesis Number	Covariate	Covariate Description	Model Stage	Populations
3	fall.sac.mainstem - keswick.discharge	Average January - March water discharge (cfs) at Keswick Dam	Upstream	Fall Sacramento Mainstem Wild
24	fall.battle.creek - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Upstream	Fall Battle Creek (CNFH) Hatchery
46	spring.deer - deer.discharge	Average October - December water discharge (cfs) at Deer Creek	Upstream	SpringDeer Creek
57	spring.butte - sacAirTemp.summer	Sacramento air temperature during summer (July - September) of the brood year	Upstream	Spring Butte Creek
58	spring.butte - sacAirTemp.spring	Sacramento air temperature during spring (January - March) emergence year	Upstream	Spring Butte Creek
40	.5.6.7-freeport.sed.conc	Average February - April monthly sediment concentration (mg/L)	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
48	.5.6.7-spring.dayflow.export	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS). February - April average	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
51	.5.6.7-spring.size.chipps	Average size of spring-run Chinook at ocean entry from Chipps Island Trawl	Sacramento - San Joaquin Delta	Spring Deer Creek Spring Mill Creek Spring Butte Creek
6	.1.2.3.4-freeport.sed.conc	Average February - April monthly sediment concentration (mg/L)	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
10	.1.2.3.4-fall.dayflow.expin	Dayflow: Export/Inflow Ratio (EXPIN). March - May average	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
11	.1.2.3.4-fall.dayflow.cd	Dayflow: Net Channel Depletion (QCD). March - May average	Sacramento - San Joaquin Delta	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
17	.1.2.3.4-upwelling.south.early	NOAA Index for upwelling at Southern Location (36 N, 122 W), average of SPRING months (April - June)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery
20	.1.2.3.4.5.6.7-curl.late	NOAA Wind Stress Curl for upwelling at Northern Location (39 N, 125 W), average of FALL months (July - December)	Nearshore Region	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek
21	.1.2.3.4.5.6.7-pdo.early	Pacific Decadal Oscillation (PDO), average of January - May monthly indices during first year of mearine residence	1st Ocean Year	Fall Sacramento Mainstem Wild Fall Battle Creek (CNFH) Hatchery Fall Feather River Hatchery Fall American River (Nimbus) Hatchery Spring Deer Creek Spring Mill Creek Spring Butte Creek

Table I.4. Fourteen covariate-by-population effects included in the final AICc-selected model.

Of the covariate-by-population effects on upstream survival incorporated in the final model three were related to atmospheric temperature, used as a proxy for tributary-specific water temperatures, and two were related to water flow conditions. The three temperature-related covariate-by-population effects were all based on air temperature at Sacramento, CA and included: 1) the effect of average spring air temperature (January - March) on survival of the fall-run Battle Creek population in the year of emergence (fall.battle.creek - sacAirTemp.spring), 2) the effect of average summer air temperature (July – September) during the brood year on offspring production and oocyte through juvenile survival for the Butte Creek spring-run population (spring.butte - sacAirTemp.summer), and 3) the effect of average spring air temperature (January – March) in the year of emergence on survival of Butte Creek spring-run Chinook (spring.butte - sacAirTemp.spring). The two upstream covariate effects related to water flow conditions included, the influence of average water discharge rates (cfs^{-1}) at Keswick Dam during the period between January and March on the survival of Sacramento mainstem spawning wild fall-run Chinook (fall.sac.mainstem - keswick.discharge), and the effect of average water discharge in Deer Creek between October and December on the brood year survival of spring-run Chinook spawning in that tributary (spring.deer - deer.discharge).

The range of covariates which best describe historical patterns in juvenile Chinook survival through the Sacramento – San Joaquin Delta stage included factors both anthropogenic and natural in origin. Interestingly, the winter (February-April) concentration of sediment (mg/L) measured at Freeport, CA was selected based upon the AICc criteria as an important explanatory covariate for both grouped fall-run (.1.2.3.4-freeport.sed.conc) and spring-run (.5.6.7-freeport.sed.conc) populations. Two other covariate effects on the combined survival of fall-run Chinook populations which relate to water flow and management in the Sacramento – San Joaquin Delta were also identified in the final model, including average March – May Dayflow metrics for: 1) QCD or net channel depletion for in-delta consumptive use (.1.2.3.4-fall.dayflow.cd), and 2) EXPIN or the ratio of total delta exports to freshwater inflows (.1.2.3.4-fall.dayflow.expin) (CDWR 2014). In addition to sediment concentration, two other covariate effects on the combined survival of the Deer, Mill, and Butte Creek spring-run populations in the Sacramento – San Joaquin Delta were present in the AICc-selected final model. These included the influence of average monthly water exports and diversions from the delta (February – April) as quantified by the Dayflow metric QEXPORTS (CDWR 2014), which represents the sum of Central Valley Project exports, State Water Project exports, Contra Costa Water District diversions, and North Bay Aqueduct exports (.5.6.7-spring.dayflow.export), and the average size of juvenile spring-run Chinook caught in the Chipps Island Trawl (.5.6.7-spring.size.chipps).

Based on the AICc criteria and thorough exploration of model space using replicate stepwise model building, the final model identified three covariates able to explain some of variance in Chinook survival in the nearshore region following ocean entry and survival during subsequent years of marine residency. Survival for the four fall-run Chinook populations in the nearshore region was explained in part by upwelling patterns during the spring months (April – June) at the southern NOAA/PFEL monitoring site located at 36°N latitude and 122°W longitude (.1.2.3.4-upwelling.south.early). Additionally, the effect of average wind stress curl during July – December of the year of ocean entry on the survival of all seven combined spring and fall-run populations was included in the final model (.1.2.3.4.5.6.7-curl.late). The last covariate present in the final model linked to broad-scale marine climate patterns was the effect of the average Pacific Decadal Oscillation Index during the winter of the first year at sea (January – May) on the combined survival of all seven populations (.1.2.3.4.5.6.7-pdo.early).

These fourteen population-by-covariate effects, spanning freshwater and marine portions of the Chinook life cycle and all seven analyzed Chinook populations, represent the most parsimonious explanation for historical patterns in Chinook survival and observed juvenile and adult abundance. This final model was used as the basis for the subsequent Bayesian analysis of the effect of each of these covariates and their realized survival influence, and used for predicting future trends in abundance under alternative water management scenarios, predictions for future climate change, and marine production patterns.

Estimation Results

In order to estimate the direction and magnitude of the 14 covariate effects identified by AICc selection criteria across 1,000 stepwise-AICc built models (Table I.4), we have employed Bayesian methods with a MCMC sampler. Separate stage-structured models were used to represent each of the seven populations, however common effects across populations for specific covariates were estimated, and shared capacity constraints in the Sacramento – San Joaquin Delta were assumed for the four fall-run and three spring-run populations separately. Estimation of model parameters was informed by juvenile and adult abundance data, reconstructed to account for observed stray rates between hatchery and wild populations. Figure I.6 displays observed adult abundance data for the four fall-run Chinook populations and three spring-run populations as well as the posterior predictive distribution from the Bayesian population dynamics model. The posterior predictive distribution represented by the red line and shaded regions, describe the median, 50% and 95% credible intervals for the predicted adult spawning abundance or hatchery returns for each population in each year.

Results indicate that the model predicts the pattern for Deer and Mill Creek spring-run populations which exhibit higher adult abundances, relative to the time series, through 1984 followed by a period of lower adult abundance through the mid-1990s, followed by higher relative abundances through 2006 (Fig. I.5). Similarly for the Butte Creek spring-run population, the model captures the period of lower spawning abundance prior 1985 followed by a pronounced increase in abundance, ending with a relative plateau in the early 2000's (Fig. I.5). Model predictions for Sacramento Mainstem spawning wild fall-run Chinook and Feather River hatchery fall Chinook both fail to capture the low returns in 1998 – 1999, but capture the reduction in abundance observed in 2007 – 2008. In general for all seven populations of spring and fall-run Chinook included in the analysis, model predictions do not explicitly capture interannual variation, but explain much of the general trend in abundance across the time series (Fig. I.5).

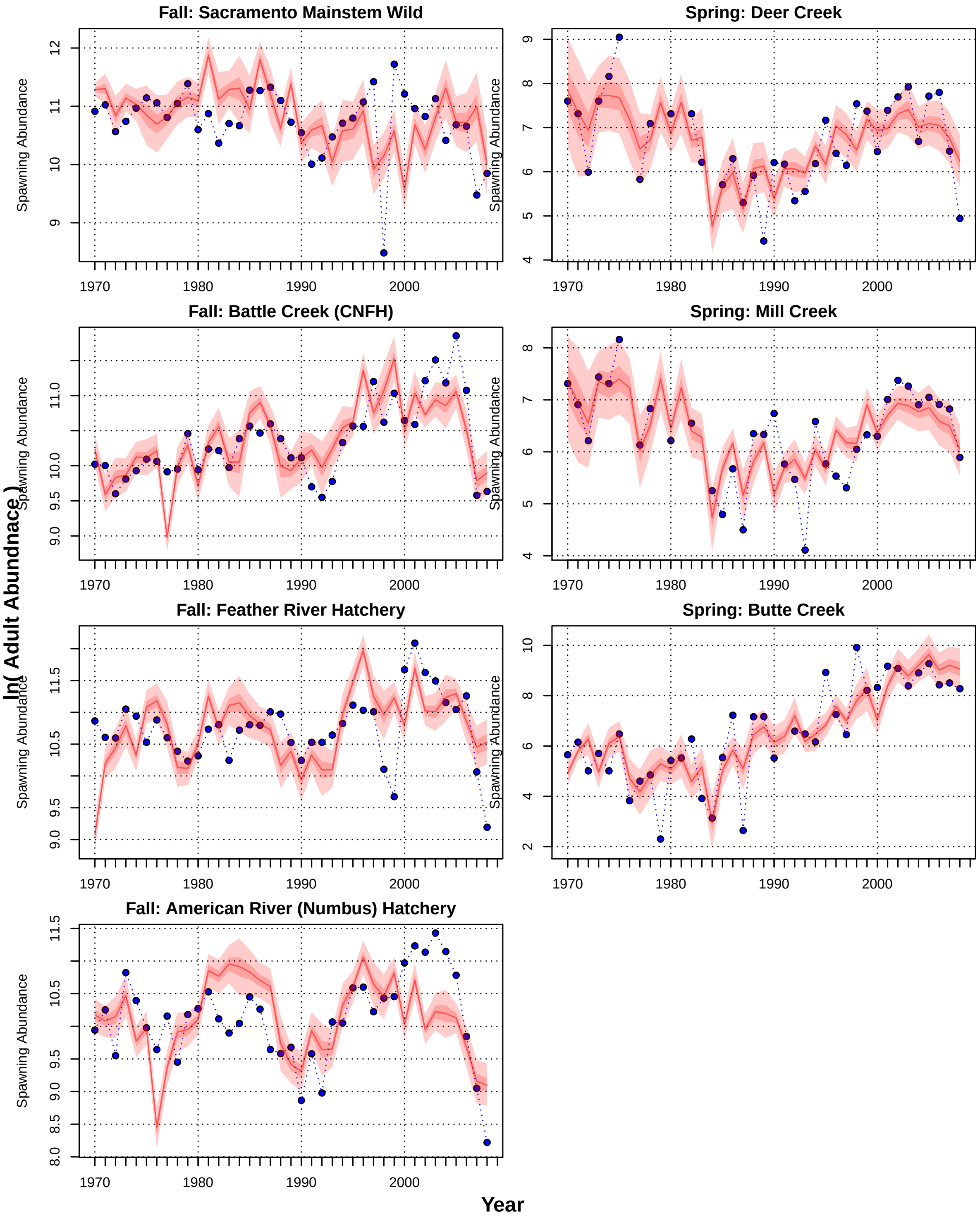


Figure I.5. **Bayesian population dynamics model fit to adult abundance data. Blue points and dashed lines indicate the observed adult abundance in each year on the spawning grounds or at the hatchery, reconstructed to account for average stray rates observed from coded wire tagging data (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013). Red shaded regions are the 95% and 50% credible intervals for the model predicted abundance in each year, and the red line describes the median of the posterior predictions for abundance in each year. Observed and predicted abundances are presented in natural log space.**

Posterior distributions for coefficients describing the direction and magnitude of influence each environmental covariate has on a specific population or group of populations were sampled, along with those for other model parameters including survival rate during the first (upstream) life-stage. Bayesian posterior distributions describe the estimated probability that a particular estimated or derived model parameter has a specific value. Figure I.6 displays posterior distributions for coefficients describing the influence of environmental covariates on survival, as well as those for parameters describing the base survival rate to Sacramento – San Joaquin Delta entry. In this figure, samples from posterior distributions arising from the three separate MCMC chains are drawn in different colors. Each parameter estimate is illustrated as a caterpillar plot whose median is described by a point, 50% credible interval by a thick line, and 95% credible interval by a thin line. The concordance of the parameter medians and credible intervals across the three MCMC chains, along with Gelman-Rubin test statistic values for all parameters ≤ 1.05, provide evidence that all three chains have converged to the same stationary distribution.

The bottom panel of figure I.6 displays model predictions for the value of the basal productivity parameter ($\beta_{s,p,0}$) in the upstream stage (Eq. I.5), or maximum survival rate to Sacramento – San Joaquin Delta entry. It should be noted that for the four wild-spawning populations (i.e. Mainstem Sacramento fall-run, and Deer, Mill, and Butte Creek spring runs), this parameter represents the maximum survival rate from egg to Delta entry, while for the three hatchery produced populations (Battle Creek (CNFH), Feather River, and American River (Nimbus) fall-run) this parameter represents the maximum survival rate from hatchery release to Delta entry. Parameter values in logit space are listed on the x-axis below the lower panel, while back transformed maximum survival rate values appear above the lower panel. Several things are clear from this figure I.6. First, the similarity in posterior distributions from each of the three chains again indicates that all three have converged to the same stationary distribution despite differing random walk trajectories through parameter space. Second, basal productivity or maximum survival rate for the upstream stage is both significantly higher and more variable for the three hatchery-reared populations. Higher maximum survival rates for these populations are to be expected given that they only represent mortality incurred after release, not mortality from fertilization to the date of release. However, the greater variance in maximum survival rate for the hatchery populations is easily discernable.

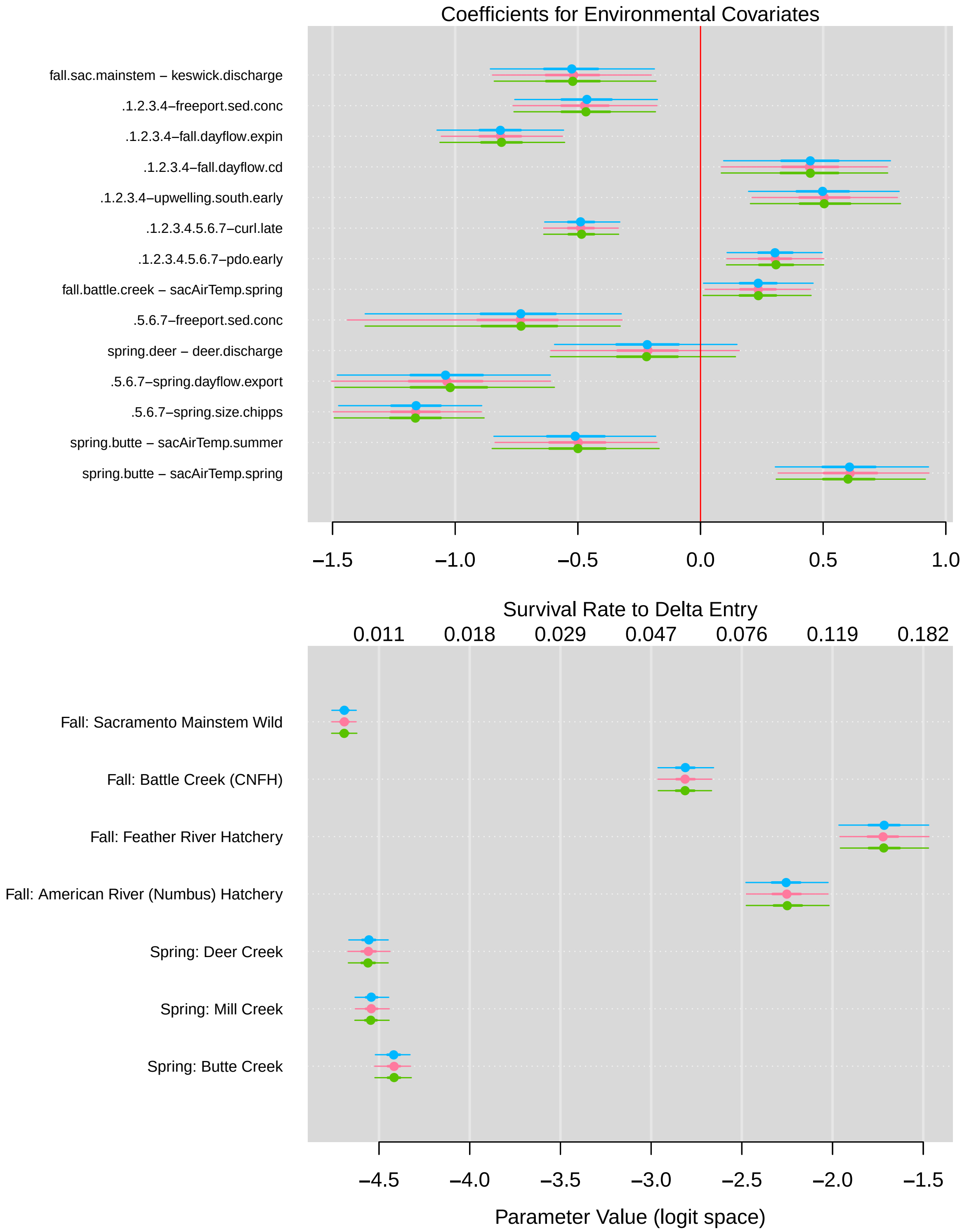


Figure I.6. Posterior probability distributions for coefficients describing the influence of environmental covariates on survival (top) and the maximum survival rate from egg (or hatchery release) to Sacramento – San Joaquin Delta entry. Caterpillar plots describe the median (dot), 50% credible interval (thick line), and 95% credible interval (thin line) of each posterior. Posteriors from each of the independent MCMC chains are depicted with different colours.

Posterior estimates for the value of the coefficients ($\beta_{s,p,c}$) describing the influence of each environmental covariate on a specified population, or group of populations, provide an indication of whether each covariate has a positive or negative influence on survival (Fig. 6, top panel). Table I.5 shows the estimated value for each of the coefficients along with their variance, and quantile range for each posterior distribution. These results indicate that of the 14 covariates included in the final model, 8 covariates were estimated to have a negative impact on stage-specific productivity (maximum survival rate), 5 were estimated to have a positive influence, and 1 was estimated to have a negative influence on average but with a 95% credible interval range overlapping zero. The covariates whose survival impact is estimated to be negative include the effect of: 1) water discharge (cfs-1) from Keswick Dam on Mainstem Sacramento spawning fall-run Chinook (fall.sac.mainstem - keswick.discharge), 2) sediment concentration at Freeport, CA (mg/L) on the combined survival of the four fall-run populations (.1.2.3.4-freeport.sed.conc), 3) the export to inflow ratio in the Sacramento – San Joaquin Delta on combine survival of the fall-run populations (.1.2.3.4-fall.dayflow.expin), 4) wind stress curl on the combined survival of all seven populations of spring and fall-run Chinook (.1.2.3.4.5.6.7-curl.late), 5) spring Freeport, CA sediment concentrations on the combined survival of the three spring-run Chinook populations (.5.6.7-freeport.sed.conc), 6) water exports from the Sacramento – San Joaquin Delta on the combined survival of the three spring-run populations (.5.6.7-spring.dayflow.export), 7) the average size of juvenile spring-run Chinook on combined spring-run survival (.5.6.7-spring.size.chipps), and 8) Sacramento air temperature during summer months of the brood year on survival of Butte Creek spring-run Chinook (spring.butte - sacAirTemp.summer).

Covariate	Mean	sd	CV	2.50%	25%	50%	75%	97.50%
fall.sac.mainstem - keswick.discharge	-0.52	0.17	0.32	-0.85	-0.63	-0.52	-0.41	-0.19
.1.2.3.4-freeport.sed.conc	-0.47	0.15	0.32	-0.76	-0.57	-0.47	-0.37	-0.18
.1.2.3.4-fall.dayflow.expin	-0.81	0.13	0.16	-1.06	-0.90	-0.81	-0.73	-0.56
.1.2.3.4-fall.dayflow.cd	0.44	0.17	0.39	0.09	0.33	0.45	0.56	0.77
.1.2.3.4-upwelling.south.early	0.50	0.15	0.31	0.20	0.40	0.50	0.61	0.81
.1.2.3.4.5.6.7-curl.late	-0.49	0.08	0.16	-0.64	-0.54	-0.49	-0.43	-0.33
.1.2.3.4.5.6.7-pdo.early	0.30	0.10	0.33	0.11	0.24	0.31	0.37	0.50
fall.battle.creek - sacAirTemp.spring	0.23	0.11	0.47	0.01	0.16	0.24	0.31	0.45
.5.6.7-freeport.sed.conc	-0.76	0.27	0.35	-1.38	-0.90	-0.73	-0.59	-0.32
spring.deer - deer.discharge	-0.22	0.19	0.87	-0.61	-0.34	-0.22	-0.09	0.15
.5.6.7-spring.dayflow.export	-1.04	0.23	0.22	-1.49	-1.18	-1.03	-0.88	-0.61
.5.6.7-spring.size.chipps	-1.17	0.15	0.13	-1.49	-1.26	-1.16	-1.06	-0.89
spring.butte - sacAirTemp.summer	-0.51	0.17	0.34	-0.84	-0.62	-0.50	-0.39	-0.17
spring.butte - sacAirTemp.spring	0.61	0.16	0.26	0.31	0.50	0.61	0.71	0.93

Table I.5. Values for the posterior probability distributions for coefficients describing the influence of environmental covariates ($\beta_{s,p,c}$) on productivity (maximum survival rate).

Five of the coefficient values were estimated to be positive (Table I.5), indicating that an increase in the value of those covariates leads to an increase in the maximum survival rate for the associated population or group of populations. These covariates which are estimated to positively influence survival include the effect of: 1) upwelling in the nearshore region during spring of the ocean entry year on the combined survival of the fall-run Chinook populations (.1.2.3.4-upwelling.south.early), 2) spring air temperature at Sacramento, CA on the survival of fall-run Battle Creek (CNFH) Chinook (fall.battle.creek - sacAirTemp.spring), 3) spring air temperature at Sacramento, CA on the survival of Butte Creek spring-run Chinook (spring.butte - sacAirTemp.spring), 4) net channel depletion in the Sacramento – San Joaquin Delta resulting from within-delta consumptive use as quantified by the Dayflow metric QCD on the combined survival of the four fall-run Chinook populations (.1.2.3.4-fall.dayflow.cd), and 5) the magnitude of the Pacific Decadal Oscillation during winter (January – May) of the first year at in the ocean on the combined survival of all seven spring and fall-run Chinook populations (.1.2.3.4.5.6.7-pdo.early). For the 13 covariates classified above as having either a distinct positive or negative effect on survival, the posterior distribution describing the probability of the true value for each coefficient had a 95% credible interval that was completely above or below zero. Although the estimated median value for the coefficient describing the effect of Deer Creek discharge (cfs^{-1}) on Deer Creek spring-run Chinook survival (spring.deer - deer.discharge) is less than zero (i.e. -0.22, Table I.5) indicating an negative influence on survival, the 95% credible interval overlaps with zero indicating a significant probability (p=0.121) of the covariate having either no influence or a positive influence on survival.

While posterior probability distributions for coefficients representing the influence of each environmental covariate on stage and population-specific productivity ($\beta_{s,p,c}$) describe the model estimate for how much an increase or decrease in the value of that covariate is expected to change stage-specific productivity parameter of the Beverton-Holt equation (Eq. I.4), it is difficult to directly compare these estimated coefficient values for several reasons. First, the basal productivity rate ($\beta_{s,p,0}$) for each stage is population-specific, meaning that the magnitude of estimated coefficients ($\beta_{s,p,c}$) is always relative to the to the basal productivity rate for the population of interest. Second, coefficient values and basal productivity rates are estimated in logit space to ensure the resultant productivity value is smoothly scaled between 0 and 1 (Eq. I.5), and comparing coefficients and basal productivity rates in logit space may be difficult to interpret. Therefore, we have endeavored to translate the magnitude of the estimated environmental covariate effects into more easily interpretable changes in survival.

In order to translate the value of estimated coefficients describing the influence of environmental covariates into predictions for realized changes in survival, we calculated the survival rate for the seven populations from egg, or hatchery release, through adults returning to freshwater under a range of scenarios. Survival rates for each population were calculated by tracking a set number of individuals forward in time across life-stages, assuming no harvest mortality, and using parameter values sampled from the joint posterior for the estimation model. One thousand independent sets of model parameter values were sampled from their joint posterior in order to preserve posterior correlation, and used to quantify the variation in predictions for the influence of each environmental covariate on survival, arising from estimation uncertainty. Survival rate was calculated as the sum of spawning adults across return years, divided by the number of eggs or hatchery releases. The spawning abundance, used as the basis for calculating survival rates, was the 1970 – 2010 average for the wild-spawning populations (i.e. mainstem Sacramento fall-run, as well as Deer, Mill, and Butte Creek spring-run) and the average release numbers for the most recent 10 years for the Battle Creek (CNFH), Feather River, and American River (Nimbus) hatchery populations. Likewise, the most recent 10-year average was used for capacity of wild juvenile fall-run Chinook in the Sacramento mainstem and for the total capacity for spring-run and fall-run Chinook rearing in the Sacramento – San Joaquin Delta.

The distribution of survival rate predictions for each population (p), across the 1,000 independent sets of parameter values (i), was first calculated for a base case ($Sbase_{p,i}$). Under the base case the value for all environmental covariates was set at zero, which for z-standardized covariates is equal to the long-term average. Subsequently the covariate-specific survival ($Scov_{p,i,c}$) of each population across the 1,000 parameter sets was determined, as each covariate (c) was sequentially changed to have a value of 1. Covariate-specific survival ($Scov_{p,i,c}$) thus represents the population (p) and sample (i) specific survival rate when covariate c is increased in value to 1 standard deviation above the long-term mean. From this, the percentage difference in survival for each population resulting from an increase in the value of an environmental covariate was calculated as: $\%\ difference\ in\ Survival_{p,i,c} = \frac{(Scov_{p,i,c} - Sbase_{p,i})}{Sbase_{p,i}} * 100$. Table I.6 displays the mean and standard deviation for the expected percentage change in survival for each population across the sampled parameter sets, when each covariate is increased in value by 1 SD from the mean.

Covariate	Fall: Sacramento Mainstem Wild	Fall: Battle Creek (CNFH)	Fall: Feather River Hatchery	Fall: American River (Numbus) Hatchery	Spring: Deer Creek	Spring: Mill Creek	Spring: Butte Creek
fall.sac.mainstem - keswick.discharge	-50.2 (12.5)	0.5 (0.1)	0.5 (0.1)	0.5 (0.1)	0 (0)	0 (0)	0 (0)
.1.2.3.4-freeport.sed.conc	-36.5 (10)	-36.5 (10)	-36.5 (10)	-36.5 (10)	0 (0)	0 (0)	0 (0)
.1.2.3.4-fall.dayflow.expin	-57 (6.6)	-57 (6.6)	-57 (6.6)	-57.1 (6.6)	0 (0)	0 (0)	0 (0)
.1.2.3.4-fall.dayflow.cd	43.3 (17.5)	43.3 (17.5)	43.3 (17.5)	43.3 (17.5)	0 (0)	0 (0)	0 (0)
.1.2.3.4-upwelling.south.early	51.1 (16.7)	51.1 (16.7)	51.1 (16.7)	51.1 (16.7)	0 (0)	0 (0)	0 (0)
.1.2.3.4.5.6.7-curl.late	-38.5 (5.4)	-38.5 (5.4)	-38.5 (5.4)	-38.5 (5.4)	-38.5 (5.4)	-38.5 (5.4)	-38.5 (5.4)
.1.2.3.4.5.6.7-pdo.early	29.8 (10.4)	29.8 (10.4)	29.8 (10.4)	29.8 (10.4)	29.8 (10.5)	29.8 (10.5)	29.8 (10.5)
fall.battle.creek - sacAirTemp.spring	-0.2 (0.1)	38.2 (19.4)	-0.2 (0.1)	-0.2 (0.1)	0 (0)	0 (0)	0 (0)
.5.6.7-freeport.sed.conc	0 (0)	0 (0)	0 (0)	0 (0)	-53.8 (13.3)	-53.8 (13.3)	-53.8 (13.3)
spring.deer - deer.discharge	0 (0)	0 (0)	0 (0)	0 (0)	-24.4 (20)	0 (0)	0 (0)
.5.6.7-spring.dayflow.export	0 (0)	0 (0)	0 (0)	0 (0)	-67.2 (9.1)	-67.2 (9.1)	-67.2 (9.1)
.5.6.7-spring.size.chipps	0 (0)	0 (0)	0 (0)	0 (0)	-72.5 (5.3)	-72.5 (5.3)	-72.5 (5.3)
spring.butte - sacAirTemp.summer	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	-38.4 (10.2)
spring.butte - sacAirTemp.spring	0 (0)	0 (0)	0 (0)	0 (0)	-0.1 (0)	-0.1 (0)	132.8 (47.6)

Table I.6. Percentage change in egg (or hatchery release) to adult survival resulting from covariate variation. Values in the table are the mean (sd) differences in survival between the base case and a scenario where the value of a specific covariate (row) is increased by 1 standard deviation from the long-term mean.

Figure I.7 displays the effect of each environmental covariate on each Chinook population, as the distribution of percentage change in egg (or hatchery release) to adult survival, expected when the value of a specific covariate is 1 SD above the long-term mean. Each panel in figure I.7 describes the influence of a single covariate, while each row within a panel is the survival change expected for a specific population. Within each panel the seven population-specific caterpillar plots describe the distribution of expected survival difference, with the point demarking the median, and the thick and thin lines defining the 50% and 95% credible intervals for the prediction. Two aspects of this analysis are important to consider. First, the figure describes the difference in survival between the base case (all covariates at the mean) and that when a single covariate value is changed, and although the survival differences may be the same across populations, this should not be not be taken as evidence that population-specific survival rates are also estimated to be the same. Second, an estimated survival difference at or near zero does not imply there is no survival effect, only that this interaction was not included in the final AICc-selected model. Any small, but non-zero survival effects are the result of changes in the survival of another population in response to the covariate, with which the focal population shares a capacity constraint at some point in the life cycle.

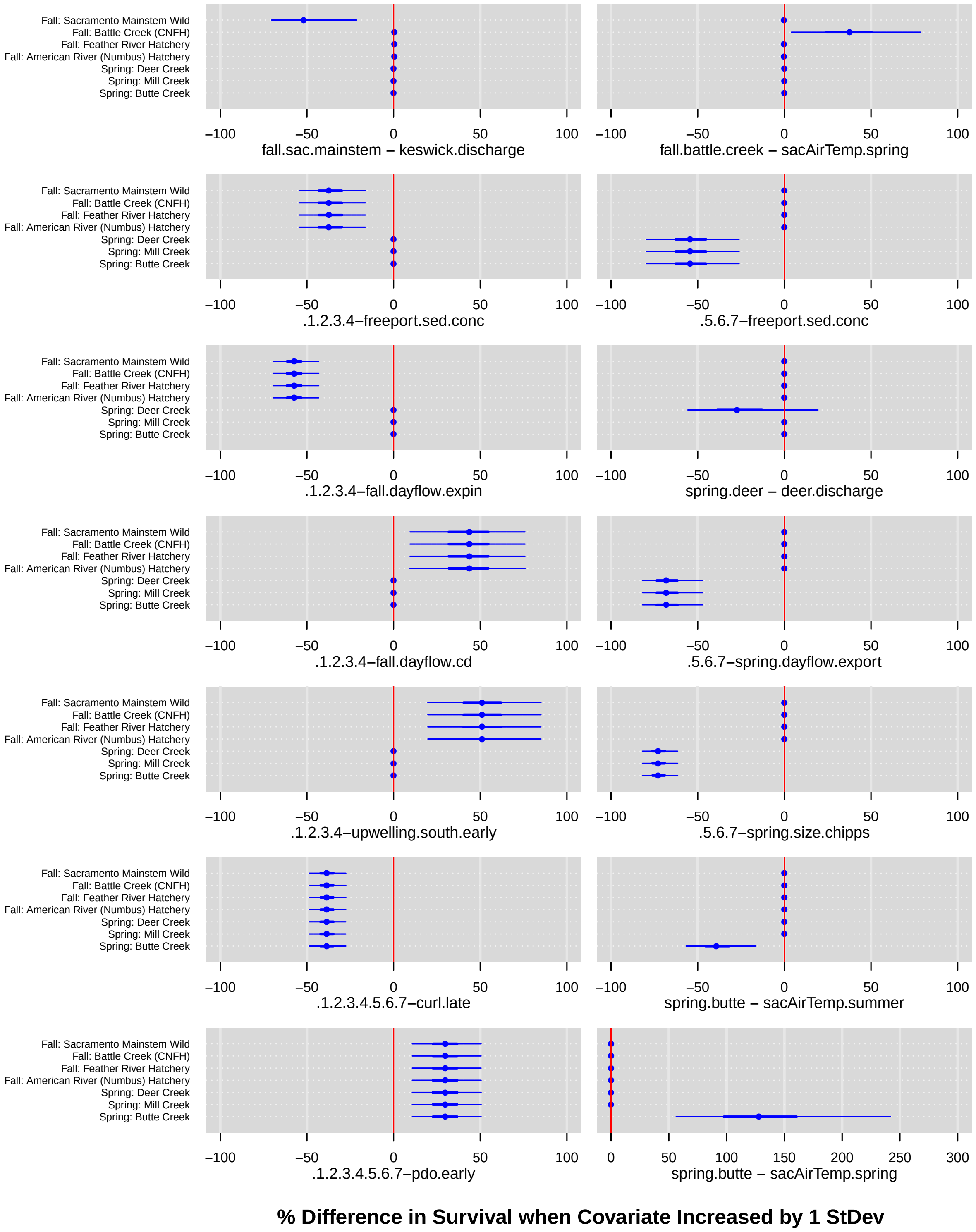


Figure I.7. Percentage change in egg (or hatchery release) to adult survival resulting from a 1 standard deviation increase in covariate values. Each panel represents the outcome of increasing the value of a specific covariate (listed below the x-axis), with each caterpillar plot describing the effect on each population (y-axis). Plotted values are the difference in survival between a scenario where the covariate value is increased and a base case where all covariates are equal to their long-term mean. Caterpillar plots describe the median (dot), 50% interval (thick line), and 95% interval (thin line) for each survival difference accounting for estimation uncertainty.

Results of this analysis of the environmental drivers of survival for Sacramento River fall and spring-run Chinook salmon indicate that several factors have the potential to significantly influence survival in the upstream portion of juvenile migration. Keswick Dam discharge is predicted to reduce egg to adult survival by 52.2%, for each increase in discharge rate of 1 SD. Increased air temperatures in the spring months following emergence are expected to increase the survival of Battle Creek (CNFH) fall-run Chinook by 37.5%, although the 95% credible interval for this predictions ranges from a moderate a modest 4.4% increase to a 79.8% increase indicating significant uncertainty in this prediction. Spring time air temperatures are expected to influence the early juvenile survival of Butte Creek spring-run Chinook in a similar direction but to a much greater extent with a predicted 124.7% increase. Conversely, increased summertime air temperatures during the period of adult upstream holding and egg development are expected to reduce survival by 39.4%, indicating that summertime temperatures may be reaching lethal levels or affecting adult fertility. The final environmental variable linked to the upstream stage and early juvenile survival is water discharge in Deer Creek, which is expected to reduce survival for Deer Creek spring-run Chinook by a modest 26.2%. However, it is important to note that there is significant uncertainty in this prediction with an increase in Deer Creek discharge by 1 SD predicted to have result in anywhere between a 59.4% reduction in survival and a 27% increase in survival 95% of the time.

Later in the life cycle for Sacramento River Chinook, several factors are expected to significantly influence juvenile survival in the Sacramento – San Joaquin Delta. A 1 SD increase in the concentration of sediment (mg/L) at Freeport, CA is expected to result in a 37.1% reduction in the survival of the four fall-run Chinook populations. Sediment concentration is predicted to have a slightly larger influence on survival of the three spring-run populations, with a 54.3% reduction in egg to adult survival. Water exports from the Sacramento – San Joaquin Delta, although quantified through different metrics, are expected to reduce survival of both spring and fall-run juvenile Chinook. An increase in total exports of 1 SD from the 1967-2010 average is predicted to result in a 68.1% reduction in the survival of Deer, Mill, and Butte Creek spring-run Chinook. Similarly, an increase in the ratio of Delta water exports to Delta inflow of 1 SD is expected to reduce survival of the four fall-run populations by 57.8%. Interestingly however, net channel depletion or the quantity of water removed from Delta channels to meet consumptive needs (Dayflow: QCD) is predicted to increase the survival of fall-run Chinook by 43.7%. The final covariate linked to survival of spring-run Chinook in the Sacramento – San Joaquin Delta is the average size of spring-run Chinook in the Chipps Island Trawl survey. Each increase in the average size of juvenile Chinook by 1 SD from the mean (1967-2010) is predicted to reduce survival by 72.9%.

Environmental conditions in the nearshore and marine portions of the Chinook life cycle were also found to have a significant impact on survival to adulthood. An increase in average nearshore upwelling during late spring (April – June) in the region south of San Francisco Bay of 1 SD above the mean, is expected to increase survival to adulthood by 51.2% for the four wild and hatchery-reared fall-run Chinook populations. Also related to marine patterns of nutrient transport and productivity, an increase average wind stress curl during the fall (July – December) of the first year of marine residency was estimated to reduce survival for the seven populations of spring and fall-run Chinook by 39%. The final covariate linked to Chinook survival in the marine environment was the Pacific Decadal Oscillation index during winter (January – May) of the first year of marine residence. An increase in PDO value of 1 SD above the 1967 – 2010 mean is predicted to increase survival of the seven populations of spring and fall-run Chinook by 30%, however there exists significant uncertainty in this prediction with the 95% credible interval ranging from 10.1 - 51% increase in egg or hatchery release to adult survival.

PART I DISCUSSION

This evaluation of the putative environmental drivers of survival for seven populations of spring and fall-run Chinook spawning within the Sacramento River watershed was comprised of two essential components. The first component was model selection or the process of determining the weight of evidence from the data for which subset of the 59 hypothesized covariate-by-population effects were able to best explain historical variation in Chinook salmon survival, and are therefore informative for predicting future trends in abundance. One thousand potential best-fit models were built using forward stepwise based upon AICc as the selection criteria. The percentage of the 1,000 best-fit models resulting from stepwise-AICc building which included a specific covariate provide a good indication of the relative amount of support each of these competing hypotheses had from the adult and juvenile abundance data (Table I.3). The fact that a range of covariates influencing both grouped and single Chinook populations at all points in the life cycle were present amongst those with a high inclusion rate provide evidence that there not exist a single population bottleneck within the life cycle. This indicates that variation in environmental factors a multiple points within the life cycle play a role in determining interannual survival to adulthood. Of further importance is the observation that both natural covariates, including temperature, water flow, and marine productivity patters, as well as those of anthropogenic origin (i.e. water exports, export/inflow ratio, and water routing) appear amongst the set with the highest inclusion rate. This finding indicates that variation in survival of Sacramento River Chinook population in not driven by natural or anthropogenic processes in isolation. The final model (Table I.4), chosen based on having the lowest AICc value amongst the 1,000 candidate best-fit models, likewise includes a range of covariates throughout the life cycle representing both natural and anthropogenic processes are statistically important predictors of survival.

The influence of striped bass (*Morone saxatilis*) on survival of spring-run Chinook was of particular interest given findings by Lindley and Mohr (2003), which indicated that higher future abundances of striped bass were likely to lead to greater extinction potential for winter-run Chinook. While the effect of striped bass on survival on spring-run Chinook was included in 36% candidate best-fit models, it did not appear in the final (lowest AICc) model. When included alongside other covariates in the final model, the estimated effect of striped bass abundance was centered near zero, indicating an inability to estimate a distinctly negative impact on grouped survival of spring-run Chinook. This result indicates that while striped bass abundance does explain some of the variation in spring-run Chinook survival, other explanatory covariates provide a better alternative explanation for historical abundance observations.

The estimated effect that water exports from the Sacramento – San Joaquin Delta on juvenile Chinook survival through this region was also of importance. While the effect of average water export levels on spring-run Chinook survival and the influence of export/inflow ratio on fall-run Chinook survival both appear in the final model, these two covariate effects have a 54% and 37% inclusion rates across the 1,000 candidate best-fit models. The fact that these export-related covariate effects do not appear at the top of the list of most often included covariates, indicates that while they have substantial potential to explain historical patterns in spring and fall-run Chinook survival, as indicated by distinctly negative survival effects whose 95% credible intervals do not overlap zero (Figure I.7 and Table I.6), there are other environmental covariate which explain a greater proportion of variation in historical abundance.

The second component of this evaluation was to estimate the direction and magnitude of change in survival rates resulting from variation in each of the covariates in the final model using Bayesian methods. When evaluating population dynamics model estimates for the effect of environmental covariates on survival, it is important to place each result in the proper biological context and determine if there exists a rational mechanistic explanation. The effect of Sacramento air temperatures on several populations appeared as AICc-selected explanatory covariates for several populations. Sacramento air temperature was employed as a proxy for water temperatures in upstream regions of the Sacramento River watershed for two reasons. First, significant and often linear relationships exist for between stream temperatures and air temperatures in most regions. Second, stream temperature data were not available continuously for the requisite time series (1967 – 2010) for all locations, resulting in the necessity for interpolation based on the relationship with air temperature. Therefore, for consistency in the covariate time-series and to reduce the risk of introducing additional uncertainty into the estimation process, we elected to use air temperatures as covariates in place of interpolated water temperatures. Results indicate a positive influence of increased spring (January - March) air temperatures on the survival of Battle Creek (CNFH) fall-run Chinook and Butte Creek spring-run Chinook. This temperature metric coincides with the period prior to and during which juvenile Chinook are rearing. The estimated positive influence of spring temperatures on Chinook survival could result indirectly from the increase in primary production fostered by increased water temperatures and subsequent effects on food availability. In this way growth potential for juvenile Chinook in freshwater depends indirectly on temperature in the rearing environment through food availability, and directly through effects on metabolism as warmer conditions allow juveniles to approach their bioenergetic optimum. Finally, there is some evidence that acclimation to higher temperatures early in life my facilitate higher thermal tolerance later in life, although research in this area has primarily focused on Great Lakes rainbow trout and has not been explicitly evaluated in Chinook (Myrick and Chech 1998). While spring time temperatures were estimated to have a positive influence at this point in the lifecycle, it is important to note that higher temperatures experienced later in the lifecycle during summer months may approach upper tolerance limits, resulting in negative survival impacts. However, the effect of increased summertime temperatures on juvenile survival was not evaluated as part of this analysis.

Contrary to the estimated positive effect of spring temperatures, air temperature during the summer months (July - September) of the brood year were found to have a negative impact on the survival of Butte Creek spring-run Chinook (Table I.6). For Butte Creek spring-run Chinook this time period coincides with the point in the life-cycle when adults are holding in freshwater prior to spawning. Prior to the creation of impassable barriers to upstream migration, the life history of spring-run Chinook was adapted to make use of high spring runoff events from snowmelt to migrate upstream into high elevation streams with tolerable temperature regimes where they could successfully mature during the summer months and await spawning when waters cooled to below 14 – 15^{0}C (Williams 2006). However, in Butte Creek mortality rates during the holding period were observed to exceed 20-30% in 2002 and 65% in 2003 during high temperature events (Ward et al. 2003). This is likely the result of the increased metabolic demands for adult spring-run Chinook while holding in freshwater during high temperature events, and the increased rate of disease onset and parasite load observed in other members of the *Oncorhynchus* genus exposed to high temperatures (Kocan et al. 2009).

Water flow conditions during juvenile rearing were also found to be important predictors of Chinook survival. Water discharge rates at Keswick Dam were found to negatively influence survival of mainstem spawning wild fall-run Chinook, and water discharge in Deer Creek was found to reduce survival of the Deer Creek spring-run population although to a lesser extent (Table I.6). While it is reasonable to assume that higher discharge rates could lead to greater access to valuable off-channel rearing habitat, water flow conditions additionally have the potential to influence foraging ability by juveniles through the availability of drifting food sources (Neuswanger et al. 2014). None the less the finding that fall-run Chinook survival was negatively influenced by increased water flow contradicts findings by Stevens and Miller (1983) and Newman and Rice (2002). With respect to the influence of water discharge on the survival of Deer Creek spring-run Chinook, this tributary is prone to concentrated high flow events due to flood control levees and a lack of riparian vegetation in its lower reaches (Tompkins 2006). For Deer Creek this may indicate that high water flow rates reduce foraging opportunities for juvenile Chinook, rather than enhancing them, as would be the case in a system with greater floodplain connectivity.

Findings related to the influence of environmental covariates on survival of fall and spring-run Chinook in the Sacramento – San Joaquin Delta are of particular interest in this study. First, the effect of sediment concentration in waters at Freeport, California appeared in the final AICc-selected model, and increases in sediment concentration were estimated to have a substantial negative influence on the survival of both spring and fall-run populations. This finding is contrary to a priori expectations that increased sediment concentrations might provide a survival benefit, if they limit the efficacy of visual predators such as striped bass. We remain limited in our ability to explain the estimated negative effect of sediment concentrations save for the fact that increased sediment influx might be linked to production potential for phytoplankton and the benthic periphyton which form the basis for the aquatic food web. Similarly, the estimated negative influence of average juvenile spring-run Chinook size on the common survival of the three spring-run populations appears contrary to a priori expectations. In the review of size selective mortality in teleost fishes Sogard (1997) found general support for the "bigger is better" hypothesis across taxa. Claiborne et al. (2011) also found that juvenile to adult survival of yearling Chinook from the Willamette River Hatchery increased with size at ocean entry. However, in an evaluation of the effect of size on survival from analysis of scale samples from Chinook returning to the same hatchery, Ewing and Ewing (2002) found either no significant size difference between juveniles at the hatchery and those at ocean entry, or in the case of the 1989 – 1990 brood years evidence for greater survival of smaller individuals. It is important to note that spring-run juvenile size data was unavailable until 1976. As a result we were forced to assume the long-term average for this covariate prior that year which may have influenced results related to this particular covariate.

Results of this analysis related to the influence of water exports from the Sacramento – San Joaquin Delta indicate a negative influence of the export/inflow ratio on the combined survival of the four fall-run Chinook populations and a negative influence increased total Delta exports on the combined survival of spring-run Chinook populations (Table I.6). These findings indicate that higher export rates lead to reduced survival for Sacramento River Chinook on average, however a mechanistic explanation remains elusive. Direct entrainment mortality seems an unlikely mechanism given the success of reclamation and transport procedures, even given increased predation potential at the release site. Changes to water routing may provide a more reasonable explanation for the estimated survival influence of Delta water exports. Higher exports, or export/inflow ratio, result in greater water diversion into the interior delta where survival has been observed to be substantially lower than that in the Sacramento River mainstem (Perry et al. 2010), potentially resulting from an increased encounter rate with predators or prolonged residence in areas with suboptimal feeding opportunities or dissolved oxygen concentrations.

In conjunction with freshwater drivers of survival for spring and fall-run Chinook populations of the Sacramento River watershed, results of this analysis indicate that several attributes of the marine environment have a significant influence on survival. Two covariates related to nearshore and offshore ocean current patterns and resultant nutrient movement within the water column were included as part of the final AICc-selected model. These covariates were the strength of nearshore upwelling and wind stress curl. Nearshore upwelling results in deep, cooler, and nutrient rich waters moving toward limnetic zone, with onshore transport and convergence fostering higher nearshore productivity during spring and summer. Conversely, wind stress curl is associated with offshore divergent transport (Wells et al. 2008). Our results indicate that increased nearshore upwelling during April – June of the year of ocean entry results in an increase in the combined survival of the four fall-run Chinook populations. Four alternative covariates quantifying upwelling patterns were evaluated as competing hypotheses for fall-run Chinook survival at different locations and quantifying time periods. Covariates were constructed using information from PFEL/NOAA monitoring sites both north and south of San Francisco Bay and for both the spring (April – June) and fall (July – December) periods. The AICc-selected covariate that appeared in the final model used the upwelling index data for spring time-period and at the southern location. Interestingly, although the effect of upwelling at the southern location in the spring months on the combined survival of spring-run Chinook appeared in 22% of candidate best-fit models, it did not appear in the final (lowest AICc) model, indicating that while upwelling may also be an important predictor of spring-run Chinook survival it appears to explain more variation in fall-run Chinook survival.

Wind stress curl was found to have a negative influence on the combined survival of all seven spring and fall-run Chinook populations. These results are not unexpected given findings by Wells et al. (2007) that indicate greater Chinook growth in the first year of life with increased nearshore upwelling and decreased wind stress curl. Wells et al. (2008) likewise found that reductions in wind stress curl were linked to increased production of rockfish species although they note this may be more related to dispersal of juvenile rockfish. The estimated reduction in survival for Chinook associated with greater wind stress curl is likely explained by trophic interactions, with findings by Macias et al. (2012) indicating that biomass concentrations for phytoplankton and zooplankton are likely to be substantially higher with coastal upwelling as opposed to wind stress curl driven upwelling offshore.

The Pacific Decadal Oscillation (PDO) describes a persisting periodicity in sea surface temperature, mixed layer depth, and strength and direction of ocean currents (Mantua and Hare 2002). Estimates for the influence of the PDO during January – May of the first year at sea indicating for the seven spring and fall-run Chinook populations, indicate increased survival is likely to be observed in during positive PDO events. This result is contrary to findings by Hare et al. (1999) which indicate positive PDO conditions favor production in Alaskan salmon stocks and disfavor the productivity of West Coast stocks, as well as findings by Wells et al. (2006) which highlight the negative covariation between size of Columbia River Chinook size and PDO values.

PART II SIMULATION OF FUTURE ABUNDANCE UNDER ALTERNATIVE CLIMATE, OCEANOGRAPHIC, AND WATER USE SCENARIOS

INTRODUCTION

The purpose of conducting forward population projections was to simulate future survival for Sacramento River Chinook under alternative climate, oceanographic, and water management scenarios. Simulating the four populations of fall-run and three populations of spring-run Chinook forward in time, provides a means for weighing differences in future survival under alternative water export levels, relative to the uncertainty in future climate change and ocean productivity. In order to generate predictions for future survival, we integrated results from the Bayesian estimation model with expectations for future environmental conditions under two alternative future ocean production trends, two predictions for future climate change, and at four potential levels of future water exports (see Appendix B). In addition to differences in future Chinook survival arising from natural and anthropogenic environmental factors, we have also propagated both estimation and process uncertainty forward in our predictions for future abundance and realized survival rates.

Future climate scenarios were based upon the U.S. Bureau of Reclamation's (USBR) Operations and Criteria Plan (OCAP) Study (USBR 2008). Two alternative scenarios for overland climate change were evaluated, the OCAP Study 9.2 and 9.5. The OCAP Study 9.2 (referenced as: **cc92**) describes a wetter and cooler prediction for future climate change, with a mean increase in temperature of 0.42° C and an increase in precipitation of 12.5%. Conversely, the OCAP Study 9.5 (referenced as: **cc95**) describes a dryer and warmer outlook for future climate change in the Central Valley, with a mean increase in temperature of 1.56° C and a decrease in precipitation of 12%. In addition to differing scenarios regarding climate change, two alternative predictions for future ocean conditions were explored. These two scenarios, one representing traditional perceptions of positive growth conditions for Chinook (referenced as **oceanUP**) and the other representing negative growth conditions (referenced as **oceanDOWN**), describe alternative patterns in nearshore upwelling and temperature, and future trends in broad-scale ocean currents.

Paired with these alternative scenarios for future climate change and ocean production, were four scenarios related to the magnitude of future water exports from the Sacramento-San Joaquin Delta. The four future scenarios for total water exports included: 1. **expAVG** (future exports equal to the 1967 – 2010 average), 2. **expZERO** (zero future water exports), 3. **expUP30** (an increase in future exports to 30% above the historical average), and 4. **expDOWN30** (a decrease in future exports to 30% below the historical average). While it is clear that some of these water export scenarios are economically infeasible (i.e. expZERO) they were included as part of the population projections to bound the range of potential biological outcomes from management actions. All export scenarios are based upon the historical export values calculated as the average of March – May Dayflow (QEXPORT) values for fall-run Chinook, and the average of February – April values for spring-run Chinook.

In total, these 2 onshore climate change scenarios, 2 ocean production scenarios, and 4 water export scenarios, resulted in 16 different realizations of the future environment for Chinook populations of the Sacramento River watershed. These sixteen environmental scenarios were subsequently translated into future covariate values (see Appendix B), for use as inputs in projecting the populations forward in time and determining realized future survival rates.

SIMULATION METHODS

Realized future survival rates were simulated by projecting all seven populations of Sacramento River Chinook forward in time for 50 years (2007 – 2057). The structure of the population dynamics model utilized to estimate stage-specific survival rates and the direction and magnitude of response by populations (or groups of populations) to environmental covariates, formed the basis for these forward population projections. Population and brood year specific cohorts of Chinook were tracked forward in time through the same six spatio-temporal life-stages (i.e. upstream/tributaries, Sacramento-San Joaquin Delta, nearshore, and the 1st, 2nd, and 3rd years in the ocean). In the same way as the estimation model, both the wild-spawning and hatchery production life cycles were represented in population projections, with wild-spawning populations linked to future cohort production through a fixed fecundity per individual, and hatchery production fixed at the population-specific average of releases from the most recent 10-year period. Stage-specific capacities for Sacramento mainstem-spawning fall-run Chinook in the upstream stage, and the grouped spring-run and fall-run populations in the Sacramento-San Joaquin Delta, were fixed at the average of estimates from Hendrix et al. (2014) for the most recent 10-year period. Estimated values for population dynamics model parameters including stage and population-specific productivity rates, and coefficients describing the direction and magnitude of influence that environmental covariates have on stage-specific productivity (maximum survival) rates, were used when simulating future trends in abundance.

When simulating future trends in Chinook abundance in order to evaluate differences in realized survival, it was necessary to account the two major sources of uncertainty in our analysis and propagate this uncertainty forward into predictions under alternative environmental and export scenarios. The first source of uncertainty in generating robust predictions for future abundance is uncertainty in the estimates of population dynamics model parameters. This includes uncertainty in the estimated value of life-stage and population specific basal productivity rates, as well as coefficients describing the influence of environmental covariates on survival. Estimation uncertainty arises when estimated values for model parameters are poorly informed by the available data, leading to broad posterior probability distributions indicating a broad range of parameter values with similar probabilities of being correct given the data. To account for estimation uncertainty in model parameters, we drew 1,000 independent sets of model parameter values from the joint posterior sampled by the Bayesian estimation model. By drawing parameter sets from the joint posterior, and repeating the 50-year forward projection of the seven populations using each of the independent parameter sets, we are able to capture the influence of both the true uncertainty in parameter values and posterior correlations between estimated parameters.

The second source of uncertainty that was integrated into forward projects was process uncertainty, or temporal variation in the state of future population dynamics. For each of the 1,000 replicate forward simulations, a random process deviate was introduced in the calculation for initial abundance in the first model stage (Eq. II.2, II.3).

(II.2)

$$N_{y,s=1,p,e,i} = A_{t=y,p,a,e,i} * fec * \exp\left(\varepsilon_{y,p,i} - \frac{\sigma_p^2}{2}\right)$$

$$\varepsilon_{y,p,i} \sim N\left(0, \sigma_p\right)$$

Equation II.2 describes how process uncertainty is introduced into the wild-spawning life cycle used to represent the Sacramento mainstem fall-run, and Deer, Mill, and Butte Creek spring-run Chinook populations. The number of individuals entering the upstream (1st) model stage ($N_{y,s=1,p,e,i}$), of brood year y, population p, in simulation i of environmental scenario e, is a function of the number of spawning adults returning in calendar year t = y of population p ($A_{t=y,p,e,i}$), the fixed fecundity rate of 2,000 eggs/individual ($fec = 2{,}000$), and the exponentiated brood year y, population p, and simulation i specific process deviate ($\varepsilon_{y,p,i}$). Conversely, equation II.3 describes how initial abundance in the first model stage was calculated with process errors for the three populations of hatchery-produced fall-run Chinook, where RH_p is the fixed level of hatchery releases for each population.

(II.3)

$$N_{y,s=1,p,e,i} = RH_p * \exp\left(\varepsilon_{y,p,i} - \frac{\sigma_p^2}{2}\right)$$

$$\varepsilon_{y,p,i} \sim N\left(0, \sigma_p\right)$$

Process deviates ($\varepsilon_{y,p,i}$) for each brood year y, population p, and replicate simulation i, were generated as random draws from a normal distribution with mean equal to 0, and population-specific standard deviations (σ_p). The standard deviations for the process error distributions (σ_p) were the maximum likelihood estimates for the residual observation uncertainty from fitting the original population dynamics model to historical abundance data. In total 1,000 randomly drawn process deviates, corresponding to the replicate simulations using parameter sets drawn from the joint posterior, were generated for each population in each of the 50 years of the forward simulation. To ensure comparability, the same set sets of brood year and population specific process deviates were used across environmental scenarios.

When simulating future trends in Sacramento Chinook abundance and evaluating realized survival rates, it was necessary to incorporate the likely impact of future fishery removals. Fishing mortality was simulated based upon the current Reasonable and Prudent Alternative (RPA) management scheme for Central Valley Chinook (see “Simulation of Harvest Rates” below). Annual allowable harvest rates for fall-run Chinook are established based upon the Sacramento Index (SI), however maximum harvest rates are further contingent upon minimum abundance requirements for ESA listed winter-run Chinook. When projecting populations forward in time, it was necessary to simultaneously model the future dynamics of winter-run Chinook in response to the 16 environmental scenarios under evaluation. Results from the evaluation of Sacramento River winter-run Chinook using the OBAN model (see Appendix D) which was run in parallel with the spring and fall run model, were used to simulate the future abundance of Sacramento River winter-run Chinook across the same 50-year time-series in response to differences in future climate change, marine production, and water exports across scenarios. Moving forward in time, future harvest rates depended on the model-predicted abundance of fall-run Chinook and winter-run Chinook (see “Simulation of Harvest Rates”). Spring-run harvest rates were scaled at 95% of fall-run harvest rates.

SIMULATION OF FUTURE HARVEST RATES

Background

The Pacific Fisheries Management Council (Council) manages the harvest of salmon on the coasts of California, Oregon, and Washington. The ocean salmon fishery targets Chinook, coho, and pink salmon species, which include Sacramento River Chinook salmon. The Sacramento River Chinook stocks overlap with Klamath River Chinook salmon in a mixed stock fishery. Furthermore, the Sacramento River fall Chinook (SRFC) is an indicator stock for the Central Valley Fall complex and Klamath River fall Chinook (KRFC) is an indicator stock for the Oregon/Northern California Chinook complex. As indicator stocks, the Council calculates both acceptable biological catches (ABC) and annual catch limits (ACL) for the SRFC and KRFC.

Both Sacramento River and Klamath River Chinook are composed of stocks supported by hatchery production and stocks that are listed as a conservation concern under the Endangered Species Act (ESA). In the Sacramento River and Klamath River mixed fishery, the Sacramento winter-run (federally listed as threatened in 1990 and as endangered in 1994 under ESA), Central Valley spring-run (listed as threatened under ESA in 1999) and the California coastal (listed in 1999) may limit harvest rates. Target harvest rates for the Sacramento fall run are determined annually via a forecast of abundance indexes of Chinook salmon to both rivers. Management of the fishery occurs through a series of spatially explicit openings and closures to structure the harvest effort in such a manner to ensure conservation of portions of the stocks that may be at low abundances while allowing harvest of those stocks that are healthy. There are a series of Council meetings to review the forecasted abundance and possible management alternatives.

NMFS developed a Biological Opinion in 2010 (2010 Opinion) to evaluate the effects of the ocean salmon fishery on winter run stock (Biological Opinion on the Authorization of Ocean Salmon Fisheries Pursuant to the Pacific Coast Salmon Fishery Management Plan and Additional Protective Measures as it affects the Sacramento River Winter Chinook Salmon (winter-run) Evolutionary Significant Unit (NMFS 2010)). In the 2010 Opinion, NMFS identified that winter-run cohorts could be reduced (i.e., decrease in the number of spawners relative to the number of spawners in the absence of the fishery) by 10 to 25% due to the ocean salmon harvest with an average rate of 20%. Most of the impacts occur south of Point Arena, CA from contacts with the recreational fishery (O’Farrell 2012).

To avoid a jeopardy conclusion on the operation of the ocean salmon fishery, NMFS developed a Reasonable and Prudent Alternative (RPA) to allow explicit control of the management process to reduce impacts when extinction risk of winter run increases (e.g., due to low stock size or periods of decline). After the issuance of the 2010 Opinion, the Council was given options to either increase size limits or enact seasonal closures to reduce the fishery impacts on winter-run in 2010 and 2011.

In 2012, NMFS performed a Management Strategy Evaluation (MSE) for different control rules based on the abundance of winter-run Chinook for setting the allowable harvest rate on the mixed stock fishery (Winship et al. 2012). The control rules set allowable impacts of age-3 winter-run south of point Arena as: 1) 0 impact (a closed fishery south of Point Arena); 2) 25% impact, which is the historical estimate of impact rate; 3) 20% impact, which is the current rate; and four alternatives (4-7) that reduce impact rates at certain winter-run thresholds. These MSE compared the impact rate under each of the control rules relative to the potential for increasing extinction risk of winter-run Chinook.

Management of Sacramento River Chinook

Fall-run

The fishery impact rate for SRFC is set by evaluating the Sacramento Index (SI) in each year. The SI is calculated as the sum of a) harvest south of Cape Falcon, OR; b) SRFC impacts due to non-retention in ocean fisheries; c) harvest in the recreational fishery in the Sacramento River basin; and d) SRFC spawner escapement. The SI is forecasted each year using a regression model with an autocorrelated error term that uses the number of SRFC jacks from the previous year as the dependent variable.

The estimates of the SI are subsequently used to determine the status of the fishery as overfished, approaching overfished, rebuilding, or rebuilt. The important metrics for determining the status are the minimum stock size threshold (MSST) (91,500 for SRFC) and the stock size at maximum sustainable yield (122,000). Given the status of the fishery, the allowable biological catch, annual catch limit, and the overfished limit can then be calculated.

The determination of the fishing rate is described as follows (PFMC 2014). The discrete fishing rate (F) at the overfishing limit, F_{OFL}, is defined as being equal to F_{MSY} (or the maximum fishery mortality threshold) and the spawner size (S) at the overfishing limit, $S_{OFL} = N \text{ x } (1 - F_{MSY})$. Because, SRFC is a Tier-2 fishery, the fishing rate consistent with the allowable biological catch $F_{ABC} = F_{MSY} \times 0.90$ and $S_{ABC} = N \text{ x } (1 - F_{ABC})$, where N is the spawner equivalent units. Finally, the fishing rate consistent with the allowable catch limits, F_{ACL}, is equivalent to F_{ABC} and $S_{ACL} = N \text{ x } (1-F_{ACL})$, which results in $S_{ACL} = S_{ABC.}$. The impact rate is determined by the SRFC control rule as a function of the potential spawner abundance (in this case the spawner abundance is the Sacramento Index = SI) (Figure II.1).

Winter-run

The current RPA (NMFS 2012) uses a fishery control rule with a reduction in fishery impact as a function of 3-year geometric average of winter-run escapement. The escapement is defined as the total male and female, natural-origin and hatchery-origin escapement as estimated by an annual carcass survey (USFWS 2011). The fishery control rule has the following threshold definitions (Figure II.1): A) from escapement of 0 to 500, the allowable impact rate south of Point Arena is 0; B) from escapement of 501 to 4000, the impact rate is linearly increasing from 0.1 to 0.2; C) from escapement of 4000 to 5000, the impact rate is 0.2. The impact rate for escapement > 5000 is undefined. For purposes of the MSE, NMFS assumed that the impact rate would be 0.2 for any 3-year geometric mean of escapement > 4000 as described on pg. 57 of Winship et al. (2012). We assumed the same upper bound of 0.2 for age-3 impact when the 3-year geometric average escapement was > 5000.

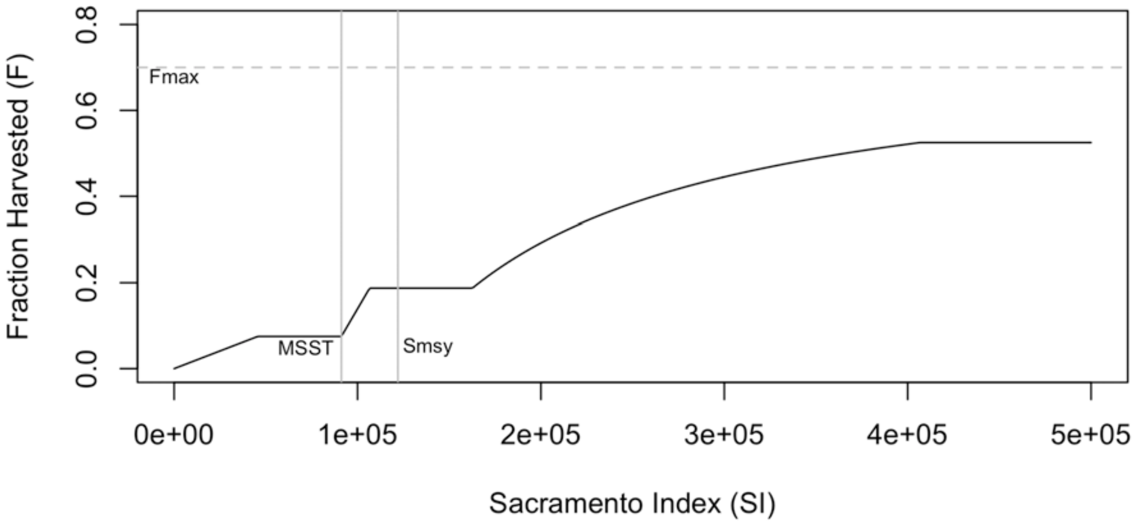


Figure II.1. Fishery control rule as a function of the potential spawner abundance (Sacramento Index) used for setting impact rates for Sacramento River fall-run Chinook.

The fishery control rule defines the impact rates south of Point Arena, which largely encompasses the winter-run marine distribution. Fall-run Chinook are found north of Point Arena, and the fishery control rule for those areas is dependent upon the abundance index for fall run.

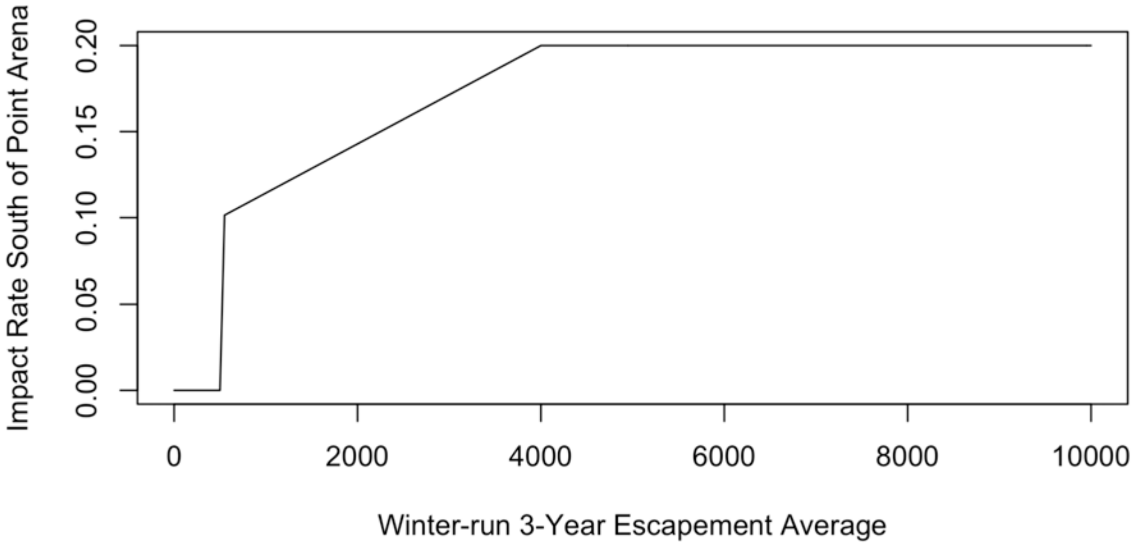


Figure II.2. Fishery control rule as a function of the trailing 3-year geometric average of winter-run abundance.

For example, the SI forecast in 2014 was 634,650 (PFMC 2014). The spawner escapement associated with overfishing in 2014 is 139,623, which is calculated as a function of F_{MSY} (0.78) and the SI abundance forecast of 634,650. The SRFC is a Tier 2 stock, so the $F_{ABC} = F_{MSY} * 0.90 = 0.70$, and the spawner escapement associated the allowable biological catch was forecasted to be $S_{ABC} = N\ (1\text{-}F_{ABC}) = 190{,}395$.

In 2014, the 3-year geometric mean of winter-run abundance was 2,380, which resulted in a maximum forecasted impact rate on age-3 winter-run of 15.4% (in comparison it was 13.7% in 2012 and 12.9% in 2013).

Reducing the maximum impact rate on age-3 winter-run may have important consequences for the actual harvest rates on SRFC. Recently, Satterthwaite et al. (2013) compared the ocean distribution of fall-run, winter-run, and spring-run during the summer and fall, which provides some understanding of the spatial differences in the relative contacts per unit effort of the fishery, which is a proxy for the spatial distribution of each run. Sacramento River fall-run have relative contacts per unit effort of approximately 0.2 for management areas located south Latitude 42 N at the CA OR border, and 0.1 north of Latitude 42 N and Cape Falcon at the OR WA border. These results suggest that the closing of fishing south of Point Arena, as would be required for winter-run 3-year average escapement of less than 500, can have potential consequences for the total fall-run impact rate. For more information, please see PFMC (2014).

Spring Run

There are no explicit fishery management rules for spring run, though it has been noted in past NMFS Biological Opinions (e.g., NMFS 2010) that protections for winter run are likely to be beneficial for spring run. Comparisons of ocean and river impact rates of spring-run relative to SRFC by US Fish and Wildlife Service for the purposes of meeting the goals of the Central Valley Project Improvement Act (CVPIA) indicated equivalent ocean fishery rates were assumed for sprint-run and fall-run, whereas river impact rates were consistently lower for spring-run (Chinookprod_032011.xlsx obtained from http://www.fws.gov/stockton/afrp/). Overall, total fishing impact rates for spring-run were approximately 0.95 of fall-run.

Harvest Model

The management of SRFC requires annual management rules to optimize the fishery due to changing abundances of winter-run and Klamath River stock sizes in addition to the status of other stocks (e.g., PFMC 2014). The management process can be simplified by making several assumptions about the fishery management dynamics:

- Klamath River Fall Chinook do not limit the values of F_{ABC} calculated annually for SRFC.
- The Klamath River fall age 4 harvest rate limits, intended to protect California Coastal Chinook, do not limit the values of F_{ABC} calculated annually for SRFC.
- Abundance of age-3 SRFC and winter-run are obtained from the spring-run & fall-run life cycle model and the winter-run models, respectively. In the actual management of SRFC, estimates of an adult (age 3-5) abundance index in year *t* are calculated from regressions to age-2 abundances in year *t*-1.

- The fishery acts without error; thus, management overfishing (i.e., total annual exploitation rate exceeds the maximum fishing mortality threshold of 0.78) cannot occur.

The following steps were developed for calculating the annual impact rate for SRFC (F_{FR}), and Sacramento winter-run Chinook (F_{WR}).

1. Calculate an estimate of the Sacramento Index as the sum of the four components identified previously.
2. Determine the fall-run impact rate F_{FR} based on the fishery control rule for SRFC (Figure II.1). The control rule specifies that even if the stock is approaching an overfished condition (the SRFC stock has a 3 year geometric average (t-2, t-1, current year) that is below the threshold of 91,500), a *de minimis* fishery will occur at the rate defined by the fisheries control rule.
3. Calculate the trailing 3-year geometric average of winter-run abundance.
4. Depending upon the 3-year geometric value, set the fishery impact rate for winter-run (Figure II.2). If the winter-run impact rate is 0, reduce F_{FR} by 25% to account for lost fishing opportunities south of Point Arena.
5. Set the impact rate for spring-run $F_{SR} = 0.95F_{FR}$ to reflect reduced river impact rates.

RESULTS

Future trends in abundance for seven populations of fall and spring-run Chinook spawning in tributaries of the Sacramento River watershed were simulated under different scenarios for future climate change and ocean productivity, and alternative levels of water export from the Sacramento-San Joaquin Delta. Results from a Bayesian multi-stock population dynamics model, fit to historical abundance data, were used to parameterize forward simulations. In addition, future trends in abundance for Sacramento winter-run Chinook were also simulated to allow for implementation of the current fishery management process. All eight populations were simulated forward in time for 50 years in response to the 16 alternative environmental scenarios (combinations of future climate, ocean productivity, and water exports), subject to capacity interactions arising from juvenile competition, and accounting for estimation uncertainty and process error in future predictions. The forward simulation for each environmental scenario was replicated 1,000 times with randomly drawn process deviates and model parameter values.

Differences in future outcomes for these populations in response to the 16 scenarios are best quantified through comparison of realized survival rates within populations and across scenarios. Realized survival rate was calculated in two ways depending on the life history of the individual populations. First, for wild-spawning Chinook stocks (mainstem Sacramento fall-run, and Deer, Mill and Butte Creek spring-run), realized survival was calculated as the as the survival rate from egg to spawning adult, or the sum of spawning adults from a brood year across return years, divided by the spawning abundance producing that cohort multiplied by the assumed fecundity (Eq. II.4).

(II.4)
$$RS_{y,p,e,i} = \frac{\sum_{a=1}^{Nages} A_{t,p,a,e,i}}{E_{y,p,e,i}}$$
$$t = y + \tau_a$$

In equation II.4, realized survival ($RS_{y,p,e,i}$) from brood year y, of population p, for environmental scenario e, and simulation i, is a function of the adult abundance surviving both natural and fishing mortality and returning to spawn ($A_{t,p,a,e,i}$) in calendar year t, of population p and age a, resulting from simulation i of environmental scenario e, and the number of eggs ($E_{y,p,e,i}$) resulting from brood year y for that population, scenario and simulation. τ_a represents the difference between brood year y and the calendar year of return t, for individuals returning at each age a.

Realized survival for the hatchery-produced populations (Battle Creek (CNFH), Feather River, and American River (Nimbus) fall-run) is determined by the ratio of returning adult spawners ($A_{t,p,a,e,i}$) to the number of hatchery for that population (RH_p), which is assumed constant in the future (Eq. II.5)

(II.5)
$$RS_{y,p,e,i} = \frac{\sum_{a=1}^{Nages} A_{t,p,a,e,i}}{RH_p}$$
$$t = y + \tau_a$$

Predictions for future realized survival rates for the three spring-run (Fig. II.3) and four fall-run (Fig. II.4) populations across years and replicate scenarios, accounting for future fishing mortality, across environmental and export scenarios show some consistent patterns. As expected, survival rates for the hatchery-produced Chinook populations were much higher than those predicted for the wild-spawning populations, given that realized survival was measured as survival from release to spawning adult, as opposed to egg to adult survival (Table II.1). For the fall-run Chinook populations, the final model estimated a net positive impact of nearshore upwelling on survival, as a result these four populations show higher average survival rates for scenarios which included a 10% increase in upwelling (oceanUP) across both future climate change and water export scenarios. Across fall-run populations, simulated positive upwelling conditions in the future resulted in an average increase in realized survival of between 12% and 67% (mean: + 44%) across export scenarios, when compared with those scenarios incorporating a 20% reduction in nearshore upwelling (oceanDOWN, Table II.1). With respect to the spring-run Chinook populations, substantially smaller differences in realized survival rates in response to the oceanUP scenarios were observed, with 5 – 17% decreases in average realized egg to adult survival (Fig. II.3). Winter-run Chinook on the other hand, were predicted to exhibit higher survival in response to the increased upwelling under the oceanUP scenario, with 7 – 36% higher survival (Table II.1)

Predictions for differences in realized survival rate across water export scenarios indicated similar general trends across both populations and potential differences in future climate change. For all populations realized survival rates were predicted to be highest under the zero export scenario, followed by scenarios simulating a 30% reduction in exports, average exports, and a 30% increase in water exports (Fig. II.3, II.4). When compared to scenarios simulating future survival in response to water export levels at the 1967 – 2010 average, spring-run Chinook populations are expected to exhibit a higher average realized survival in response to a 30% reduction in export volumes, with survival 27 – 48% higher for Deer Creek, 29 – 51% higher for Mill Creek, and 19 – 38% higher for Butte Creek Chinook, across environmental scenarios. Fall-run Chinook populations are predicted to exhibit somewhat smaller increases in survival under a 30% export reduction (expDOWN30) relative to average water exports in the future (expAVG), with realized survival higher by 12 – 26% for Sacramento mainstem wild-spawning Chinook, and between 14% and 27% for the three hatchery-produced fall-run Chinook populations across environmental scenarios (Table II.2). Winter-run Chinook are predicted to respond to a 30% reduction in future water exports, with only a 3 – 9% increase in survival relative to the average export scenario (Table II.2).

When future dynamics of Sacramento Chinook populations were simulated with a 30% increase in water exports (expUP30), compared to the average export scenario the mainstem Sacramento wild-spawning Chinook were predicted to experience 16 – 28% lower median realized survival rates from egg to spawning adult, while the three hatchery-produced populations were predicted to exhibit a 14 – 25% reduction in future survival from release to adulthood, depending on the climate change and ocean production scenario (Fig II.4, Table II.2). Simulation of future Deer, Mill, and Butte Creek survival indicated that, relative to the average water export scenario, average realized egg to adult survival was predicted to be 39 – 53% lower in the presence of a 30% increase in future water exports (Fig. II.3, Table II.2). The simulation results again indicate that the response by winter-run Chinook to altered export levels is minimal, with a 0 – 3% reduction in average realized egg to adult survival, across environmental scenarios.

Predictions for realized survival under the zero future export scenario (expZERO) were higher for all populations, however the magnitude of the difference in survival between this and the average export scenario (expAVG) was largely contingent upon the climate change scenario and population of interest. The Deer and Mill Creek spring-run populations exhibited the largest difference in realized survival between the zero and average export scenarios, under the OCAP 9.2 climate change prediction and positive ocean conditions (cc92.oceanUP) (Fig. II.3). Predicted survival in the absence of exports was 79% higher for Deer Creek, 85% higher for Mill Creek, and 59% higher for Butte Creek Chinook, compared to average exports (Table II.2). Interestingly, the Butte Creek spring-run Chinook population also showed one of the smallest responses to the zero export scenario across populations, with only 27% higher survival compared to the average export scenarios under the OCAP 9.5 climate change and lower ocean production environmental scenario (cc95.oceanDOWN). This increase in predicted survival is quite minimal when compared to the 62 – 83% higher survival predicted for the fall-run Chinook populations with zero exports, under the same environmental scenario (Table II.2). In general however, average realized survival for fall-run Chinook under the zero export scenario is expected to be 28 – 62% higher for the mainstem Sacramento wild-spawning population and 44 – 83% higher for the hatchery-produced populations, when compared to expectations under the average export scenario. While results indicated that realized winter-run Chinook survival would be minimally influenced by a 30% increase or reduction in future exports, the zero export scenario is predicted to increase survival by 28 – 91%, most appreciably when combined with a cooler and wetter future climate change scenario and positive future marine conditions (cc92.oceanUP).

In addition to higher median realized survival rates, the zero export scenario is also predict to also produce more variable survival in the future. While most pronounced for the spring-run Chinook populations, when the variability in realized survival is compared across export scenarios it is consistently higher for the zero export case, across all populations (Fig. II.3, Fig. II.4). The Butte Creek population exhibits the greatest variation in future survival, specifically under the zero export scenario, and for the OCAP 9.2 climate change pathway across export scenarios (Fig. II.3).

While these forward simulation results suggest that higher and more variable realized survival can be expected under the zero export scenario, across populations, climate change trajectories, and ocean productivity patterns, it is also evident that a 30% reduction in water exports (expDOWN30) is likely to achieve an increase in realized survival of a substantial magnitude in many cases. For example, on average across environmental scenarios the Butte Creek population is expected to exhibit a 41% increase in average realized survival under the zero export scenario, and a similarly large increase of 27%, with a 30% reduction in spring export volumes (Fig. II.3, Table II.2). This amounts to a difference of only a 14 percentage points in the predicted survival rate increase; between the zero export and 30% export reduction scenarios. Results are similar for the other spring-run populations, with a difference of 25 percentage points for Mill and Deer Creek spring-run Chinook. Improvements in survival under the zero export scenario, relative to the 30% export reduction scenario (expDOWN30), are on average greater for the hatchery-produced fall-run Chinook populations, but likewise suggest that on average across environmental scenarios, a difference in survival of only 26 – 43 percentage points is likely to be observed (Table II.2).

The percentage difference in realized survival increase, for the zero export and 30% reduction scenarios, relative to the average export scenario, is most variable for the winter-run Chinook population. The percentage increase in survival difference between expZERO and expDOWN30 is smallest under cc95.oceanDOWN scenario at 25, and greatest under the cc92.oceanUP scenario. This indicates that under a cooler and wetter future climate with greater upwelling (cc92.oceanUP), the ceasing all exports (expZERO) is likely to have a substantially higher survival benefit relative to reducing exports by 30% (expDOWN30). While, in the face of a hotter and drier future climate with reduced nearshore upwelling (cc95.oceanDOWN) where survival is severely limited by natural processes, both before and after the delta, the benefits of a 30% reduction and zero exports are more similar (Table II.2). This same pattern is predicted for the spring-run Chinook populations, but not the fall-run populations.

With respect to the influence of climate change on predictions for future realized survival, differences in outcomes amongst climate change scenarios differed across populations and were smaller on average when compared differences resulting from alternative export scenarios. The Butte Creek spring-run Chinook population is predicted to have consistently higher realized survival under the OCAP 9.2 climate change forecast, which represents a slightly slower rate of warming paired with increased precipitation (Fig. II.3). Conversely, both the spring-run Deer Creek and fall-run Sacramento mainstem wild-spawning populations show slightly, but consistently, higher survival under the OCAP 9.2 climate change trajectory which describes a greater increase in temperature paired with lower levels of future precipitation (Table II.1).

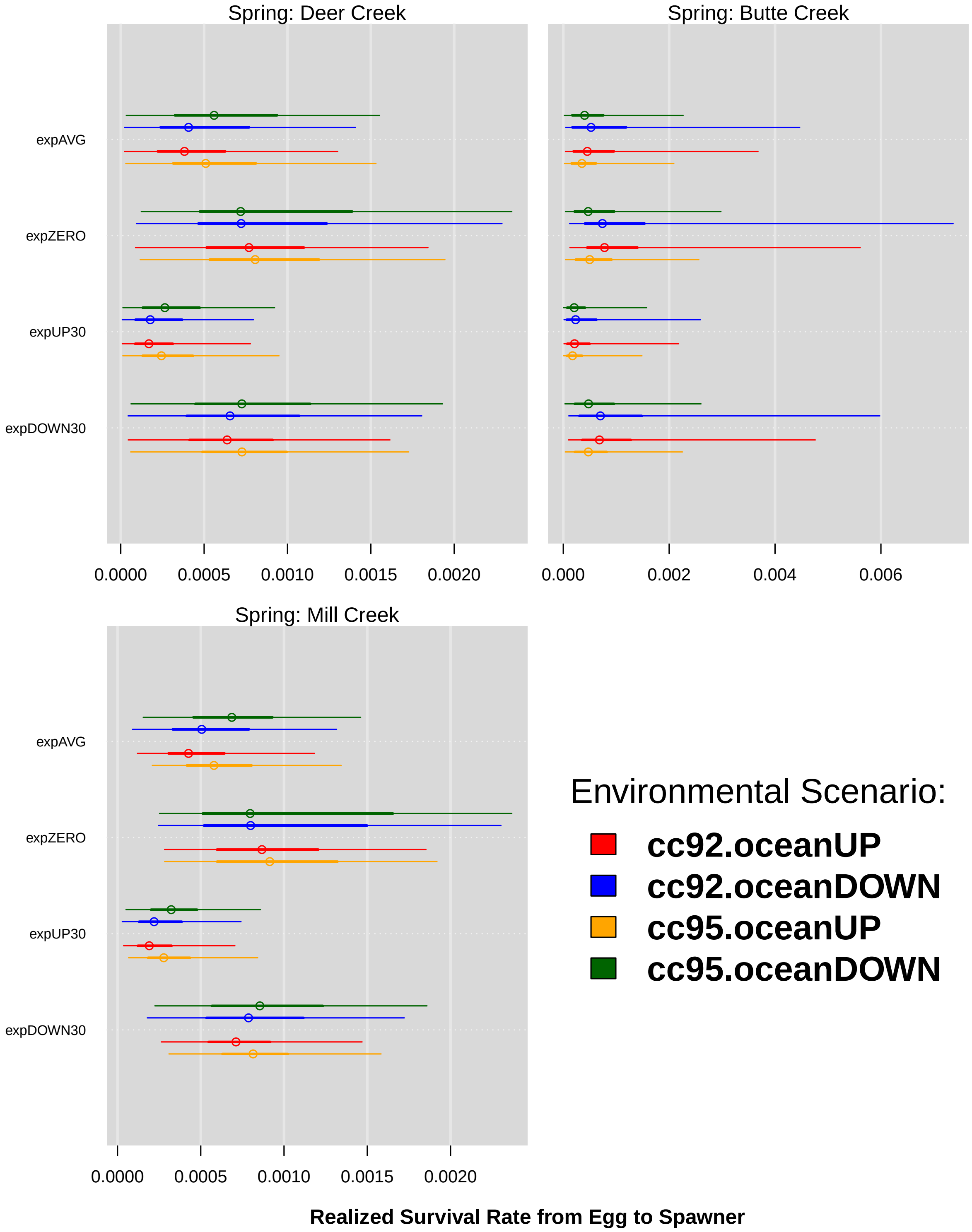


Figure II.3. Caterpillar plots describing the predicted distribution of realized survival to return, across years and simulations, for spring-run Chinook populations. The circle, thick line, and thin line describe the median, 50% credible interval and 95% credible interval for the predictions.

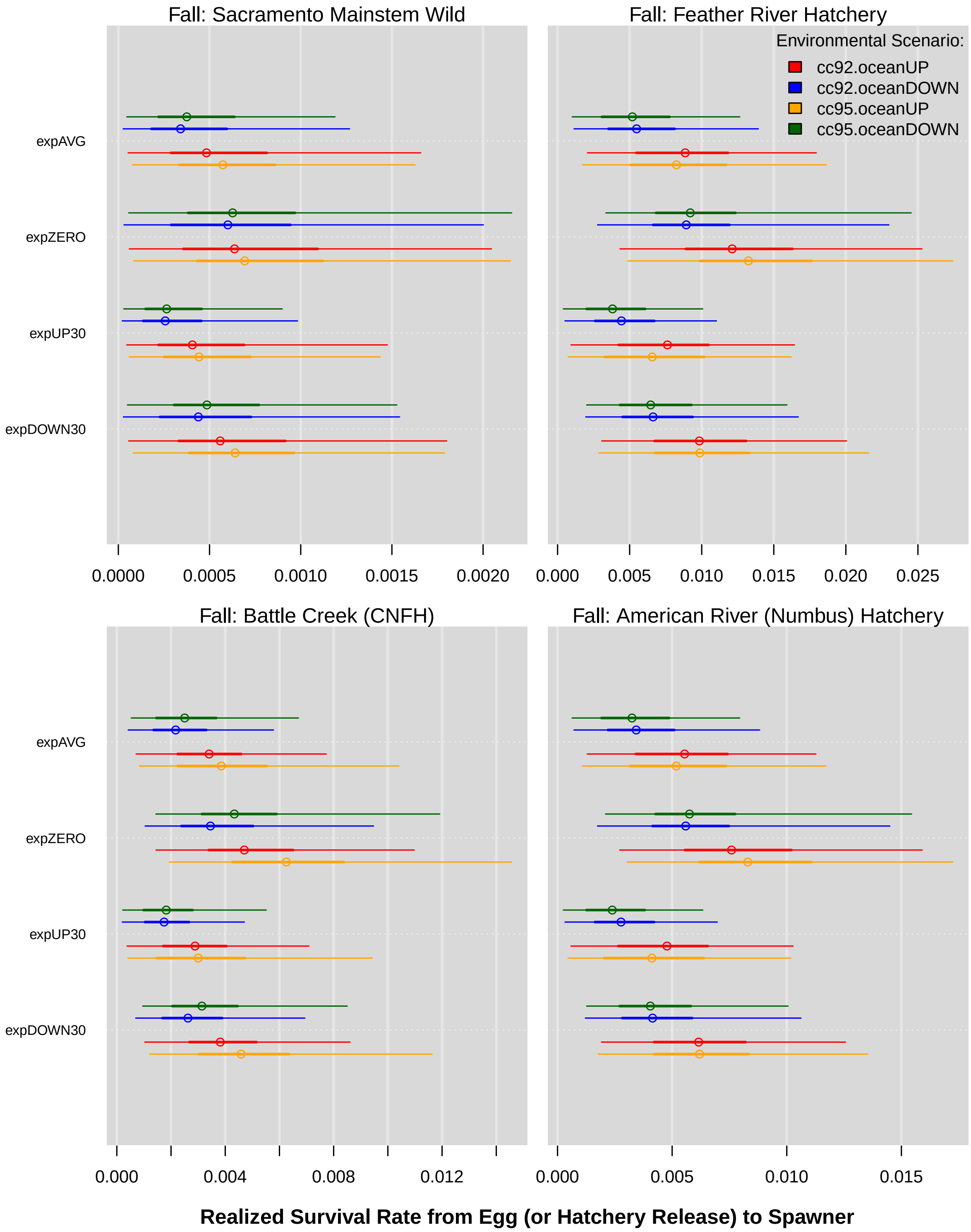


Figure II.4. Caterpillar plots describing the predicted distribution of realized survival to return, across years and simulations, for four fall-run Chinook populations. The circle, thick line, and thin line describe the median, 50% credible interval and 95% credible interval for the predictions.

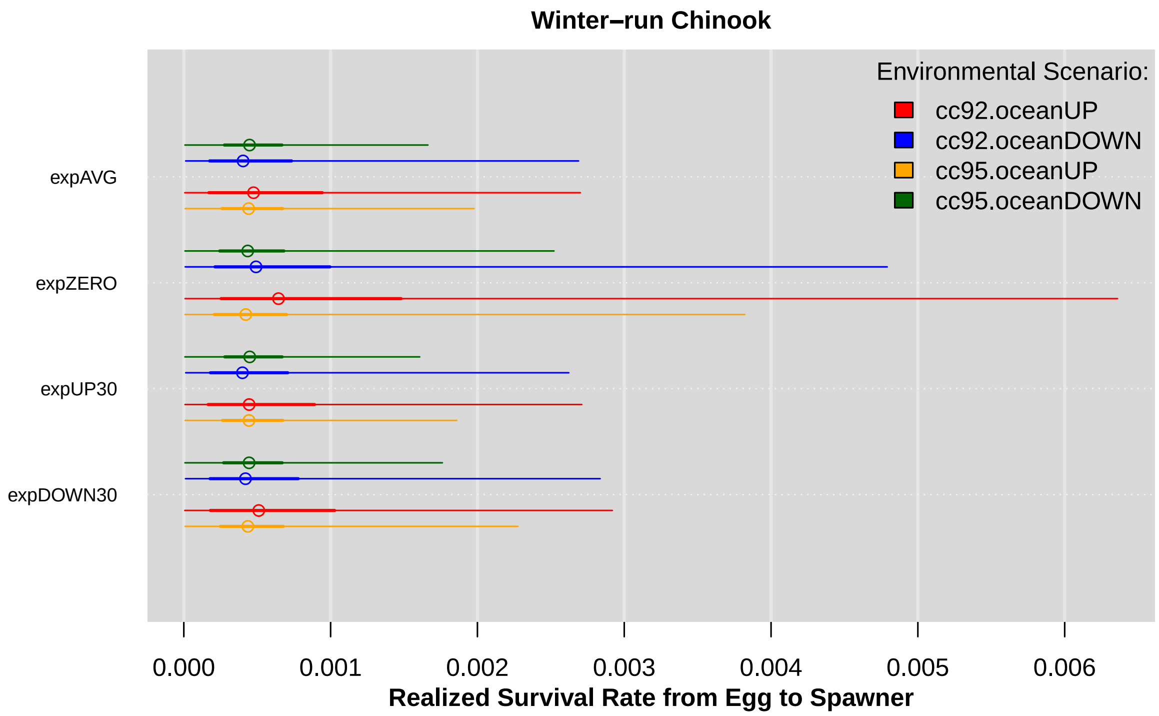


Figure II.5. Caterpillar plots describing the predicted distribution of realized survival to return, across years and simulations, for winter run Chinook populations. The circle, thick line, and thin line describe the median, 50% credible interval and 95% credible interval for the predictions.

Population	Export Scenario	cc92.oceanUP	cc92.oceanDOWN	cc95.oceanUP	cc95.oceanDOWN
Fall: Sacramento Mainstem Wild	expAVG	0.060%	0.043%	0.064%	0.046%
	expZERO	0.077%	0.068%	0.083%	0.074%
	expUP30	0.050%	0.033%	0.053%	0.033%
	expDOWN30	0.067%	0.052%	0.072%	0.058%
Fall: Battle Creek (CNFH)	expAVG	0.355%	0.245%	0.420%	0.274%
	expZERO	0.513%	0.394%	0.665%	0.484%
	expUP30	0.303%	0.195%	0.342%	0.205%
	expDOWN30	0.406%	0.295%	0.500%	0.346%
Fall: Feather River Hatchery	expAVG	0.894%	0.605%	0.867%	0.562%
	expZERO	1.292%	0.983%	1.411%	1.026%
	expUP30	0.764%	0.483%	0.700%	0.420%
	expDOWN30	1.019%	0.731%	1.040%	0.713%
Fall: American River (Numbus) Hatchery	expAVG	0.560%	0.380%	0.543%	0.352%
	expZERO	0.810%	0.617%	0.885%	0.643%
	expUP30	0.479%	0.303%	0.439%	0.263%
	expDOWN30	0.639%	0.459%	0.652%	0.447%
Spring: Deer Creek	expAVG	0.047%	0.052%	0.059%	0.065%
	expZERO	0.083%	0.090%	0.089%	0.095%
	expUP30	0.023%	0.025%	0.031%	0.033%
	expDOWN30	0.069%	0.075%	0.077%	0.082%
Spring: Mill Creek	expAVG	0.050%	0.058%	0.064%	0.071%
	expZERO	0.092%	0.100%	0.098%	0.105%
	expUP30	0.024%	0.027%	0.033%	0.036%
	expDOWN30	0.075%	0.084%	0.085%	0.092%
Spring: Butte Creek	expAVG	0.077%	0.092%	0.051%	0.058%
	expZERO	0.122%	0.136%	0.068%	0.074%
	expUP30	0.041%	0.049%	0.031%	0.034%
	expDOWN30	0.106%	0.121%	0.062%	0.069%
Winter-run Chinook	expAVG	0.069%	0.061%	0.059%	0.055%
	expZERO	0.133%	0.098%	0.085%	0.070%
	expUP30	0.067%	0.060%	0.058%	0.055%
	expDOWN30	0.076%	0.064%	0.062%	0.056%

Table II.1. Median of simulations for the predicted percent realized survival from egg or hatchery release to spawning adult, across water export and future environmental scenarios. Matrix of scenario-specific realized survival predictions for each population are shaded from red (low) to green (high) for ease of interpretation.

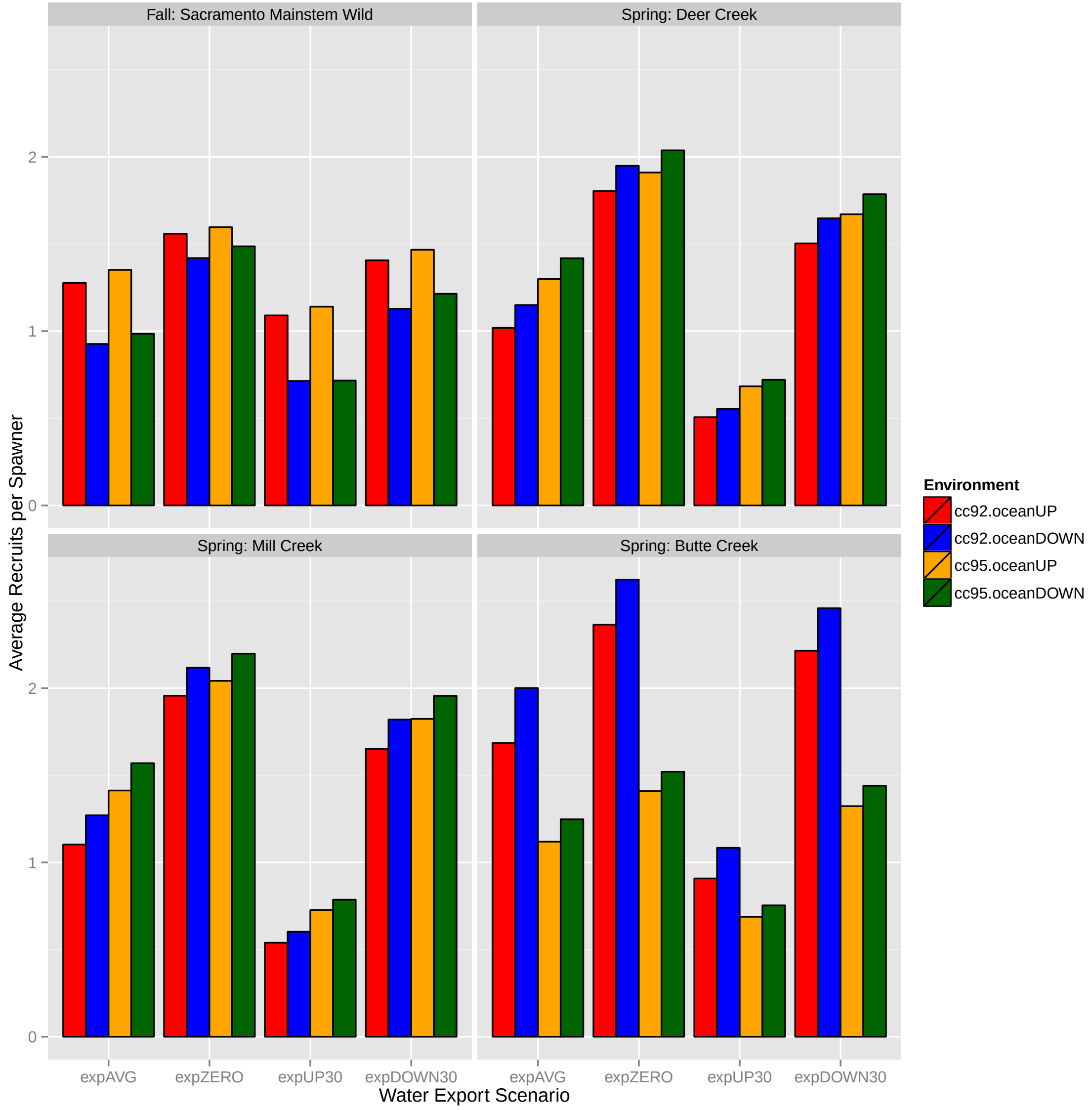
Population	Export Scenario	cc92.oceanUP	cc92.oceanDOWN	cc95.oceanUP	cc95.oceanDOWN
Fall: Sacramento Mainstem Wild	expZERO	30%	59%	28%	62%
	expUP30	-16%	-23%	-18%	-28%
	expDOWN30	12%	23%	12%	26%
Fall: Battle Creek (CNFH)	expZERO	44%	61%	58%	77%
	expUP30	-15%	-20%	-18%	-25%
	expDOWN30	14%	21%	19%	26%
Fall: Feather River Hatchery	expZERO	45%	62%	63%	83%
	expUP30	-14%	-20%	-19%	-25%
	expDOWN30	14%	21%	20%	27%
Fall: American River (Numbus) Hatchery	expZERO	45%	63%	63%	83%
	expUP30	-15%	-20%	-19%	-25%
	expDOWN30	14%	21%	20%	27%
Spring: Deer Creek	expZERO	79%	72%	50%	46%
	expUP30	-50%	-52%	-47%	-49%
	expDOWN30	48%	44%	29%	27%
Spring: Mill Creek	expZERO	85%	74%	53%	47%
	expUP30	-51%	-53%	-49%	-50%
	expDOWN30	51%	46%	32%	29%
Spring: Butte Creek	expZERO	59%	47%	32%	27%
	expUP30	-46%	-47%	-39%	-41%
	expDOWN30	38%	31%	21%	19%
Winter-run Chinook	expZERO	91%	60%	44%	28%
	expUP30	-3%	-2%	-1%	0%
	expDOWN30	9%	5%	5%	3%

Table II.2. Percent difference in median realized survival from average export (expAVG) scenario, across environmental scenarios. Values shaded from red (low) to green (high) for ease of interpretation.

In addition to estimates for future realized survival rates, for wild-spawning populations the average productivity of populations across years and replicate scenarios was also evaluated. Figure II.6, displays the average number of recruits per spawner for the Sacramento mainstem wild-spawning fall-run Chinook population, and the Deer, Mill, and Butte Creek spring-run populations and winter run, under alternative water export scenarios and environmental conditions. Scenarios that predict average productivity of less than 1 recruit-per-spawner, indicate that those populations are unlikely to remain viable in the future and will tend toward extinction in the presence of environmental stochasticity. Forward simulation results for the mainstem Sacramento fall-run Chinook population indicate that under the average (expAVG) and 30% increase (expUP30) water export scenarios, average productivity in the face unfavorable ocean conditions producing a 20% reduction in future upwelling (oceanDOWN) is expected to be less than one recruit-per-spawner (Fig. II.6). However, under both of these future export scenarios average recruits-per-spawner is expected to expected to exceed one under favorable future ocean conditions (oceanUP).

Predicted future realized productivity (recruits-per-spawner) for the Deer, Mill, and Butte Creek spring-run populations is predicted to be significantly lower under the scenario representing a 30% increase in future exports (expUP30). For both the Deer Creek and Mill Creek populations, average realized productivity (recruits-per-spawner) is predicted to be less than one with a 30% increase in water exports (expUP30), across all four combinations of future climate change and marine conditions (Fig. II.6). Predictions for future productivity of the Butte Creek population indicate that with the more gradual climate warming and greater future precipitation under the OCAP 9.2 scenario indicate that even with a 30% increase in water exports (expUP30) the population may be expected to produce at or near 1 recruit-per-spawner, and therefore remain viable.

Average future productivity (recruits-per-spawner) is expected to be highest across environmental scenarios under the zero export (expZERO) and 30% reduction in future exports (expDOWN30). However, realized productivity is predicted to vary across populations in response to future climate change and ocean production scenarios. For the mainstem Sacramento wild-spawning fall-run population, future productivity in the face of positive ocean conditions and specifically increased nearshore upwelling (oceanUP) is predicted to be highest and exceed one recruit-per-spawner, independent of the climate change or export scenario. The form of future climate change is predicted to have the greatest impact on the Butte Creek spring-run Chinook population, with higher productivity, in terms of recruits-per-spawner, under the OCAP 9.2 scenario (Fig. II.6). This results from the fact that this population was found to be particularly sensitive to summertime temperatures, which are predicted to increase more precipitously under the OCAP 9.5 climate change scenario leading to reduced over-summer survival of adults holding prior to spawning. Spring run stocks are much more sensitive to exports than fall and winter run, but both fall and winter do see slight improvement under export restrictions.



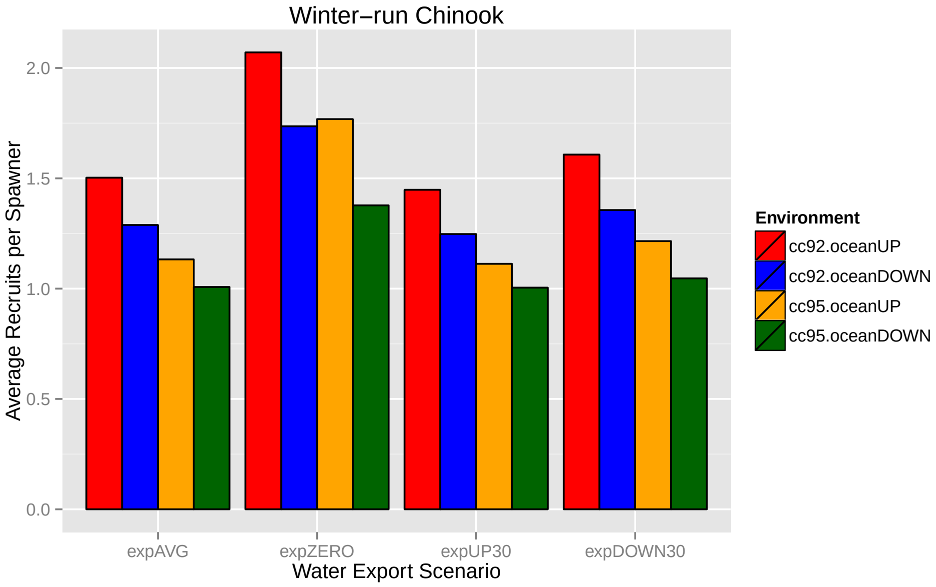


Figure II.6. Average number of realized recruits per spawner, across populations, environmental and export scenarios

PART II DISCUSSION

Results from a Bayesian population dynamics model estimating the stage and population specific maximum survival rates and changes in survival in response to natural and anthropogenic environmental covariates were used to parameterize simulations for future trends in population-specific abundance under alternative water export, climate change, and ocean production scenarios. Both estimation and process uncertainty were incorporated into future predictions by, first sampling model parameter values from the joint posterior, and second incorporating stochastic process deviations into the first modeled life-stage. One thousand replicate simulations of the 50-year future time series were used to fully quantify the influence of these two sources of uncertainty. The likely impact from future ocean harvest of Chinook was incorporated by simultaneously modeling the future trends in abundance for winter-run Chinook in the Sacramento system and replicating the current fishery management decision rules. We did not explore the impacts of modifying the harvest regime, but obviously any change in the fraction of fish harvested would have an analogous impact to increasing survival via changing exports or other environmental factors.

Results from these forward simulations in the form of estimates for future realized survival rates from egg, or hatchery release, to spawning adult, and estimates for realized productivity (recruits-per-spawner) indicate that while all populations are sensitive to differences in future water exports from the Sacramento-San Joaquin Delta, differences in the future environment are likely to have substantial population-specific impacts. The observation that predicted realized survival and productivity are generally higher for the fall-run populations and equal or lower for the spring-run populations under the oceanUP scenario results from several characteristics of the forward simulation model. The oceanUP scenario represents a 10% increase in future nearshore upwelling, paired with a smaller increase in future water temperatures at the Farallon Islands. While nearshore upwelling was found by the estimation model to significantly increase survival in the nearshore region for fall-run Chinook populations, this covariate was not AICc-selected for the spring-run populations. As a result, predictions for future realized survival for the fall-run Chinook populations show as consistently higher survival and productivity patterns in response to the oceanUP scenario. This prediction for higher realized survival for fall-run Chinook populations agrees with insights by Lindley et al. (2009) pointing to unusually low nearshore upwelling patterns as one of the proximate causes of the failure of the 2004 – 2005 fall-run brood years. In addition, the grouped survival of all seven Chinook populations was found to have a positive relationship with the Pacific Decadal Oscillation. The oceanUP scenario described an initial negative PDO phase, followed by a positive PDO phase, resulting in lower marine survival initially followed by higher marine survival in later years for the populations. The opposite pattern in marine survival was observed for the seven Chinook populations under the oceanDOWN scenario in response to the PDO pattern simulated in the opposite direction.

Future climate change scenarios had mixed impacts across populations as a result of the estimated response by populations to the environmental covariates impacted by the OCAP 9.2 and 9.5 predictions. The cooler and wetter OCAP 9.2 scenario had a particularly strong influence on the Butte Creek population, because a strong negative influence of high summertime temperatures was predicted for this population. However, the increase in water flow associated with the OCAP 9.2 scenario resulted in increased sediment concentration at Freeport, CA. Given the negative relationship between sediment concentration at this location and survival for both fall and spring-run Chinook, this aspect of the OCAP 9.2 scenario did result in some reduction in survival for all populations, although in some cases this effect was outweighed by the interaction with temperature.

Across all combinations of future export and environmental scenarios predictions for both realized survival and productivity (recruits-per-spawner) were highly variable. While we have focused on predicted differences in median survival and average productivity, the 95% credible intervals for these predictions overlap in almost all cases. This indicates that the combination of both estimation and process uncertainty introduced in the forward simulation process leads to significant variability in future abundance and our quantified metrics. This is particularly pronounced in future predictions of realized survival for the Butte Creek population, which are extremely right skewed (Fig. II.3).

Quantifying results of forward simulations for wild-spawning Chinook populations in terms of average productivity (recruits-per-spawner) provided an efficient means for determining under what water export scenarios and environmental conditions specific populations are expected to persist (recruits-per-spawner > 1), or decline toward extinction (Fig. II.5). For several of the populations under the 30% increase in future water export scenario (expUP30), and for the fall-run mainstem Sacramento wild-spawning population under the average export scenario paired with decreased future upwelling (oceanDOWN), average productivity was predicted at less than one. While this result suggests that under those conditions specific populations may be expected to decline in abundance, it is important to fully understand the assumptions involved in this prediction. First, the forward simulations assume that future fishing mortality rates will vary in accordance with current management practices, as influenced by the Sacramento Index and harvest limitations based upon the abundance of winter-run Chinook. A reduction in future fishing mortality rate may be sufficient to increase the productivity of these populations above 1 recruit-per-spawner and facilitate persistence. Second, predictions for future productivity do not account for the stray rates amongst hatchery and wild populations leading to source-sink dynamics (Johnson et al. 2012). These effects may be most important for the Sacramento mainstem wild-spawning fall-run Chinook population, which was found in 2010 and 2011 to have 20 – 27% of its observed spawning abundance resulting from hatchery-reared strays (Kormos et al. 2012, Palmer-Zwahlen and Kormos 2013). Whether the contribution of straying individuals may be enough to facilitate persistence of populations under environmental and export scenarios that are predicted by these analysis to lead to decline (recruits-per-spawner < 1), remains unknown.

REFERENCES

Battin, J., M. W. Wiley, M. H. Ruckelshaus, R. N. Palmer, E. Korb, K. K. Bartz, and H. Imaki. 2007. Projected impacts of climate change on salmon habitat restoration. Proc Natl Acad Sci U S A **104**:6720-6725.

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations.

Brooks, S. P., and A. Gelman. 1998. General methods for monitoring convergence of iterative simulations. Journal of Computational and Graphical Statistics **7**:434-455.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference : a practical information-theoretic approach. 2nd edition. Springer, New York.

CDF&W. 2014. GrandTab 2014.04.22: California Central Valley Chinook population report. California Department of Fish and Wildlife.

CDWR. 2014. DAYFLOW Data.*in* C. D. o. W. Resources, editor.

Claiborne, A. M., J. P. Fisher, S. A. Hayes, and R. L. Emmett. 2011. Size at release, size-selective mortality, and age of maturity of Willamette River Hatchery yearling Chinook salmon. Transactions of the American Fisheries Society **140**:1135-1144.

Ewing, R. D., and G. S. Ewing. 2002. Bimodal length distributions of cultured chinook salmon and the relationship of length modes to adult survival. Aquaculture **209**:139-155.

Fournier, D. A., H. J. Skaug, J. Ancheta, J. Ianelli, A. Magnusson, M. N. Maunder, A. Nielsen, and J. Sibert. 2012. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software **27**:233-249.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 2004. Bayesian data analysis. 2nd edition. Chapman & Hall/CRC, Boca Raton, Fla.

Gelman, A., and D. B. Rubin. 1992. Inference from iterative simulation using multiple sequences. Statistical Science **7**:457-511.

Hare, S. R., N. J. Mantua, and R. C. Francis. 1999. Inverse production regimes: Alaska and West Coast Pacific salmon. Fisheries **24**:6-14.

Hendrix, N., E. Danner, C. M. Greene, H. Imaki, and S. T. Lindley. 2014. Life cycle modeling framework for Sacramento River Winter-run Chinook salmon. NOAA Technical Memorandum.

Hilborn, R., and M. Mangel. 1997. The ecological detective: confronting models with data. Princeton University Press, Princeton, NJ.

Honea, J. M., J. C. Jorgensen, M. M. McClure, T. D. Cooney, K. Engie, D. M. Holzer, and R. Hilborn. 2009. Evaluating habitat effects on population status: influence of habitat restoration on spring-run Chinook salmon. Freshwater Biology **54**:1576-1592.

Huber, E. R., and S. M. Carlson. in review. Temporal trends of California Central Valley fall run Chinook salmon hatchery release practices.

Johnson, R. C., P. K. Weber, J. D. Wikert, M. L. Workman, R. B. MacFarlane, M. J. Grove, and A. K. Schmitt. 2012. Managed metapopulations: do salmon hatchery 'sources' lead to in-river 'sinks' in conservation? PLoS ONE **7**:e28880.

King, R., B. Morgan, O. Gimenez, and S. Brooks. 2010. Bayesian analysis for population ecology. CRC Press.

Kocan, R., P. Hershberger, G. Sanders, and J. Winton. 2009. Effects of temperature on disease progression and swimming stamina in Ichthyophonus-infected rainbow trout, Oncorhynchus mykiss (Walbaum). Journal of Fish Diseases **32**:835-843.

Kormos, B., M. Palmer-Zwahlen, and A. Low. 2012. Recover of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest 2010. California Deparment of Fish and Game, Sacramento, California.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L. W. Botsford, D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza, A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. Macfarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, and T. H. Williams. 2009. What caused the Sacramento River fall Chinook stock collapse?

Lindley, S. T., and M. S. Mohr. 2003. Modeling the effect of striped bass (*Morone saxatilis*) on the population viability of Sacramento River winter-run chinook salmon (*Oncorhynchus tshawytscha*). FISHERY BULLETIN **101**:321-331.

Macias, D., P. J. S. Franks, M. D. Ohman, and M. R. Landry. 2012. Modeling the effects of coastal wind- and wind-stress curl-driven upwellings on plankton dynamics in the Southern California current system. Journal of Marine Systems **94**:107-119.

Mantua, N. J., and S. R. Hare. 2002. The Pacific decadal oscillation. Journal of Oceanography **58**:35-44.

Moussalli, E., and R. Hilborn. 1986. Optimal Stock Size and Harvest Rate in Multistage Life-History Models. Canadian Journal of Fisheries and Aquatic Sciences **43**:135-141.

Myrick, C. A., and J. J. Chech. 1998. Temperature effects on Chinook salmon and Steelhead: a review focusing on California's Central Valley populations. Bay-Delta Modeling Forum.

Neuswanger, J., M. S. Wipfli, A. E. Rosenberger, and N. F. Hughes. 2014. Mechanisms of drift-feeding behavior in juvenile Chinook salmon and the role of inedible debris in a clear-water Alaskan stream. Environmental Biology of Fishes **97**:489-503.

Newman, K. B., and P. L. Brandes. 2010. Hierarchical Modeling of Juvenile Chinook Salmon Survival as a Function of Sacramento-San Joaquin Delta Water Exports. North American Journal of Fisheries Management **30**:157-169.

Newman, K. B., and J. Rice. 2002. Modeling the survival of Chinook salmon smolts out-migrating through the lower Sacramento River system. Journal of the American Statistical Association **97**:983-993.

Palmer-Zwahlen, M., and B. Kormos. 2013. Recovery of coded-wire tags from Chinook salmon in California's Central Valley escapement and ocean harvest in 2011. California Department of Fish and Wildlife, Sacramento, California.

Perry, R. W., J. R. Skalski, P. L. Brandes, P. T. Sandstrom, A. P. Klimley, A. Ammann, and B. MacFarlane. 2010. Estimating survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta. North American Journal of Fisheries Management **30**:142-156.

Poytress, W. R., J. J. Gruber, F. D. Carrillo, and S. D. Voss. 2014. Compendium report of Red Bluff Diversion Dam rotary trap juvenile anadromous fish production indices for years 2002-2012. Report of U.S. Fish and Wildlife Service to California Department of Fish and Wildlife and US Bureau of Reclamation.

Scheuerell, M. D., R. Hilborn, M. H. Ruckelshaus, K. K. Bartz, K. M. Lagueux, A. D. Haas, and K. Rawson. 2006. The Shiraz model: a tool for incorporating anthropogenic effects and fish-habitat relationships in conservation planning. Canadian Journal of Fisheries and Aquatic Sciences **63**:1596-1607.

Sogard, S. M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: A review. Bulletin of Marine Science **60**:1129-1157.

Stevens, D. E., and L. W. Miller. 1983. Effects of river flow on abundance of young Chinook salmon, American Shad, Longfin Smelt, and Delta Smelt in the Sacramento-San Joaquin River system. North American Journal of Fisheries Management **3**:425-437.

Tompkins, M. R. 2006. Floodplain connectivity and river corridor complexity: Implications for river restoration and planning for floodplain management. University of California, Berkley.

USBR. 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento, California.

Ward, P. D., T. R. McReynolds, and C. E. Garman. 2003. Butte Creek spring-run Chinook salmon, *Oncorhynchus tshawytscha* pre-spawn mortality evaluation, 2003. California Department of Fish and Game, Chico, California.

Wells, B. K., J. C. Field, J. A. Thayer, C. B. Grimes, S. J. Bograd, W. J. Sydeman, F. B. Schwing, and R. Hewitt. 2008. Untangling the relationships among climate, prey and top predators in an ocean ecosystem. Marine Ecology-Progress Series **364**:15-29.

Wells, B. K., C. B. Grimes, J. C. Field, and C. S. Reiss. 2006. Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*O. tshawytscha*) and the ocean environment. Fisheries Oceanography **15**:67-79.

Wells, B. K., C. B. Grimes, and J. B. Waldvogel. 2007. Quantifying the effects of wind, upwelling, curl, sea surface temperature and sea level height on growth and maturation of a California Chinook salmon (Oncorhynchus tshawytscha) population. Fisheries Oceanography **16**:363-382.

Williams, J. G. 2006. Central valley salmon: a perspective on Chinook and steelhead in the Central Valley of California. San Francisco Estuary & Watershed Science **4**.

Zar, J. H. 2010. Biostatistical analysis. 5th edition. Prentice-Hall/Pearson, Upper Saddle River, N.J.

Zeug, S. C., P. S. Bergman, B. J. Cavallo, and K. S. Jones. 2012. Application of a Life Cycle Simulation Model to Evaluate Impacts of Water Management and Conservation Actions on an Endangered Population of Chinook Salmon. Environmental Modeling & Assessment **17**:455-467.

APPENDIX A LINKAGES TO THE CENTRAL VALLEY LIFE CYCLE MODEL

BACKGROUND

The National Marine Fisheries Service (NMFS) Southwest Fisheries Science Center (SWFSC) initiated a project to develop life-cycle models of salmon populations in the Central Valley. The project objective is to build a framework to quantitatively evaluate how the management and operation of the Federal Central Valley Project (CVP) and California State Water Project (SWP) affect Central Valley salmon populations. The modeling framework will evaluate the current operations of the CVP and SWP, i.e., Operational Plan and Criteria (OCAP), and evaluate future water conveyance structures as proposed in the Bay Delta Conservation Plan (BDCP). The NMFS Central Valley Life Cycle Model (CVCLCM) targeted winter-run as the first race of Chinook for model development (Hendrix et al. 2014).

The CVCLCM framework is a stage-structured model. Stages in the model were based on developmental state as well as geographic location (e.g., smolts in the delta, smolts in the mainstem river, or smolts in a floodplain). State transitions among life-history stages are defined by a modified Beverton-Holt (Beverton 1957) that allows individuals exceeding the capacity of a habitat to move to a different geographic location rather than die in that habitat (Greene and Beechie 2004). The Beverton-Holt with movement function is defined by a survival rate, capacity, and movement rate (Figure A.1). Each of these parameters can be modeled as a function of environmental or anthropogenic factors that may be influenced by management (e.g., spatial extent of floodplain habitat as it affects capacity) and operational actions (e.g., flow as it affects movement or water temperature as it affects survival).

Capacity estimates for the river and delta habitats from the CVCLCM were used in the current fall-run and spring-run model. In addition, there are several products from the current model that will be useful to the CVCLCM, which is developing fall-run and spring-run life cycle models.

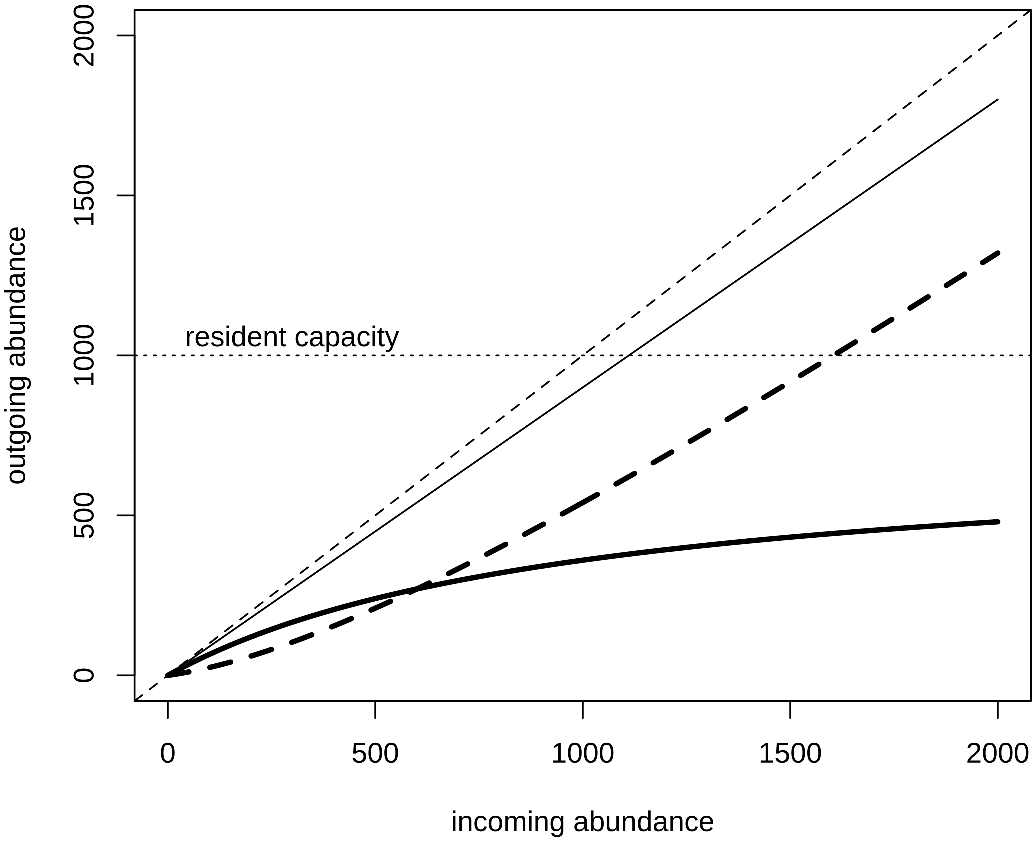


Figure A.1. Beverton-Holt with movement transition function. Outgoing abundance (thin solid line) is composed of migrants (thick dashed line) and residents (thick solid line), which are affected by the resident capacity (dotted horizontal line). Those fish that are not residents leave as migrants. The 1:1 line (thin dashed) is also plotted for reference.

PRODUCTS FROM THE CVCLCM USED IN THE FALL-RUN AND SPRING-RUN MODEL

Capacities

The CVCLCM developed estimates of monthly capacities for use in the Beverton-Holt transition function. The capacities were estimated in four habitats/geographic areas: 1) Sacramento River from headwaters to the city of Sacramento (river), 2) Yolo bypass (floodplain), 3) delta (city of Sacramento to Chipps Island) and 4) Chipps Island to the Golden Gate Bridge (bay). Two of these areas were used in the current fall-run and spring-run life-cycle model. The Sacramento River monthly capacity estimates were used for the Sacramento River mainstem spawning fall-run population in Stage 1 and the delta capacity estimates were used in fall-run (average delta capacity March to May) and spring-run (average delta capacity February to April) capacities for Stage 2.

Capacities for the river, floodplain, delta, and bay habitats were calculated in the CVCLCM as a function of habitat-specific capacity models (Hendrix et al. 2014). We provide details on the river and delta calculations and habitat capacity estimates, because they were included in the fall-run and spring-run model. In particular, the calculation of River capacity was modified since the publishing of the methods in Hendrix et al. (2014). Although the initial model development in the CVCLCM was focused on winter-run, the estimates of capacity are applicable to all races of Chinook in the Central Valley.

River Capacities

The River capacities were defined as a function of velocity and depth. For each variable preferred versus not-preferred categories were defined (Table A.1). The possible combinations of the 2 levels of 2 variables provided 4 categories of habitat quality for rearing Chinook salmon. The Central Valley is primarily a hatchery-dominated system with fish released at smolt size for rapid migration to the ocean, and natural stocks are at historically low levels; therefore, current estimates of fish density from the Central Valley may not be indicative of densities at capacity. As a result, densities from the Skagit River, WA were used to inform the maximum density estimates for each category (Greene et al. 2005). Two densities were used to calculate capacities: the 90th percentile and the 95th percentile of the distribution of densities by habitat category in the Skagit River.

Table A.1. Habitat variables used to define the River capacity.

Variable	Preferred or Not-preferred	Range
Velocity	Preferred	$\leq$ 0.15 m/s
	Not preferred	> 0.15 m/s
Depth	Preferred	> 0.2 m and $\leq$ 1m
	Not preferred	$\leq$ 0.2m or > 1m

Areas of habitat under each of the 4 categories were calculated by running the HEC-RAS model on a series of Sacramento River cross-sections that define cells. Each cell in the cross-section has a depth and velocity, and altering the flow changes the depth and velocity of a particular cell. The area of each cell that corresponded to a specific combination of velocity and depth category was tabulated for each monthly flow associated with a cross-section. The appropriate density of Chinook salmon for each of the 4 categories was applied to arrive at a density estimate for the Sacramento River in each month (Figure A.2).

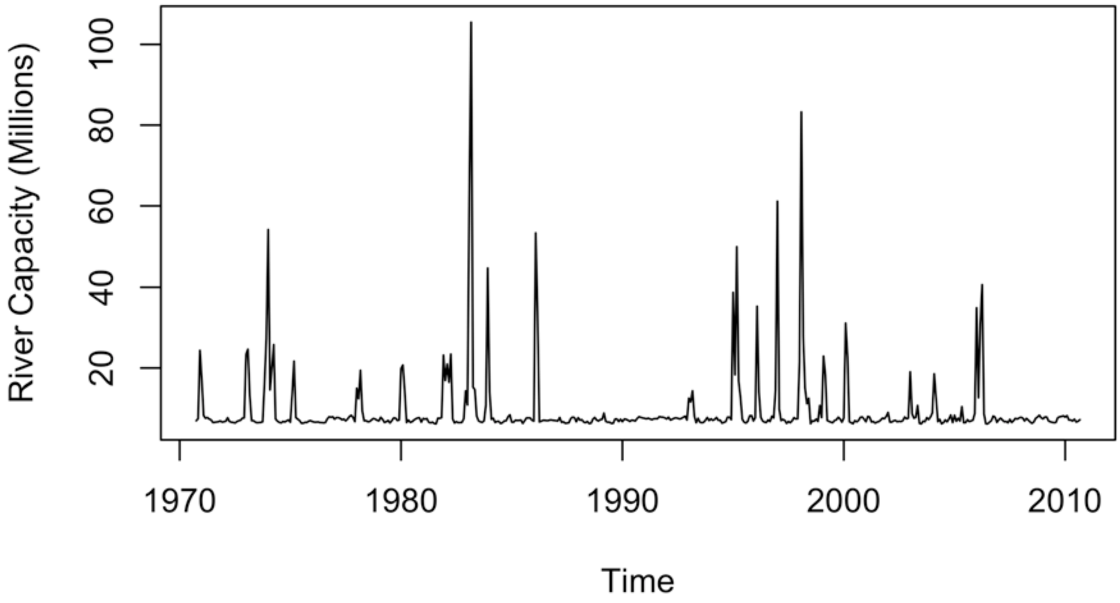


Figure A.2. Monthly capacity of Chinook salmon in the Sacramento River using a 90th percentile estimate of fish density.

Delta Capacities

The monthly capacities in the delta were defined as a function of several habitat attributes including: channel type, cover, shoreline type, blind channel area, salinity and vegetated cover along riverbanks. Analysis was conducted by using Geographic Information System (GIS) data layers. Habitat quality was determined by defining binary High/Low ranges for each axis of habitat quality, similar to the Preferred and Not-preferred approach used in the river habitat. In the delta, 8 categories of habitat quality were defined, each with an associated maximum density. Because not all habitats are accessible by rearing Chinook, a subsequent analysis was conducted to restrict habitat areas based on connectivity. Using beach seine data collected by US Fish and Wildlife Service (Speegle et al. 2013), a generalized linear model was used to estimate the probability of juvenile habitat use by seining location. This model was subsequently used to restrict habitat use by juvenile salmonids throughout the delta. Monthly estimates of capacity in the delta reflected the restricted access to particular areas of the delta and the seasonal absence of juvenile salmonids during the summer months (Figure A.3). Additional details on the capacity calculations can be found in Hendrix et al. (2014).

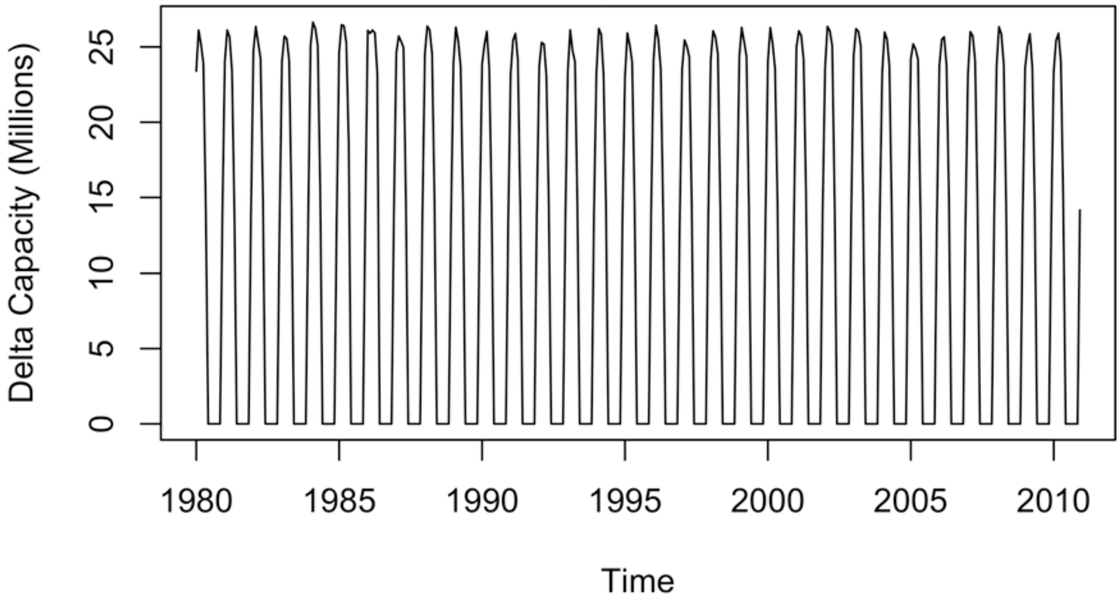


Figure A.3. Monthly capacities of Chinook salmon in the delta using a 90th percentile estimate of fish density.

PRODUCTS FROM THE FALL-RUN AND SPRING-RUN MODEL THAT COULD BENEFIT THE CVCLCM

In the current project, we are using a model for fall and spring-run that incorporates competition through density dependence via a Beverton-Holt transition. This interaction effectively removes some capacity for each of the interacting races. Initial model evaluations indicated that an external capacity value improves the ability to estimate an interaction effect e.g., between fall-run and spring-run or between hatchery and natural. Although the Beverton-Holt function in the CVCLCM incorporates a movement component, understanding the importance of both of these interactions is important in the context of the CVCLCM models for fall-run and spring-run Chinook.

The NMFS scientists developing the fall-run and spring-run CVCLCM models will benefit from interacting with the current fall-run and spring-run model. The current model uses the CVCLCM capacities for certain stages, but these can also be modeled as functions of covariates to allow further hypothesis evaluation. In addition, the time series of observations is greater for the current model than the CVCLCM, which is restricted to 1980 to 2010. Thus earlier escapement data can be used to help parameterize the CVCLCM. Finally, the speed with which alternative hypotheses can be developed and fit to the fall-run and spring-run escapement data provides a useful tool for model construction in the CVCLCM. Hypotheses can be developed and tested on the order of minutes to hours, whereas running the full CVCLCM under a new set of environmental drivers can take on the order of days.

REFERENCES

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations.

Greene, C. M. and T. J. Beechie. 2004. Consequences of potential density-dependent mechanisms on recovery of ocean-type Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 61(4):590-602.

Greene, C. M., D. W. Jensen, G. R. Pess, E. A. Steel, and E. Beamer. 2005. Effects of environmental conditions during stream, estuary, and ocean residency on Chinook salmon return rates in the Skagit River, Washington. Transactions of the American Fisheries Society 134(6):1562-1581.

Hendrix, N., Danner, E., Greene, C. M., Imaki, H., & Lindley, S. T. 2014. Life cycle modeling framework for Sacramento River Winter-run Chinook salmon. NOAA Technical Memorandum NOAA -TM-NMFS-SWFSC-530.

Speegle, J., Kirsch, J., & Ingram, J. 2013. Annual Report: Juvenile fish monitoring during the 2010 and 2011 field seasons within the San Francisco Estuary, California.

APPENDIX B CLIMATE CHANGE SCENARIO PROJECTIONS

Climate change scenario projections were used to explore the level of impact that California's Central Valley Project (CVP) and State Water Project (SWP) operations can have on spring, fall and winter run Chinook under favorable and unfavorable climate forecasts. Model covariates were divided into three categories: overland covariates (river flows, river temperatures, air temperatures), nearshore ocean covariates (upwelling, PDO, wind stress curl, Farallon ocean temperatures), and anthropogenic water use covariates (exports, export/inflow ratios). Overland model covariates reflected two climate change scenarios: a warmer/drier scenario, and a cooler/wetter scenario. Nearshore ocean covariates explored two situations: favorable nearshore conditions for Chinook at ocean entry (increases in upwelling, PDO in negative phase, less warming of nearshore oceans), and unfavorable conditions (decreases in upwelling, PDO in positive phase, greater warming of nearshore oceans). Anthropogenic water use levels were modified with regard to exports to create four options: 1. future exports=mean historical exports; 2. future exports=mean historical exports +30%; 3. future exports=mean historical exports – 30%, and 4. future exports=0. A total of 16 climate change scenarios were generated using all combinations of overland covariates, nearshore ocean covariates and anthropogenic water use covariates (Table B.1).

METHODS

As the basis for our climate change scenarios, we used the United States Bureau of Reclamation's (USBR) Operations Criteria and Plan (OCAP) Study 9.2 and 9.5 (USBR 2008). OCAP Study 9.2 reflects a mean increase in temperature of 0.75° F (=0.42° C) and an increase of 12.5% in precipitation. OCAP Study 9.5 reflects a mean increase in temperature of 2.8° F (=1.56° C) and a decrease in precipitation of 12%. These temperature and precipitation changes represent a mean 30-year change between 1971-2000 and projected 2011-2040 levels. Study 9.2 and 9.5 are the extreme corners of a bounding box that captures the 10th and 90th percentiles for temperature increase and precipitation change that were predicted by 112 climate projections from a variety of climate models and greenhouse gas emission levels (USBR 2008). USBR used the following methodology to generate OCAP Study 9.2 and 9.5:

1. Plot temperature change (ΔT) vs. precipitation change (ΔP) over central California for each of 112 archived Downscaled CMIP3 Climate Projections (Downscaled CMIP3 Climate Projections Archive website).
2. Determine the 10th and 90th percentiles for predicted temperature and precipitation change.
3. Identify the levels of ΔT and ΔP associated with the 10th and 90th percentiles in the climate projections. The intersection of the 10th and 90th percentiles for ΔT with the 10th and 90th percentiles for ΔP form a bounding box with four corners.
4. Choose climate projections that most closely reflect the four corners of the bounding box. OCAP Study 9.2 reflects the mildest climate change conditions over central California (less warming/ wetter), while OCAP Study 9.5 reflects the most dramatic climate change conditions over central California (more warming/ drier).
5. Modify CalSim-II hydrology inputs and Sacramento River Water Quality Model (SRWQM) inputs based on temperature and precipitation values generated by the climate projections.

6. Run CalSim-II and SRWQM models using historical data that has been modified to reflect climate change, but is still run retrospectively.

We used CalSim-II and SRWQM outputs for OCAP Study 9.2 and 9.5 (USBR 2008 Appendix R zipped data), but projected the hindcast covariate values from 1946-2002 onto years 2007-2063 to obtain a forward projection, while retaining year-to-year variability in covariate values and the covariance structures present in the natural system. OCAP Study 9.2 and 9.5 provided two types of scenario outputs:

1. Streamflows and controlled discharges from dams and weirs: The CalSim-II model predicts mean monthly streamflows and discharges at various points throughout the Sacramento River system and the Delta, including the following covariates from the spring, fall and winter run Chinook models:
    a. **Keswick Dam discharge** (fall run): CalSim-II channel flows at C5 from OCAP Study 9.2 and 9.5 were used for years 1946-2002, averaged over January-March. Averaged values were then projected forward to become scenario values for 2007-2063 (Fig. B.1, Table B.2D).
    b. **Deer Creek discharge** (spring run): CalSim-II channel flows for Deer Creek were not available in OCAP Study 9.2 and 9.5. Instead, CalSim-II channel flows at C11305 (just past the confluence of Mill Creek, Deer Creek, Antelope Creek and discharge point D11305) from OCAP Study 9.2 and 9.5 were used for years 1946-2002, averaged over October-December. Deer Creek was separated from the other constituents of C11305 using the following methodology:
        i. CalSim-II channel flows at C11309 (Deer Creek), C11305 and D11305 were obtained from OCAP scenario NAA_Existing (no action alternative) for years 1946-2002, averaged over October-December. Deer Creek flow C11309 was divided by the sum of D11305 and C11305 to determine which proportion of Deer + Mill + Antelope Creek flows should be attributed to Deer Creek.
        ii. CalSim-II values C11305 + D11305 from OCAP Study 9.2 and 9.5 were multiplied by the vector of proportions for Deer Creek, one for each year (mean over all years=0.42, sd=0.05). These values were then projected forward to become scenario values for 2007-2063 (Fig. B.2, Table B.2D).
    c. **Exports / Inflow Ratio** (fall run): CalSim-II delta inflows (INFLOW-DELTA parameter) from OCAP Study 9.2 and 9.5 for 1946-2002, averaged over March-May, were used as the denominator in the Exports/Inflow ratio, while the four export scenarios (see *8. CVP and SWP Dayflow Exports*; and *8b. Mean Daily Exports March-May*, below) formed the numerator (Fig. B.3, Table B.2E).
    d. **Bend Bridge minimum monthly flow** (winter run): CalSim-II channel flows at C109 from OCAP Study 9.2 and 9.5 were used over years 1946-2002, selecting the minimum monthly flow between August-November. Minimum flow values were then projected forward to become scenario values for 2007-2063 (Fig. B.4, Table B.3A).
    e. **Freeport sediment concentration as a function of Freeport flow** (spring and fall run): Sediment concentrations at Freeport, averaged annually over February-April, were modelled as a linear function of Freeport flows (also averaged annually over February-April) from CalSim-II scenario

NAA_Existing at C169. The linear model equation, with intercept set to zero, is:

Freeport sediment conc. = CalSim-II flow at Freeport * 0.0022487

The R-squared value for the regression is 0.834 (Fig. B.5). Freeport flows from OCAP Study 9.2 and 9.5 for years 1946-2002, averaged over February-April, were then used in conjunction with the linear model to generate sediment concentrations. These were projected forward to years 2007-2063 (Fig. B.6, Table B.2D).

2. River temperatures: SRWQM generates mean monthly river temperatures at various nodes along major rivers in the Sacramento River system (USBR 2008 Appendix R zipped data)
   a. **Sacramento River temperature at Bend Bridge** (winter run): SRWQM outputs for OCAP Study 9.2 and 9.5 were extracted along the Sacramento River at Bend Bridge for 1946-2002. Model predictions were averaged for months July-September and projected onto years 2007-2063 (Fig. B.7, Table B.3B).

In addition to the OCAP Study 9.2 and 9.5 scenario outputs, we also used several other sources of data to generate scenario covariates:

3. Nearshore ocean upwelling estimates: Upwelling indices were obtained from NOAA’s Pacific Fisheries Environmental Laboratory (PFEL Upwelling website). We increased and decreased historic values (1946-2002) of upwelling by +10% and -20% to account for a range of changes to upwelling that might occur under climate change (N. Mantua pers. comm., 12/8/14). These altered historic values were then projected onto years 2007-2063.
   a. **Upwelling at 36° N, 122° W** (spring and winter run): NOAA upwelling index values at 36° N, 122° W (southwest of Monterey, CA) were averaged over April-June for years 1946-2002, and adjusted up or down before being projected onto 2007-2063 (Fig. B.8, Tables B.2B & B.3A).
4. Pacific Decadal Oscillation (PDO) index: PDO indices were obtained from the Joint Institute for the Study of the Atmosphere and Oceans (Mantua and Hare). Over the last century, the PDO has displayed a 20-30 year autocorrelation pattern (Mantua et al. 1997). To capture the future impact of positive (warm) and negative (cold) PDO cycles on Chinook populations, we used two ranges of historic PDO data and projected them forward to years 2007-2063: one was a sequence that began with a positive PDO phase before flipping to a negative PDO phase, while the other began with a negative PDO phase and then flipped to a positive PDO phase. Pacific Northwest and West coast salmon production is enhanced during the negative phase of the PDO, and tends to decline during positive phases of the PDO (Mantua et al. 1997, Hare et al. 1999).
   a. **PDO** (spring and fall run): PDO values between 1900 and 2013 were averaged annually over January-May, and two sequences with opposite patterns were selected for future scenarios (Fig. B.9). The sequence of years between 1922-1978 began with a positive PDO phase, flipping to a negative phase around 1947. The sequence of years between 1946-2002 began with a negative PDO phase, flipping to a positive phase around 1977 (Fig. B.10, Table B.2B).

5. Wind Stress Curl Index: Calculated values for NOAA wind stress curl index for upwelling at Northern Location (39° N, 125° W) were obtained from NOAA's Pacific Fisheries Environmental Laboratory (PFEL Derived Winds website).
    a. **Curl Index** (spring and fall run): Historic curl index values from 1946-2002 averaged over July-December were increased or decreased by 20% and plotted as forward projections for 2007-2063 (Fig. B.11). Curl trajectories from 1967-2063 suggested a long-term autocorrelation pattern (Fig. B.11). Because we did not have compelling reasons to believe that future curl values would follow the same pattern as historic values, we set the future scenario curl index equal to mean curl from 1967-2010 (standardized curl index = 0) (Table B.2B).
6. Farallon Islands ocean temperature: Water temperature data at the Farallon Islands (37° 41.8' N, 122° 59.9' W) were not available for all years between 1946 and 2002, so the methodology of projecting covariate values from 1946-2002 under climate change onto years 2007-2063 could not be used. Instead, we calculated the mean water temperature over February-April for 1967-2012, and increased it by 0.42° C (=0.75° F) to correspond with OCAP Study 9.2, and by 1.56° C (=2.8° F) to correspond with OCAP Study 9.5.
    a. **Farallon Islands ocean temperature** (winter run): Mean water temperature from February-April during years 1967-2012 was 11.8° C. This was increased to 12.3° C and 13.4° C to match with OCAP Study 9.2 and 9.5, respectively (Fig. B.12, Table B.3B).
7. Sacramento air temperatures: Sacramento air temperature projections for 2007-2063 were obtained from the Downscaled CMIP3 Climate Projections archive (Downscaled CMIP3 Climate Projections Archive website) for the same climate projections that were used to generate OCAP Study 9.2 and 9.5. Air temperatures were obtained for the modelled grid cell containing Sacramento's latitude/ longitude (38.5556° N, 121.4689° W). OCAP Study 9.2 was based on climate model mri cgcm2.3.2a with A2 emissions, simulation #5, and OCAP Study 9.5 was based on climate model ukmo hadcm3 with A2 emissions, simulation #1.
    a. **Sacramento air temperature - spring** (spring and fall run): Climate projections for the modelled cell over Sacramento were averaged annually over January-March and adjusted up by 4.55 °F to spatially downscale climate projections to match with historic Sacramento air temperature data. The adjustment factor was obtained for each climate projection by subtracting mean projected air temperature between 1960-2010 (averaged over January-March) from mean historical Sacramento air temperature over the same period. Resulting differences were averaged for the two scenarios to obtain an adjusting value of 4.55 °F (Fig. B.13, Table B.2A).
    b. **Sacramento air temperature - summer** (fall run): Climate projections for the modelled cell over Sacramento for July-September were adjusted up by 8.82° F to spatially downscale climate projections to match with historic Sacramento air temperature data. Methodology for obtaining the adjustment factor was the same as for spring Sacramento air temperatures (see above) (Fig. B.13, Table B.2A).
8. CVP and SWP Dayflow Exports: Dayflow data for exports from the Delta were obtained from California's Department of Water Resources (CA DWR Dayflow website). Average daily exports were calculated for 1967-2010 and modified to generate four future export scenarios: 1. future exports = mean historical exports; 2.

future exports = mean historical exports +30%; 3. future exports = mean historical exports – 30%; and 4. future exports = 0.

   a. **Mean daily exports February-April** (spring run): Dayflow exports were averaged annually over February-April for years 1967-2010 to form the historical export level, which was then modified for scenarios (Fig. B.14, Table B.2C).
   b. **Mean daily exports March-May, for Export/Inflow ratio** (fall run): Dayflow exports were averaged annually over March-May for years 1967-2010 to form the historical export level for the Export/Inflow ratio (see Fig. B.3 and Table B.2E for the Export/Inflow ratio).
   c. **Total daily exports December-June** (winter run): Dayflow exports were summed over all days between December and June, then averaged over 1967-2007 to form the mean historical export level, which was then modified for scenarios (Fig. B.15, Table B.3A).

9. Daily stream flows: Streamflow data are collected daily at select locations by USGS (USGS National Water Information System website). In order to generate future predictions for OCAP Study 9.2 and 9.5, the daily stream flow data had to be correlated to an appropriate CalSim-II output using linear models.
   a. **Number of days Sacramento River flow at Verona > 56,000 cfs** (winter run): A linear model was generated to relate CalSim-II monthly flows at Verona (C160 from OCAP scenario NAA_Existing) for 1967-2003 averaged over December-March, to the total number of days between December and March that Sacramento River flow at Verona exceeded 56,000 cfs (data from USGS National Water Information System website). The linear model is:

      # Days flow > 56,000 = -25.19 + CalSim-II flow at Verona * 0.001646

      with R-squared = 0.9285. This relationship was used in conjunction with CalSim-II flows at Verona (C160) for December 1946-March 2003, averaged over December-March, to generate future scenario values (projected onto 2007-2063) for number of days that Sacramento River flow at Verona exceeds 56,000 cfs (Fig. B.16, Table B.3B)

10. Water management operations: Discharges from dams, weirs and gates are managed in California to optimize diverse interests, including efforts to increase winter run Chinook populations.
    a. **Proportion of time Delta Cross Channel gate is open, December-March** (winter run): The current operations plan is to close the Delta Cross Channel (DCC) gate while winter run Chinook are out-migrating. As a result, future scenarios assume that the proportion of time that the DCC gate is open between December and March is zero (Table B.3B).

11. Parameters for which no future conditions could be generated:
    a. **Channel Depletion** (fall run): The net channel depletion is the quantity of water removed from the Delta channels to meet consumptive use, averaged over March-May. Since future population growth may be countered by water-saving technologies and measures, we set the future value of channel depletion equal to the mean value over 1967-2010 (or a standardized value of 0) (Table B.2A).
    b. **Smolt Size at Chipps Island** (spring run): For this parameter, we assumed that size of out-migrating smolt caught at Chipps Island will not change over

future years, so smolt size for the scenario projections was set equal to mean size over 1967-2010 (standardized value of 0) (Table B.2A).

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CITATIONS

California Department of Water Resources Dayflow Data. Accessed online Dec. 20, 2014. http://www.water.ca.gov/dayflow/output/Output.cfm

Downscaled CMIP3 Climate Projections Archive. Accessed online Dec. 15, 2014. http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Projections:%20Subset%20Request

Hare, S.R., Mantua, N.J., Francis, R.C. (1999). Inverse production regimes: Alaska and West Coast Salmon. *Fisheries* 24(1): 6-14.

Mantua, N., Hare, S.R., Zhang, Y., Wallace, J.M., Francis, R.C. (1997). A Pacific interdecadal climate oscillation with impacts on salmon production. *Bulletin of the American Meteorological Society* 78: 1069-1079.

Mantua, N. and Hare, S.R., PDO Index Monthly Values: January 1900-present. Joint Institute for the Study of the Atmosphere and Ocean (University of Washington). Accessed online Dec. 30, 2014. http://jisao.washington.edu/pdo/PDO.latest

Pacific Fisheries Environmental Laboratory (NOAA) Coastal Upwelling Indices. Accessed online Dec. 20, 2014. http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/upwelling/NA/upwell_menu_NA.html

Pacific Fisheries Environmental Laboratory (NOAA) Derived Winds and Ocean Transports. Accessed online Dec. 30, 2014. http://www.pfeg.noaa.gov/products/PFEL/modeled/indices/transports/transports.html

U.S. Bureau of Reclamation, 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region. Sacramento, California. Chapter 9 and Appendix R. http://www.usbr.gov/mp/cvo/OCAP/docs/OCAP_BA_2008.pdf

U.S. Bureau of Reclamation, 2008. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region. Sacramento, California. Appendix R, zipped data. Accessed online Dec. 15, 2014. http://www.usbr.gov/mp/cvo/ocap_page.html

FIGURES

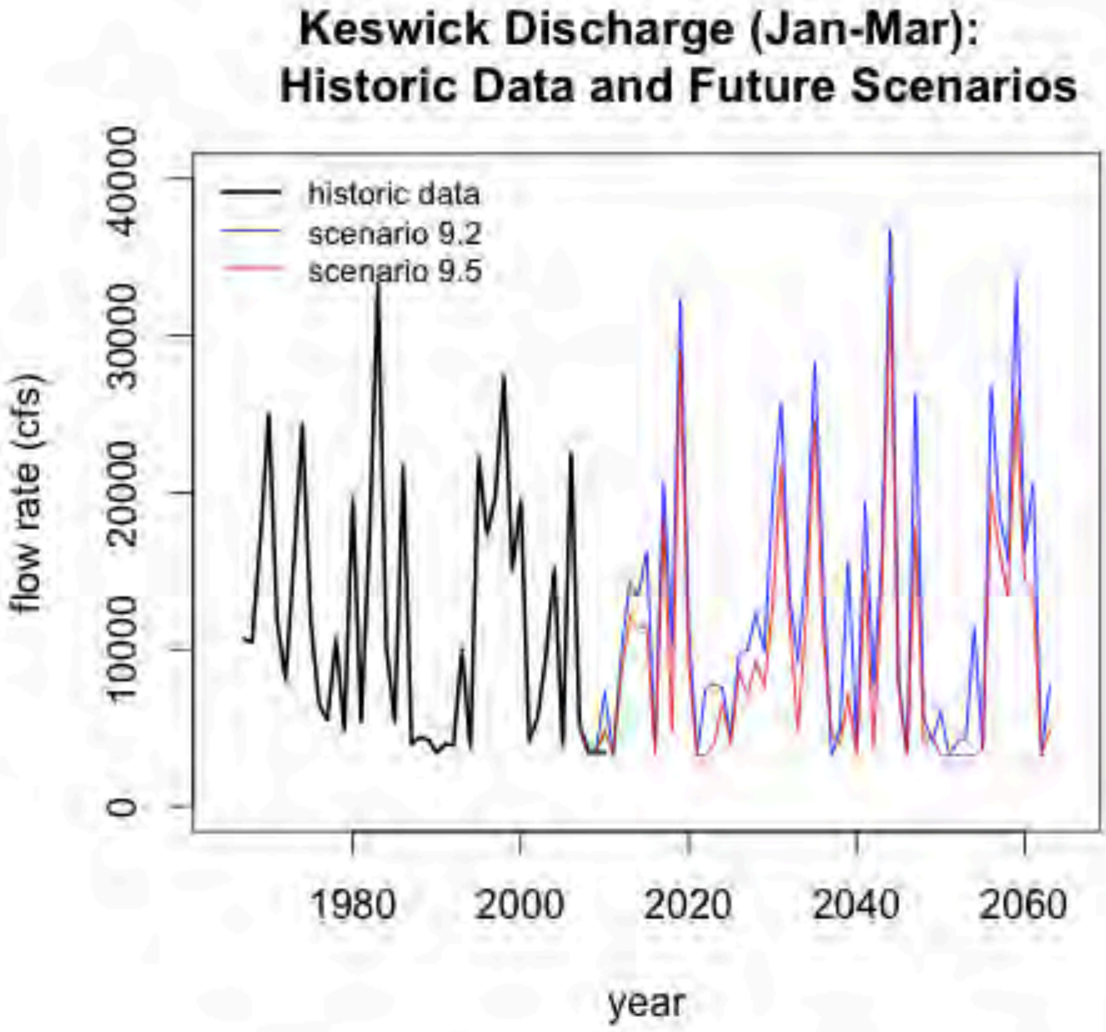

Figure B.1. Mean annual discharge (cubic feet per second, cfs) from Keswick Dam for January-March: historic data from 1967-2010 and climate change scenarios 9.2 and 9.5. Climate change scenarios were based on CalSim-II OCAP Study 9.2 and 9.5 values from 1946-2002, which were projected forward to 2007-2063.

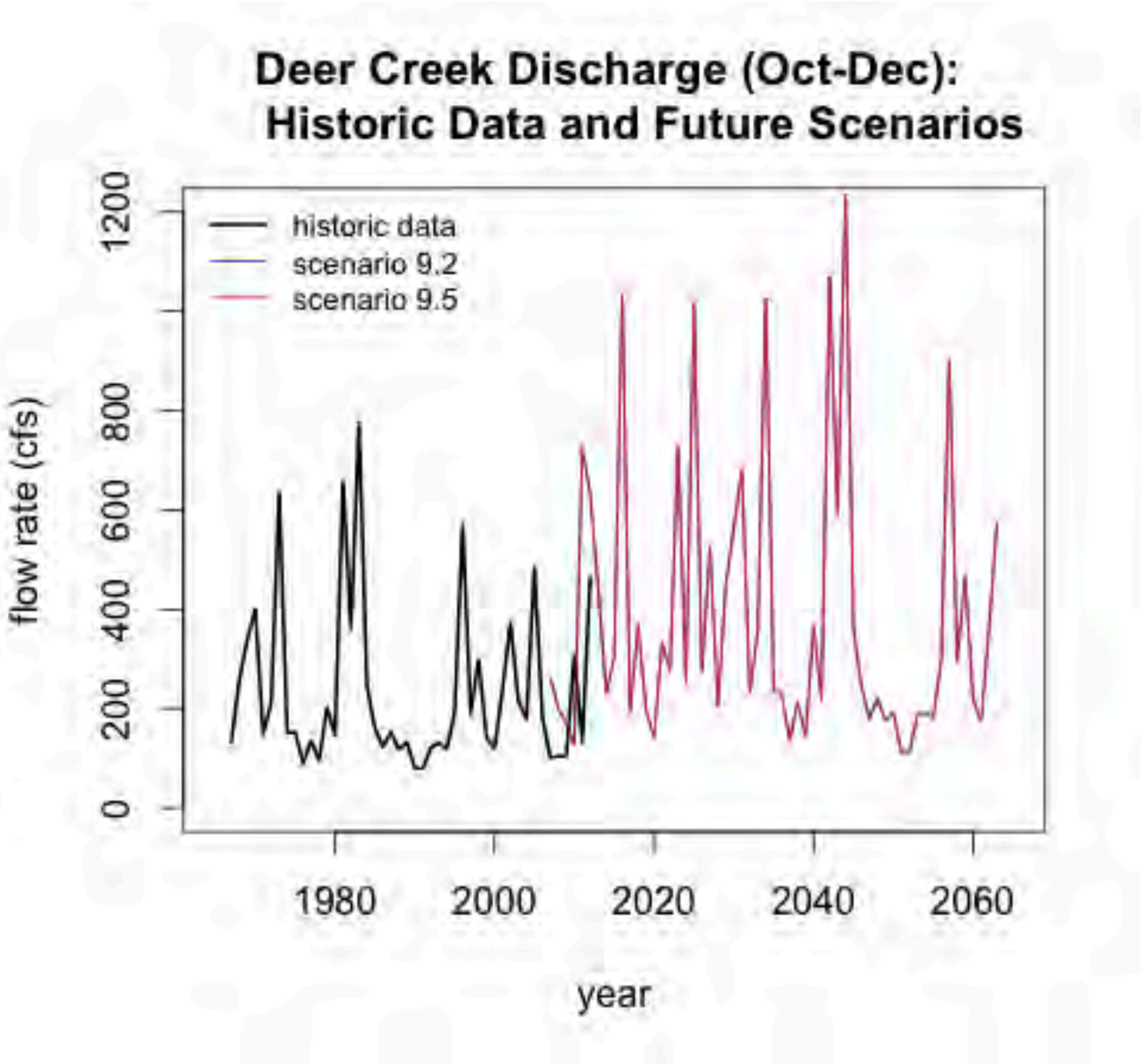

Figure B.2. Mean annual discharge (cfs) from Deer Creek for October-December: historic data from 1967-2012 and climate change scenarios 9.2 and 9.5. Climate change scenarios were based on CalSim-II OCAP Study 9.2 and 9.5 values from 1946-2002, which were projected forward to 2007-2063. Note that there is no difference in projection values between scenarios 9.2 and 9.5.

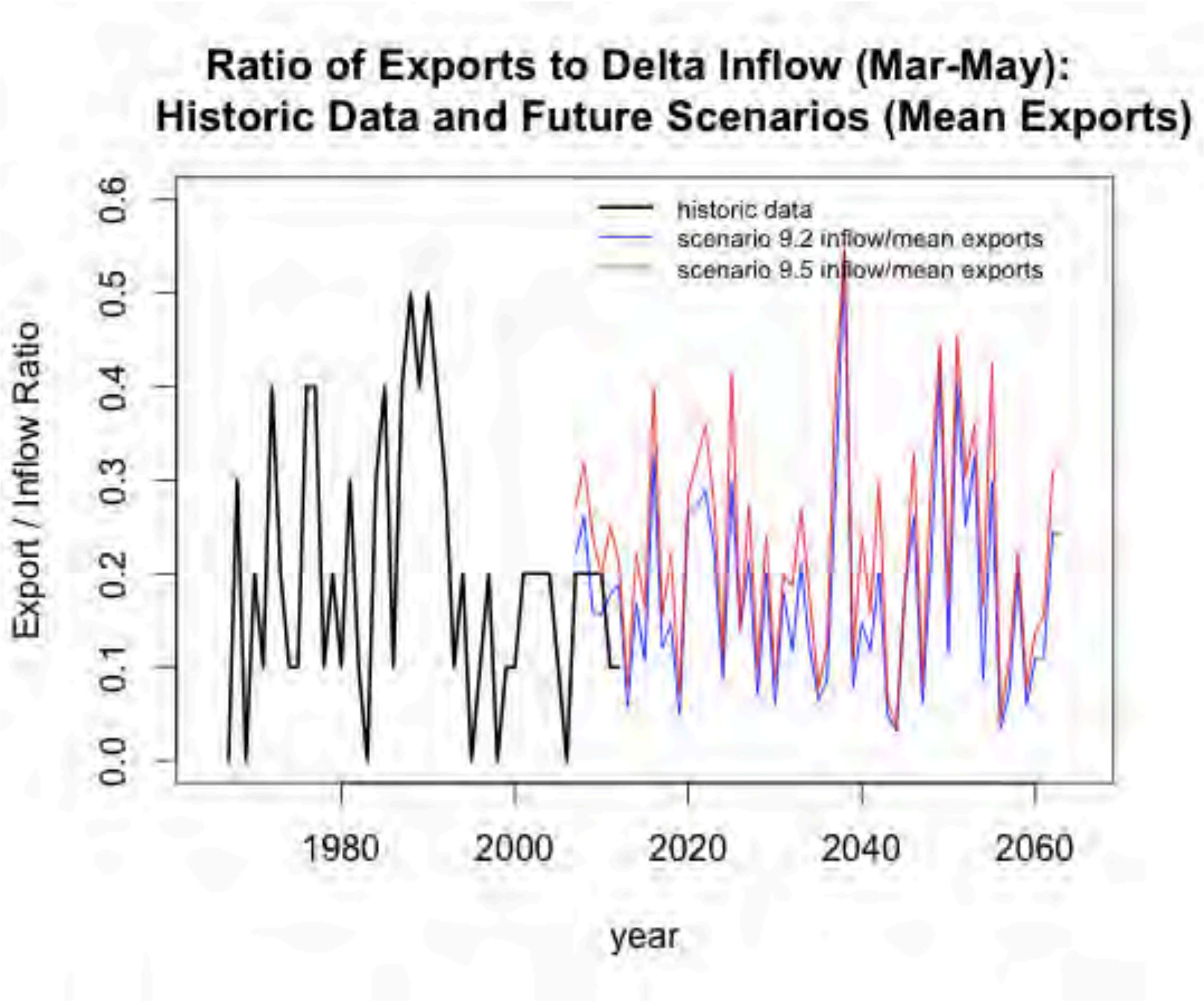

Figure B.3. Exports to inflow ratio for the Delta, averaged over March-May: historic data from 1967-2012 and climate change scenarios 9.2 and 9.5. Historic values are based on Dayflow data ((QCVP + QSWP – BBID)/ QTOT). Climate change scenarios use mean exports from 1967-2010 for the numerator, and CalSim-II Delta inflow values from OCAP Study 9.2 and 9.5 for the denominator. The CalSim-II Delta inflow values were from years 1946-2002, projected forward to 2007-2063.

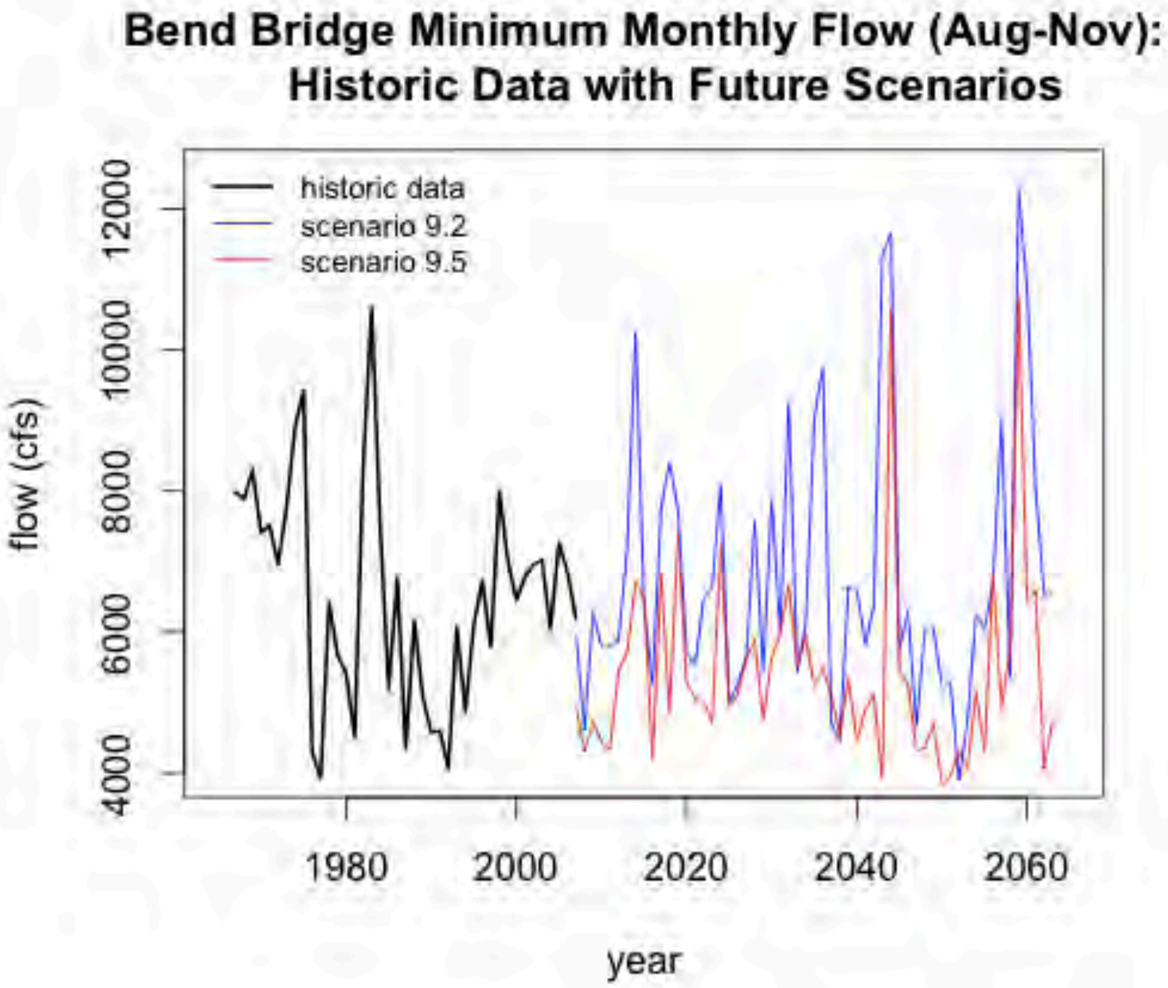

Figure B.4. Minimum monthly flow (cfs) at Bend Bridge for August-November: historic data from 1967-2007 and climate change scenarios 9.2 and 9.5. Climate change scenarios were based on CalSim-II OCAP Study 9.2 and 9.5 values from 1946-2002, which were projected forward to 2007-2063.

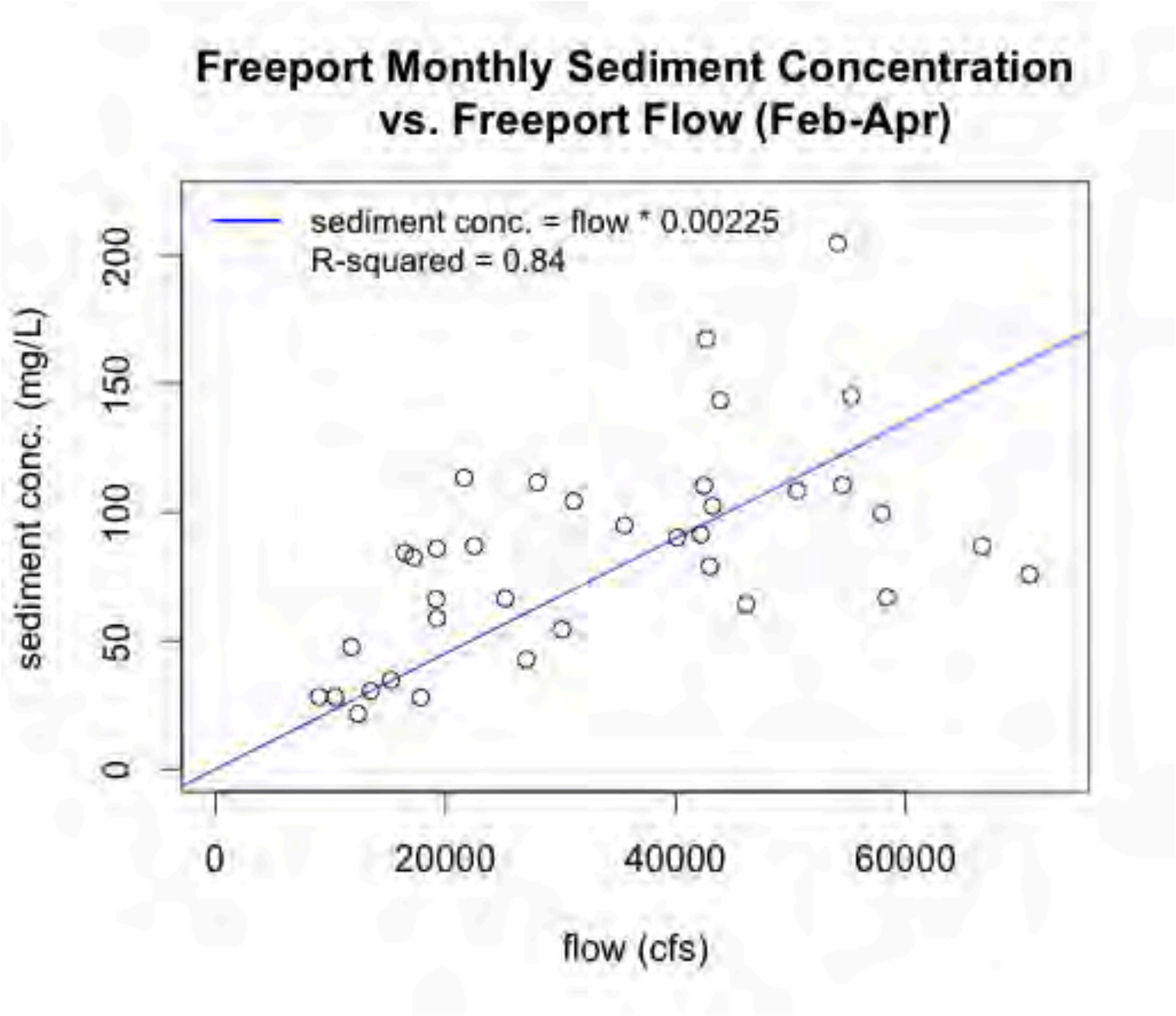

Figure B.5. Average monthly sediment concentration (mg/L) at Freeport for years 1967-2002, as a function of modelled Freeport flows (cfs) from CalSim-II OCAP scenario NAA_Existing at node C169. Each point represents one year of data, averaged over months February-April. A linear model was fit to the points, with a specified intercept of 0 (blue line):

Freeport sediment concentration = Freeport flow * 0.0022487

The adjusted R-squared for the linear model is 0.84.

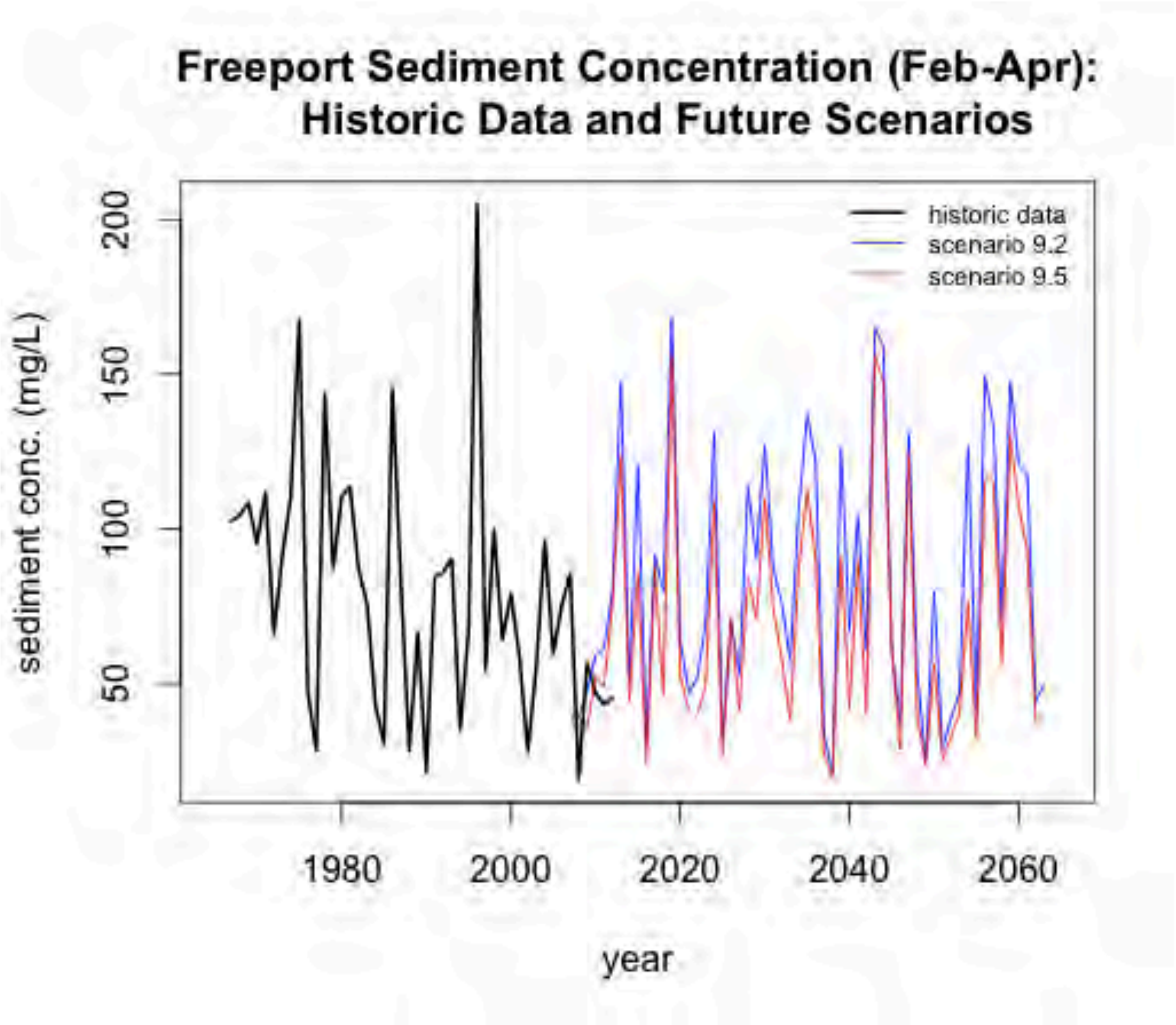

Figure B.6. Freeport sediment concentrations (mg/L) averaged over February-April: historic data from 1967-2012 and climate change scenarios 9.2 and 9.5. Climate change scenario values were obtained using Freeport flow predictions (at C169) from CalSim-II OCAP Study 9.2 and 9.5 for 1946-2002, and multiplying these values by 0.0022487 to correlate them to sediment concentrations (see Fig. B.5). The 1946-2002 climate change scenario sediment predictions were then projected forward to 2007-2063.

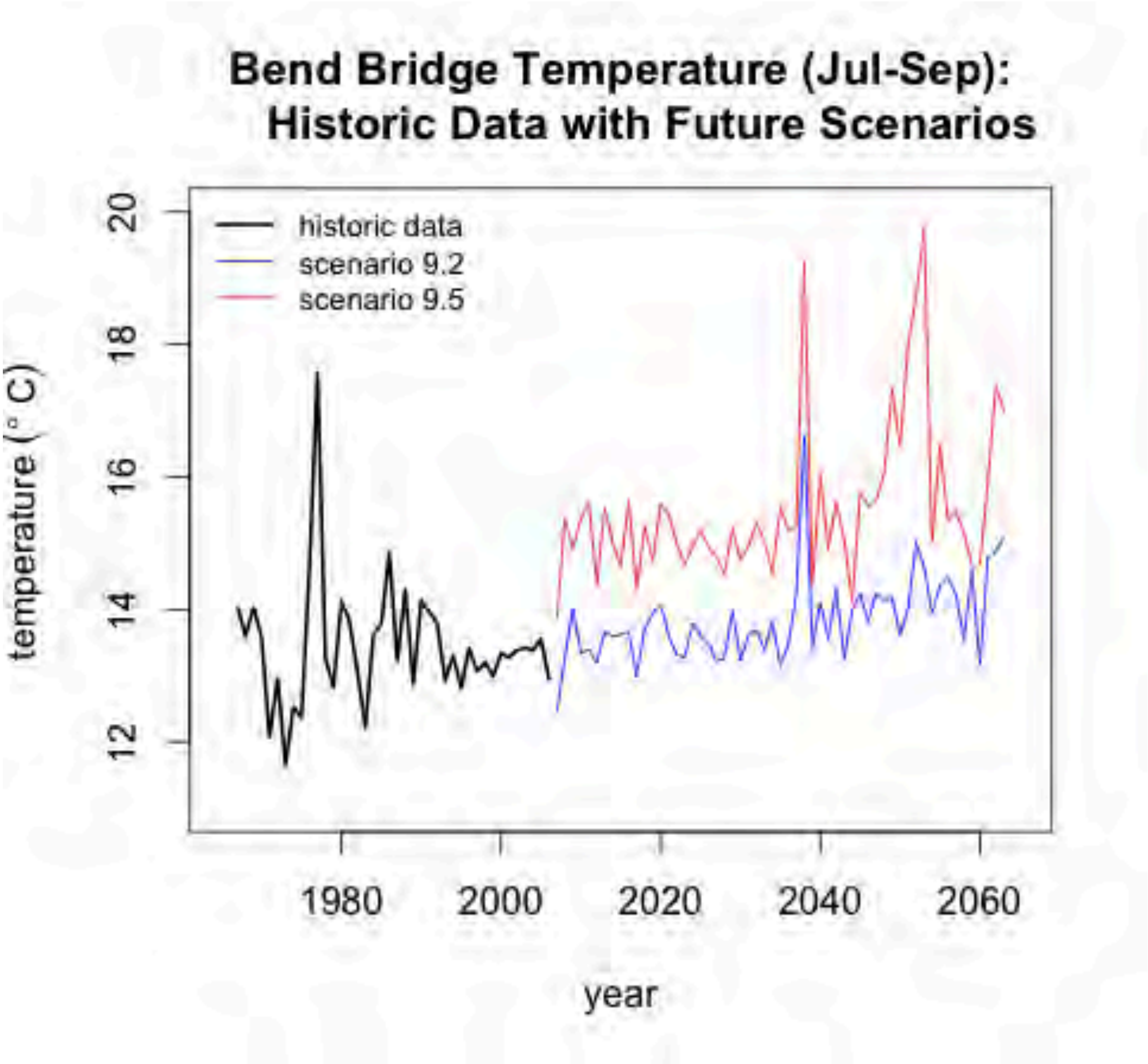

Figure B.7. Sacramento River average water temperature (° C) at Bend Bridge, averaged over July-September: historic data from 1967-2006 and climate change scenarios 9.2 and 9.5. Climate change scenarios were based on the SRWQM OCAP Study 9.2 and 9.5 values from 1946-2002, which were projected forward to 2007-2063.

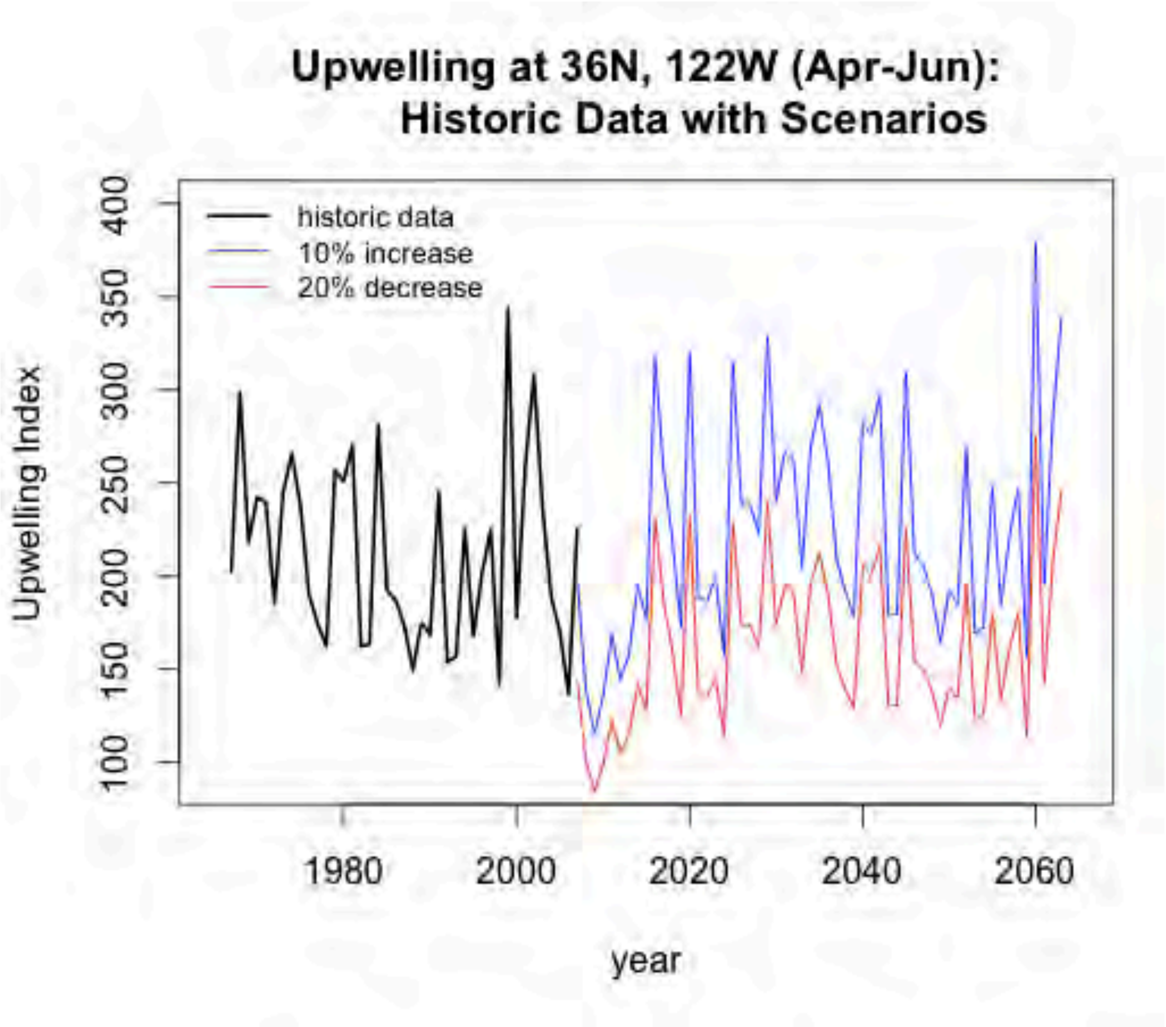

Figure B.8. NOAA upwelling index at station 36° N, 122°W averaged over April-June: historic data from 1967-2007 and two climate change scenarios. Climate change scenarios were based on historic upwelling values from 1946-2002, which were adjusted up (+20%) or down (-10%) and projected forward to 2007-2063.

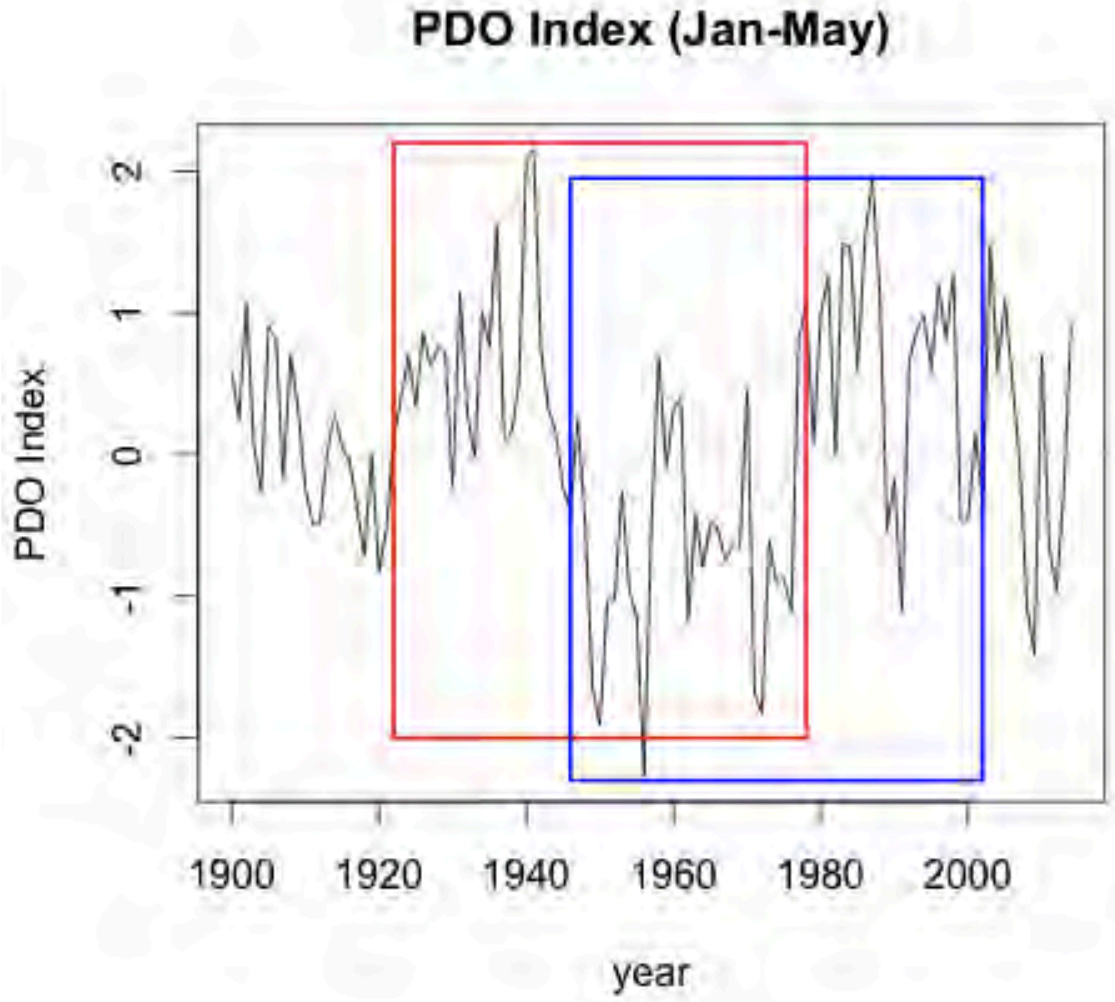

Figure B.9. Historic values of the PDO index, averaged annually over January-May. West coast salmon stocks have higher productivity during negative (cool) phases of the PDO, and lower productivity during positive (warm) phases. The sequence of years from 1922-1978 (red box) was projected forward to 2007-2063 to represent a scenario where the PDO begins in a positive cycle, while the sequence of years from 1946-2002 (blue box) was projected forward to represent a scenario where the PDO begins in a negative cycle.

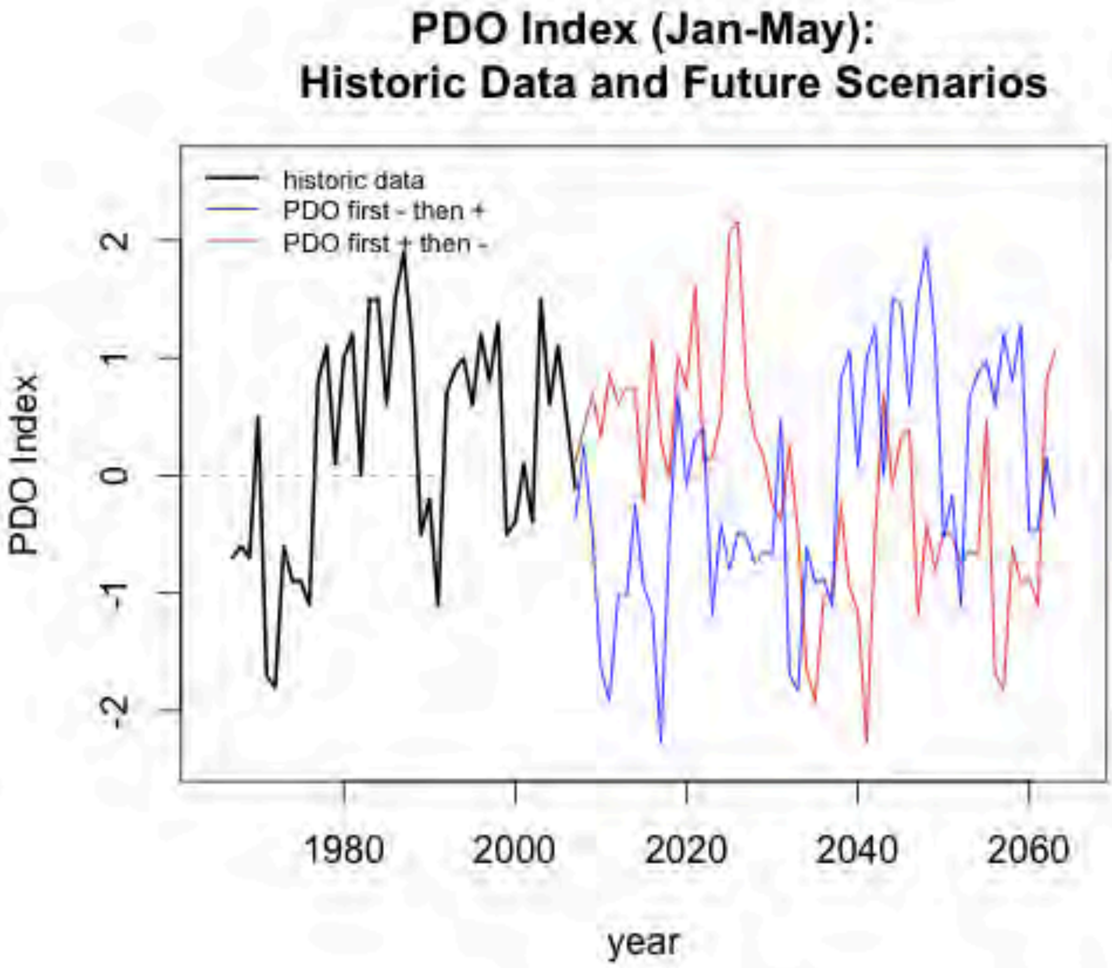

Figure B.10. PDO index averaged annually over January-May: historic data from 1967-2007 and two future scenarios. Future scenarios were projected onto 2007-2063 and consist of: 1.) a historic sequence that begins with a negative PDO index, then flips to a positive PDO index halfway through the time series (blue line: historic values from 1922-1978); and 2.) a historic sequence that begins with a positive PDO index, then flips to a negative PDO index (red line: historic values from 1946-2002).

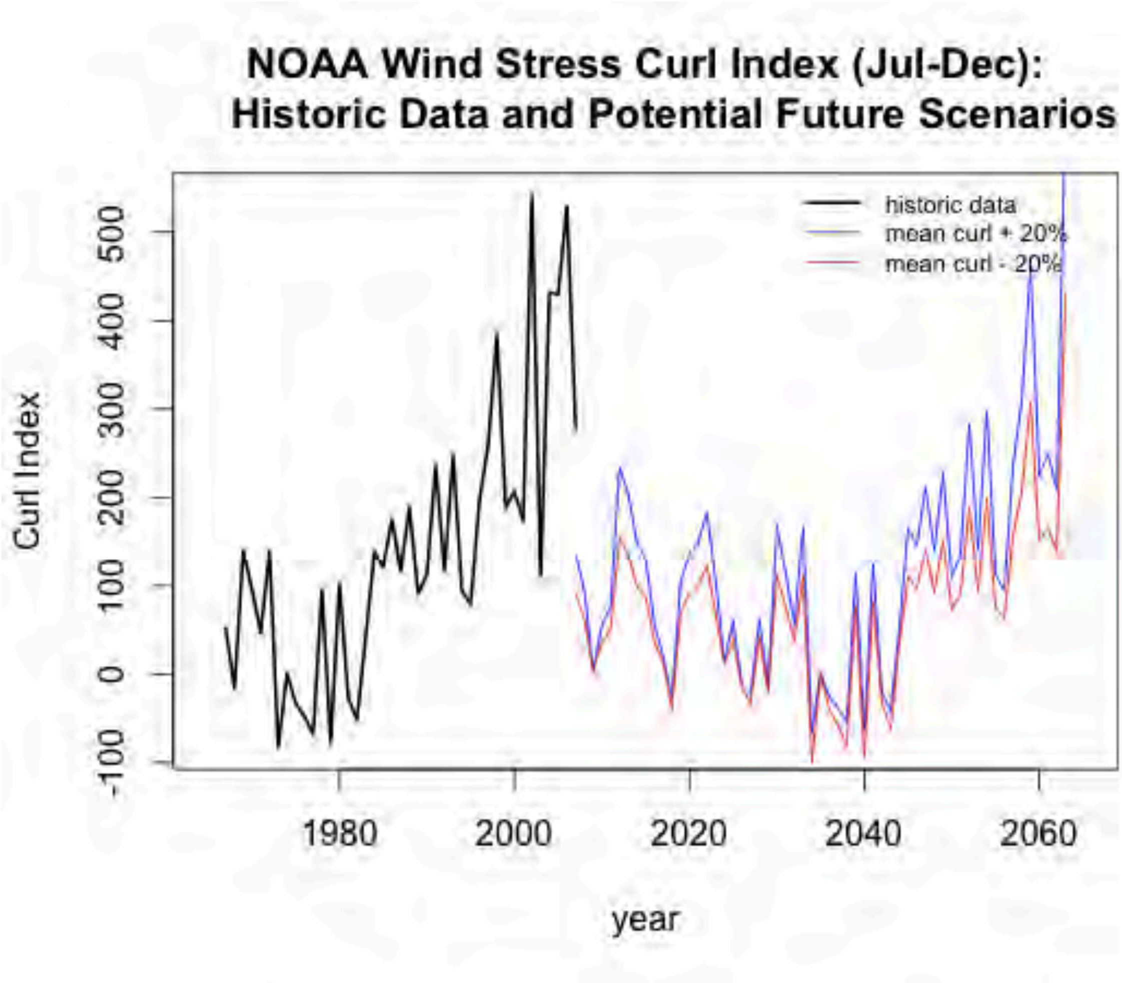

Figure B.11. NOAA wind stress curl index averaged over July-December: historic data for 1967-2007 and potential scenario values. Potential scenario values were generated by increasing (+20%) or decreasing (-20%) curl data from 1946-2002 according to the equations below, then projecting the values onto 2007-2063:

Curl + 20% = historic curl + abs value(historic curl) * 0.2

Curl – 20% = historic curl – abs value(historic curl) * 0.2

Curl index trajectories from 1967-2063 suggest a long-term autocorrelation pattern. Because we did not have compelling reasons to believe that future curl values would follow the same pattern as historic values, we set the standardized curl projections for future scenarios to 0.

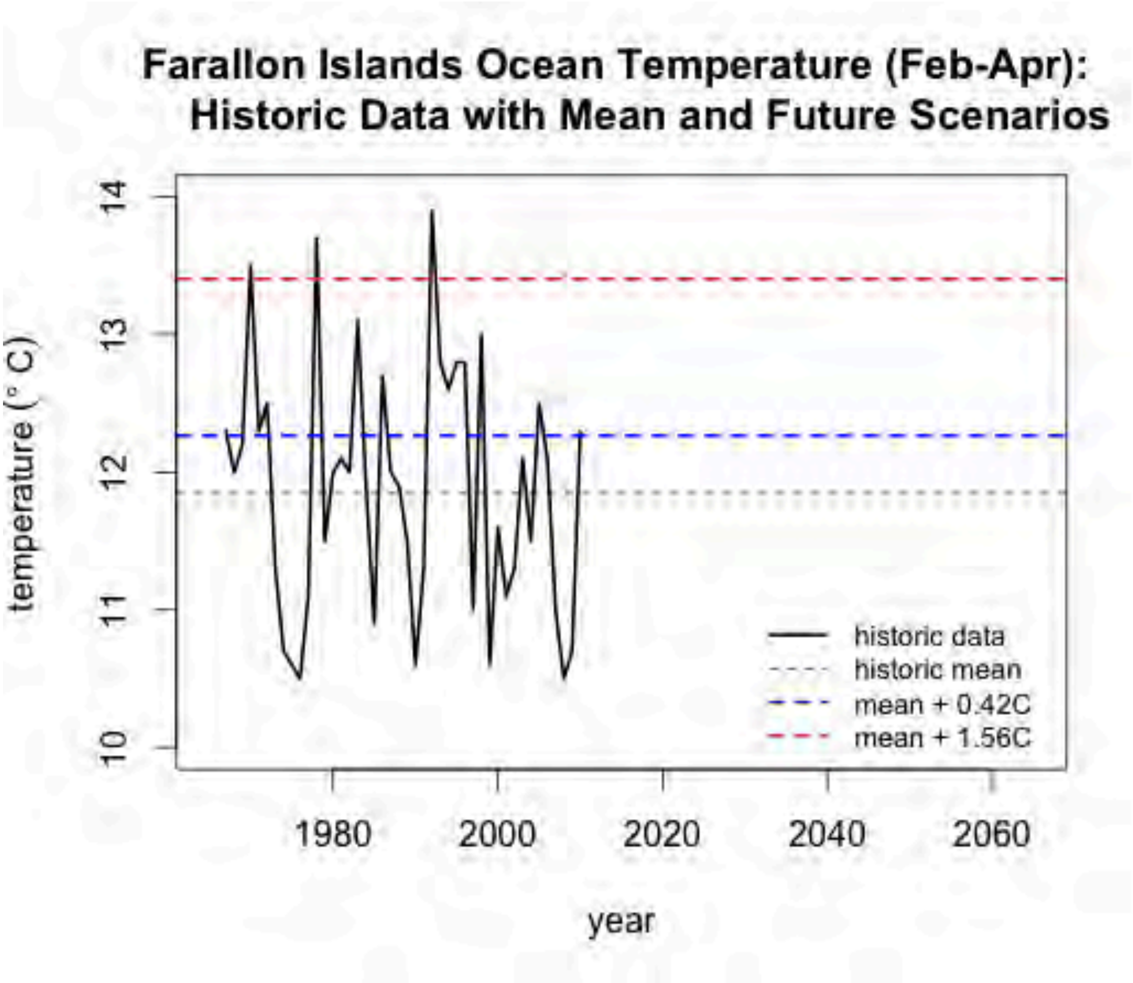

Figure B.12. Ocean temperature at the Farallon Islands averaged over February-April: historic data with mean for 1967-2010, and two climate projections: mean +0.42° C (=0.75° F, the average temperature increase for OCAP Study 9.2), and mean +1.56° C (=2.8° F, the average temperature increase for OCAP Study 9.5).

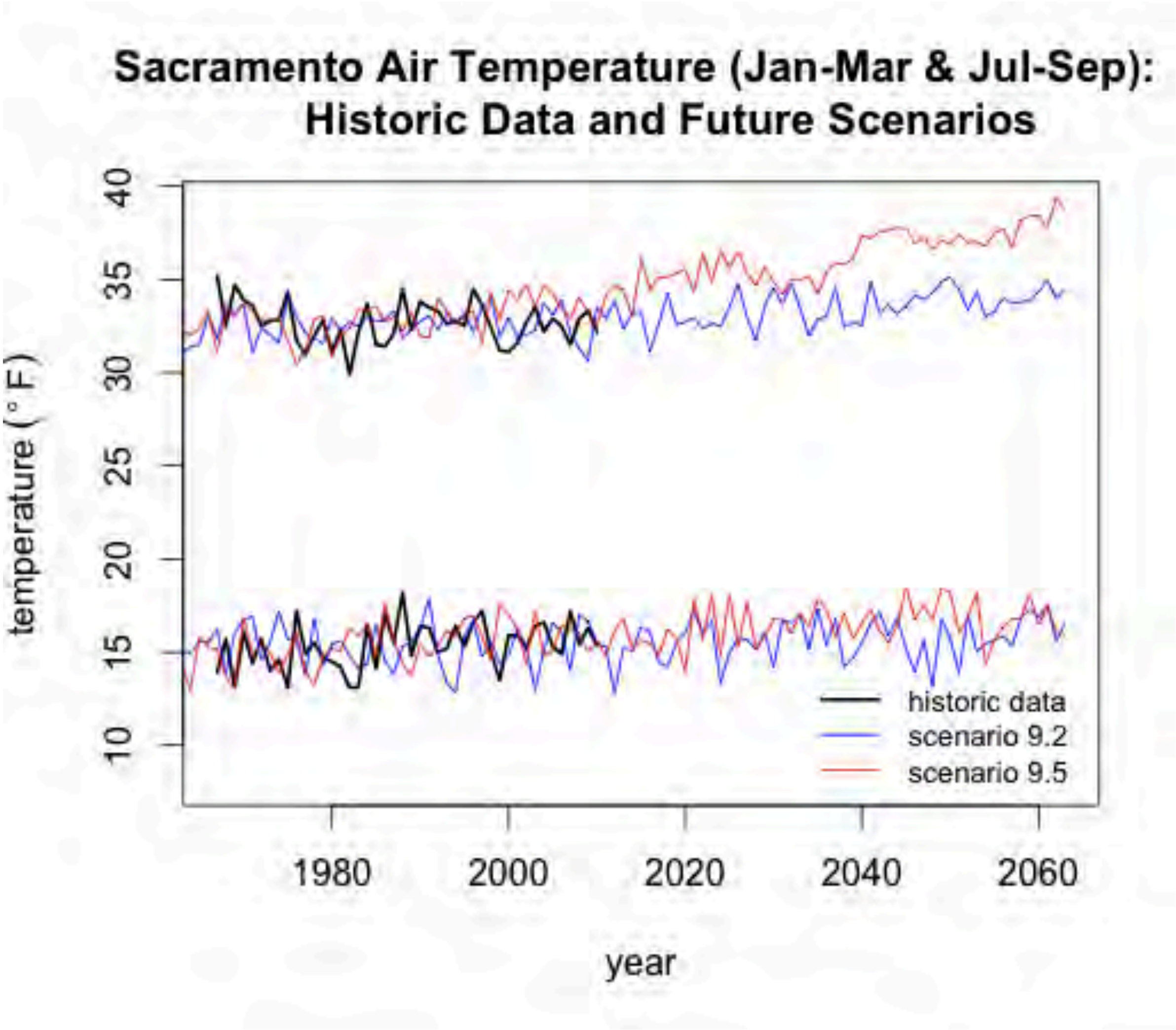

Figure B.13. Sacramento air temperature averaged over spring months (January-March, bottom lines) and summer months (July-September, top lines): historic data for 1967-2010, and future climate change predictions based on CMIP3 climate projections. CMIP3 air temperature predictions for the model cell over Sacramento were adjusted by + 4.55° F for the spring, and + 8.82° F for the summer, to spatially downscale climate projections from 1967-2010 to match the range of historic Sacramento air temperature data.

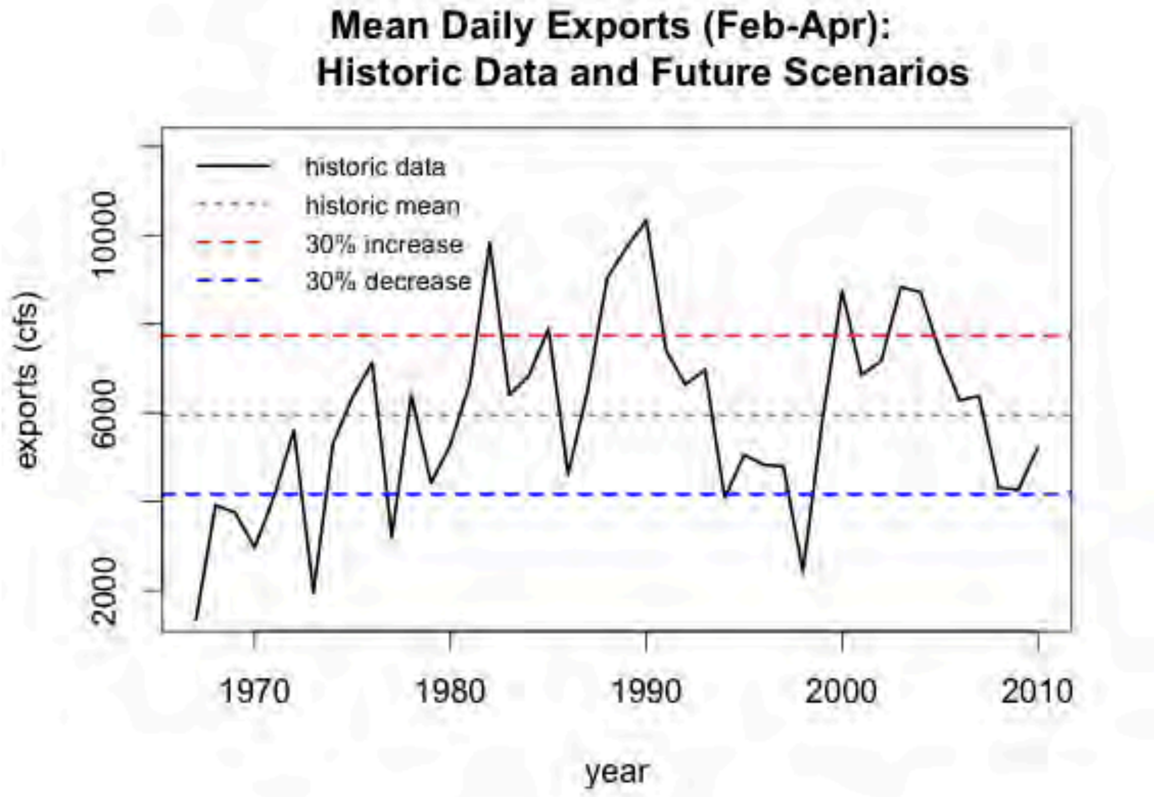

Figure B.14. Mean daily exports (cfs) averaged annually from February-April: historic data and future scenarios. Scenarios represent the following options: mean exports (1967-2010), zero exports, mean exports + 30%, mean exports - 30%.

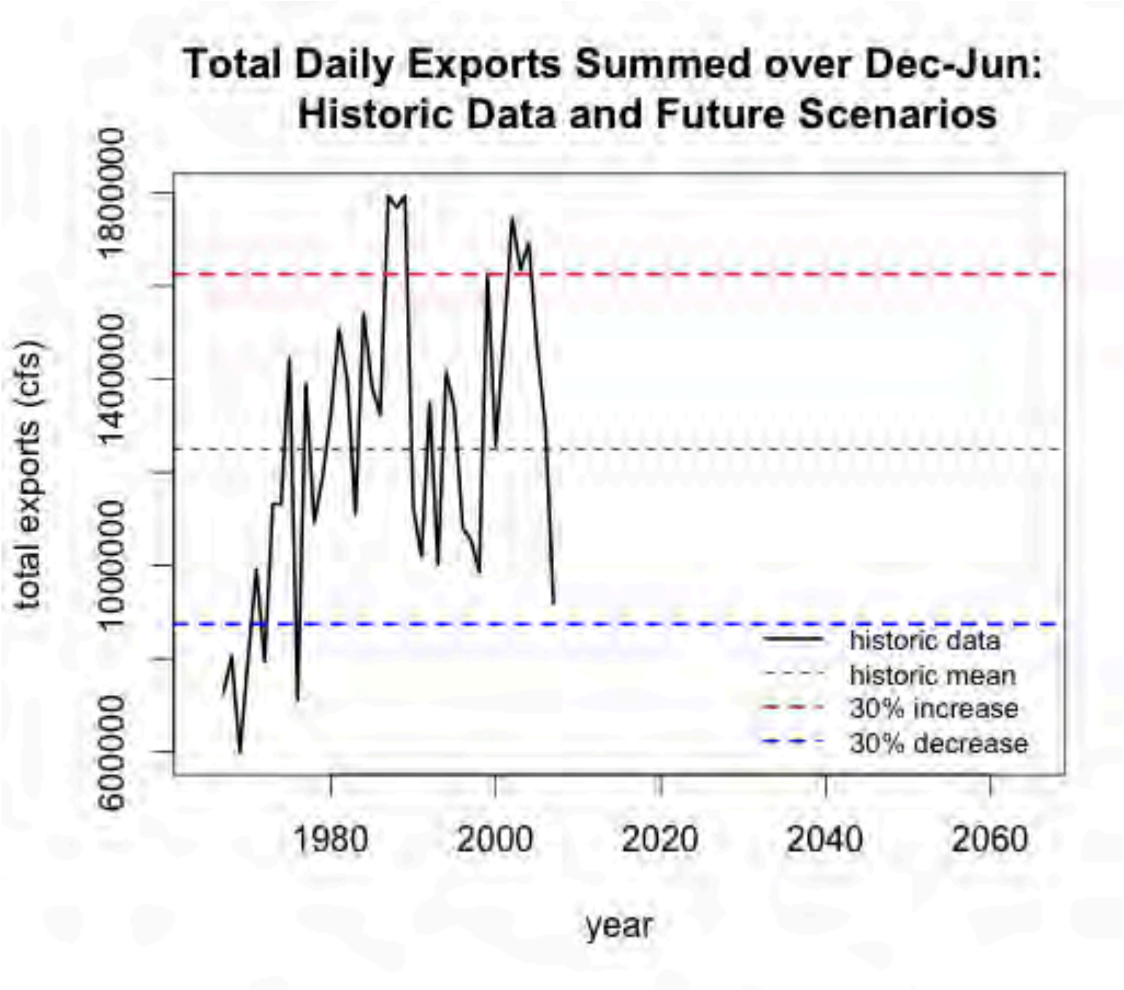

Figure B.15. Total daily exports summed over December-June: historic data and future scenarios. Scenarios represent the following options: mean total exports (1967-2010), zero exports, mean total exports + 30%, mean total exports - 30%.

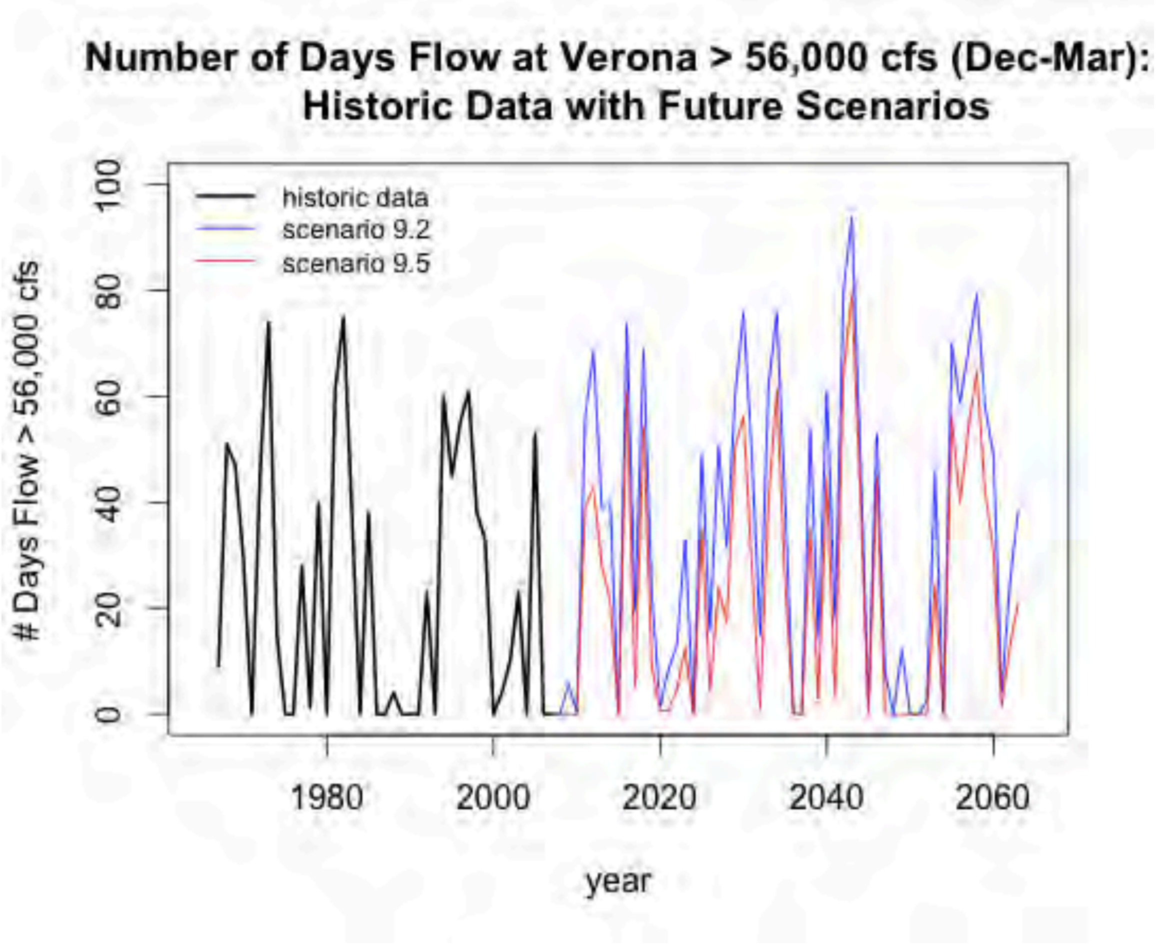

Figure B.16. Total number of days from December-March that Sacramento River flow at Verona exceeds 56,000 cfs: historic data from 1967-2007 and climate change scenarios 9.2 and 9.5. Climate change scenario values were obtained using Verona flow predictions (at C160) from CalSim-II OCAP Study 9.2 and 9.5 for 1946-2002 averaged over December-March, and adjusting these values per the linear model:

$$\#\text{ Days flow} > 56{,}000 = -25.19 + \text{CalSim-II flow at Verona} * 0.001646$$

to correlate them to the number of days that flow exceeds 56,000 cfs. The 1946-2002 climate change scenario predictions were then projected forward to 2007-2063.

TABLES

Table B.1. Scenario list with values drawn for each category of covariate.

	OCAP Study	Upwelling	Farallon Temp	PDO Index	Exports
Scenario 1	9.2	+ 10%	+ 0.42° C	- then +	Mean Level
Scenario 2	9.2	- 20%	+ 1.56° C	+ then -	Mean Level
Scenario 3	9.2	+ 10%	+ 0.42° C	- then +	Zero
Scenario 4	9.2	- 20%	+ 1.56° C	+ then -	Zero
Scenario 5	9.2	+ 10%	+ 0.42° C	- then +	Mean + 30%
Scenario 6	9.2	- 20%	+ 1.56° C	+ then -	Mean + 30%
Scenario 7	9.2	+ 10%	+ 0.42° C	- then +	Mean - 30%
Scenario 8	9.2	- 20%	+ 1.56° C	+ then -	Mean - 30%
Scenario 9	9.5	+ 10%	+ 0.42° C	- then +	Mean Level
Scenario 10	9.5	- 20%	+ 1.56° C	+ then -	Mean Level
Scenario 11	9.5	+ 10%	+ 0.42° C	- then +	Zero
Scenario 12	9.5	- 20%	+ 1.56° C	+ then -	Zero
Scenario 13	9.5	+ 10%	+ 0.42° C	- then +	Mean + 30%
Scenario 14	9.5	- 20%	+ 1.56° C	+ then -	Mean + 30%
Scenario 15	9.5	+ 10%	+ 0.42° C	- then +	Mean - 30%
Scenario 16	9.5	- 20%	+ 1.56° C	+ then -	Mean - 30%

Table B.2A. Fall and spring covariate values for Sacramento air temperature, channel depletion and smolt size at Chipps Island.

	Sacramento Air Temp (°F, Jan-Mar)		Sacramento Air Temp (°F, Jul-Sep)		Channel Depletion (cfs, Mar-May)	Size at Chipps Island (mm, Jan)
Year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	Mean	Mean
2007	14.0	16.3	32.1	32.9	521	94.1
2008	17.1	16.0	31.3	34.1	521	94.1
2009	16.7	15.0	30.6	33.2	521	94.1
2010	15.5	15.6	33.5	32.5	521	94.1
2011	15.3	14.8	32.9	34.1	521	94.1
2012	12.8	16.1	33.9	34.7	521	94.1
2013	15.3	16.8	32.3	34.4	521	94.1
2014	15.0	15.2	33.2	33.0	521	94.1
2015	16.4	15.6	33.2	36.1	521	94.1
2016	16.1	15.5	31.1	34.5	521	94.1
2017	14.5	14.8	32.6	35.1	521	94.1
2018	14.2	16.2	34.3	35.1	521	94.1
2019	15.5	15.7	32.6	35.3	521	94.1
2020	16.0	13.9	32.7	35.6	521	94.1
2021	17.3	17.8	32.9	34.3	521	94.1
2022	16.0	15.7	32.4	36.4	521	94.1
2023	16.7	18.1	32.7	34.9	521	94.1
2024	13.3	14.8	32.5	36.5	521	94.1
2025	15.0	18.1	33.5	35.6	521	94.1
2026	15.8	15.3	34.8	36.5	521	94.1
2027	15.7	17.7	32.9	35.3	521	94.1
2028	15.2	15.2	31.7	34.7	521	94.1
2029	16.1	15.8	33.6	35.6	521	94.1
2030	14.2	16.8	34.5	34.9	521	94.1
2031	16.7	16.8	33.7	34.2	521	94.1
2032	16.6	16.0	34.8	35.0	521	94.1
2033	17.0	17.0	33.5	35.0	521	94.1
2034	15.1	16.4	32.0	35.2	521	94.1
2035	17.3	17.8	32.9	34.2	521	94.1
2036	15.4	17.3	33.0	35.3	521	94.1
2037	16.8	15.8	34.6	35.9	521	94.1
2038	14.2	17.1	32.4	35.8	521	94.1
2039	14.7	15.7	32.8	36.1	521	94.1
2040	15.5	16.5	32.5	37.3	521	94.1

Table B.2A (continued). Fall and spring covariate values for Sacramento air temperature, channel depletion and smolt size at Chipps Island.

	Sacramento Air Temp (°F, Jan-Mar)		Sacramento Air Temp (°F, Jul-Sep)		Channel Depletion (cfs, Mar-May)	Size at Chipps Island (mm, Jan)
Year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	Mean	Mean
2041	16.5	17.3	34.9	37.2	521	94.1
2042	17.1	16.1	33.2	37.6	521	94.1
2043	15.9	15.5	33.6	37.6	521	94.1
2044	16.9	16.4	33.2	37.8	521	94.1
2045	15.2	18.5	33.5	37.7	521	94.1
2046	13.9	16.8	34.2	36.9	521	94.1
2047	15.7	17.5	33.9	37.3	521	94.1
2048	13.2	16.7	34.3	36.6	521	94.1
2049	16.8	18.4	34.9	37.1	521	94.1
2050	15.7	18.2	35.1	36.9	521	94.1
2051	13.8	16.0	34.5	37.4	521	94.1
2052	17.0	16.9	33.4	37.0	521	94.1
2053	15.0	18.2	34.3	37.0	521	94.1
2054	15.4	14.3	33.0	36.8	521	94.1
2055	15.6	15.7	33.3	37.5	521	94.1
2056	15.9	16.4	34.0	37.7	521	94.1
2057	15.3	16.8	33.7	36.7	521	94.1
2058	16.8	16.8	33.8	38.2	521	94.1
2059	17.3	18.1	33.9	38.4	521	94.1
2060	16.9	16.5	34.3	38.4	521	94.1
2061	17.5	17.4	35.0	37.8	521	94.1
2062	15.6	16.1	34.0	39.4	521	94.1
2063	16.6	16.0	34.4	38.7	521	94.1

Table B.2B. Fall and spring covariate values for upwelling index, wind stress curl and PDO index.

	Upwelling Index (36N, 122W, Apr-Jun)		NOAA Wind Stress Curl Index (39N, 125W, Jul-Dec)	PDO Index (Jan-May)	
Year	Up 10%	Down 20%	Mean	+ then -	- then +
2007	199	145	151	0.10	-0.38
2008	139	101	151	0.40	0.24
2009	116	84	151	0.70	-0.49
2010	136	99	151	0.33	-1.64
2011	169	123	151	0.86	-1.92
2012	144	105	151	0.61	-1.02
2013	158	115	151	0.75	-1.03
2014	195	142	151	0.72	-0.26
2015	177	129	151	-0.23	-0.95
2016	318	231	151	1.14	-1.15
2017	256	186	151	0.29	-2.27
2018	220	160	151	-0.02	-0.50
2019	173	126	151	1.01	0.69
2020	320	233	151	0.76	-0.10
2021	189	138	151	1.61	0.32
2022	186	135	151	0.12	0.40
2023	200	145	151	0.16	-1.18
2024	157	114	151	0.49	-0.42
2025	314	229	151	2.07	-0.80
2026	239	174	151	2.15	-0.48
2027	239	174	151	0.74	-0.52
2028	223	162	151	0.32	-0.74
2029	329	239	151	0.16	-0.64
2030	240	174	151	-0.24	-0.67
2031	267	194	151	-0.38	0.46
2032	263	191	151	0.24	-1.69
2033	205	149	151	-0.49	-1.83
2034	270	196	151	-1.64	-0.60
2035	292	213	151	-1.92	-0.91
2036	262	190	151	-1.02	-0.88
2037	209	152	151	-1.03	-1.10
2038	192	139	151	-0.26	0.82
2039	179	130	151	-0.95	1.06
2040	282	205	151	-1.15	0.07

Table B.2B (continued). Fall and spring covariate values for upwelling index, wind stress curl and PDO index.

	Upwelling Index (36N, 122W, Apr-Jun)		NOAA Wind Stress Curl Index (39N, 125W, Jul-Dec)	PDO Index (Jan-May)	
Year	Up 10%	Down 20%	Mean	+ then -	- then +
2041	276	201	151	-2.27	1.00
2042	297	216	151	-0.50	1.25
2043	179	130	151	0.69	-0.01
2044	180	131	151	-0.10	1.50
2045	309	225	151	0.32	1.46
2046	212	154	151	0.40	0.59
2047	206	150	151	-1.18	1.52
2048	191	139	151	-0.42	1.95
2049	165	120	151	-0.80	1.15
2050	193	140	151	-0.48	-0.53
2051	186	135	151	-0.52	-0.17
2052	270	196	151	-0.74	-1.09
2053	169	123	151	-0.64	0.66
2054	173	126	151	-0.67	0.87
2055	248	180	151	0.46	0.98
2056	185	134	151	-1.69	0.60
2057	222	161	151	-1.83	1.20
2058	248	180	151	-0.60	0.81
2059	157	114	151	-0.91	1.27
2060	378	275	151	-0.88	-0.48
2061	195	142	151	-1.10	-0.45
2062	285	207	151	0.82	0.15
2063	339	246	151	1.06	-0.35

Table B.2C. Fall and spring covariate values for mean daily exports.

	Mean Daily Exports (cfs, Feb-Apr)			
Year	Mean	None	Up 30%	Down 30%
2007	5954	0	7740	4168
2008	5954	0	7740	4168
2009	5954	0	7740	4168
2010	5954	0	7740	4168
2011	5954	0	7740	4168
2012	5954	0	7740	4168
2013	5954	0	7740	4168
2014	5954	0	7740	4168
2015	5954	0	7740	4168
2016	5954	0	7740	4168
2017	5954	0	7740	4168
2018	5954	0	7740	4168
2019	5954	0	7740	4168
2020	5954	0	7740	4168
2021	5954	0	7740	4168
2022	5954	0	7740	4168
2023	5954	0	7740	4168
2024	5954	0	7740	4168
2025	5954	0	7740	4168
2026	5954	0	7740	4168
2027	5954	0	7740	4168
2028	5954	0	7740	4168
2029	5954	0	7740	4168
2030	5954	0	7740	4168
2031	5954	0	7740	4168
2032	5954	0	7740	4168
2033	5954	0	7740	4168
2034	5954	0	7740	4168
2035	5954	0	7740	4168
2036	5954	0	7740	4168
2037	5954	0	7740	4168
2038	5954	0	7740	4168
2039	5954	0	7740	4168
2040	5954	0	7740	4168

Table B.2C (continued). Fall and spring covariate values for mean daily exports.

	Mean Daily Exports (cfs, Feb-Apr)			
Year	Mean	None	Up 30%	Down 30%
2041	5954	0	7740	4168
2042	5954	0	7740	4168
2043	5954	0	7740	4168
2044	5954	0	7740	4168
2045	5954	0	7740	4168
2046	5954	0	7740	4168
2047	5954	0	7740	4168
2048	5954	0	7740	4168
2049	5954	0	7740	4168
2050	5954	0	7740	4168
2051	5954	0	7740	4168
2052	5954	0	7740	4168
2053	5954	0	7740	4168
2054	5954	0	7740	4168
2055	5954	0	7740	4168
2056	5954	0	7740	4168
2057	5954	0	7740	4168
2058	5954	0	7740	4168
2059	5954	0	7740	4168
2060	5954	0	7740	4168
2061	5954	0	7740	4168
2062	5954	0	7740	4168
2063	5954	0	7740	4168

Table B.2D. Fall and spring covariate values for Freeport sediment concentration, Keswick discharge and Deer Creek discharge.

	Freeport Sediment Concentration (mg/L, Feb-Apr)		Keswick Discharge (cfs, Jan-Mar)		Deer Creek Discharge (cfs, Oct-Dec)	
Year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	Study 9.2	Study 9.5
2007	39.4	38.0	5243	5300	263	263
2008	39.0	36.0	3434	3304	199	199
2009	47.7	35.6	3641	3428	171	171
2010	59.0	52.4	7253	4820	127	127
2011	61.4	49.0	3250	3250	725	725
2012	79.7	75.7	9926	8546	631	631
2013	147.8	123.3	14349	12033	442	442
2014	50.6	44.4	13435	11368	230	230
2015	120.5	86.0	16243	11469	303	303
2016	30.0	24.3	3953	3250	1034	1034
2017	91.6	87.0	20651	18332	192	192
2018	79.6	45.9	10356	4860	370	370
2019	168.1	155.8	32284	29055	196	196
2020	63.6	52.3	11435	9122	142	142
2021	47.2	41.4	3250	3250	333	333
2022	51.4	39.9	7469	3250	276	276
2023	69.0	48.8	7814	3994	730	730
2024	131.0	108.6	7531	6533	252	252
2025	32.2	26.3	4428	3992	1016	1016
2026	69.7	71.0	9841	8544	275	275
2027	53.1	41.2	9921	7004	525	525
2028	113.4	84.9	12309	9262	207	207
2029	90.5	70.8	9851	7587	449	449
2030	127.2	110.0	19597	12796	564	564
2031	87.1	74.1	25746	21687	683	683
2032	76.1	57.8	13406	11874	233	233
2033	57.3	38.2	9342	4974	355	355
2034	106.2	87.0	15483	12171	1025	1025
2035	137.0	112.5	28265	24483	238	238
2036	121.7	90.0	14762	11115	229	229
2037	33.0	26.7	3250	4583	135	135
2038	20.8	19.5	4865	3933	213	213
2039	126.1	91.5	15667	6976	144	144
2040	67.2	42.1	3896	3250	367	367

Table B.2D (continued). Fall and spring covariate values for Freeport sediment concentration, Keswick discharge and Deer Creek discharge.

	Freeport Sediment Concentration (mg/L, Feb-Apr)		Keswick Discharge (cfs, Jan-Mar)		Deer Creek Discharge (cfs, Oct-Dec)	
Year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	Study 9.2	Study 9.5
2041	104.3	89.4	19408	14964	217	217
2042	60.7	39.8	7729	3740	1069	1069
2043	164.6	155.7	16139	14051	591	591
2044	159.0	147.5	36756	33072	1237	1237
2045	60.7	61.4	8095	7268	358	358
2046	37.1	28.7	3250	3250	245	245
2047	130.5	123.5	26225	17841	179	179
2048	53.8	39.3	5643	3915	221	221
2049	24.6	23.4	4105	4498	177	177
2050	79.5	56.3	6010	3250	191	191
2051	28.5	25.4	3250	3306	111	111
2052	38.8	32.7	4180	3250	111	111
2053	46.9	40.3	4337	3320	187	187
2054	126.9	76.3	11370	3250	192	192
2055	41.6	31.4	3618	3701	180	180
2056	149.1	115.9	26699	19849	297	297
2057	133.7	114.9	18602	16308	903	903
2058	70.5	56.5	15811	13367	292	292
2059	147.6	130.2	33555	26125	470	470
2060	120.2	107.2	16191	14408	216	216
2061	118.0	93.0	20572	13863	173	173
2062	44.3	37.5	3250	3250	361	361
2063	49.3	39.9	7795	4871	576	576

Table B.2E. Fall and spring covariate values for export/inflow ratios.

	Mean Daily Export/Inflow Ratio (Mar-May), Inflows for Study 9.2, Various Export Values				Mean Daily Export/Inflow Ratio (Mar-May), Inflows for Study 9.5, Various Export Values			
Year	E=Mean	Zero	Mean+30%	Mean-30%	E=Mean	Zero	Mean+30%	Mean-30%
2007	0.22	0	0.29	0.15	0.27	0	0.35	0.19
2008	0.26	0	0.34	0.18	0.32	0	0.41	0.22
2009	0.16	0	0.20	0.11	0.24	0	0.31	0.17
2010	0.16	0	0.20	0.11	0.20	0	0.26	0.14
2011	0.18	0	0.23	0.12	0.25	0	0.33	0.18
2012	0.19	0	0.24	0.13	0.21	0	0.28	0.15
2013	0.06	0	0.07	0.04	0.08	0	0.10	0.06
2014	0.17	0	0.22	0.12	0.22	0	0.29	0.15
2015	0.11	0	0.14	0.07	0.16	0	0.21	0.11
2016	0.33	0	0.42	0.23	0.40	0	0.52	0.28
2017	0.12	0	0.16	0.08	0.16	0	0.20	0.11
2018	0.15	0	0.19	0.10	0.22	0	0.29	0.15
2019	0.05	0	0.06	0.03	0.07	0	0.09	0.05
2020	0.27	0	0.35	0.19	0.29	0	0.37	0.20
2021	0.27	0	0.35	0.19	0.32	0	0.42	0.22
2022	0.29	0	0.37	0.20	0.36	0	0.47	0.25
2023	0.22	0	0.29	0.16	0.27	0	0.35	0.19
2024	0.09	0	0.11	0.06	0.11	0	0.15	0.08
2025	0.30	0	0.39	0.21	0.42	0	0.54	0.29
2026	0.14	0	0.19	0.10	0.14	0	0.18	0.10
2027	0.21	0	0.28	0.15	0.27	0	0.36	0.19
2028	0.07	0	0.09	0.05	0.10	0	0.13	0.07
2029	0.20	0	0.26	0.14	0.24	0	0.31	0.17
2030	0.06	0	0.08	0.04	0.09	0	0.11	0.06
2031	0.18	0	0.23	0.12	0.20	0	0.26	0.14
2032	0.12	0	0.15	0.08	0.19	0	0.24	0.13
2033	0.21	0	0.27	0.15	0.27	0	0.35	0.19
2034	0.12	0	0.16	0.08	0.17	0	0.23	0.12
2035	0.07	0	0.08	0.05	0.08	0	0.10	0.05
2036	0.09	0	0.11	0.06	0.12	0	0.16	0.09
2037	0.30	0	0.39	0.21	0.40	0	0.52	0.28
2038	0.55	0	0.71	0.38	0.55	0	0.71	0.38
2039	0.08	0	0.10	0.06	0.11	0	0.14	0.08
2040	0.15	0	0.19	0.10	0.24	0	0.31	0.17

Table B.2E (continued). Fall and spring covariate values for export/inflow ratios.

	Mean Daily Export/Inflow Ratio (Mar-May), Inflows for Study 9.2, Various Export Values				Mean Daily Export/Inflow Ratio (Mar-May), Inflows for Study 9.5, Various Export Values			
Year	E=Mean	Zero	Mean+30%	Mean-30%	E=Mean	Zero	Mean+30%	Mean-30%
2041	0.12	0	0.15	0.08	0.16	0	0.21	0.11
2042	0.20	0	0.26	0.14	0.30	0	0.39	0.21
2043	0.05	0	0.06	0.03	0.06	0	0.08	0.04
2044	0.03	0	0.04	0.02	0.04	0	0.05	0.03
2045	0.18	0	0.24	0.13	0.18	0	0.24	0.13
2046	0.26	0	0.34	0.18	0.33	0	0.43	0.23
2047	0.06	0	0.08	0.04	0.09	0	0.11	0.06
2048	0.22	0	0.28	0.15	0.30	0	0.39	0.21
2049	0.42	0	0.55	0.30	0.45	0	0.58	0.31
2050	0.12	0	0.15	0.08	0.17	0	0.22	0.12
2051	0.40	0	0.52	0.28	0.45	0	0.59	0.32
2052	0.25	0	0.33	0.18	0.30	0	0.40	0.21
2053	0.32	0	0.42	0.23	0.36	0	0.47	0.25
2054	0.09	0	0.11	0.06	0.17	0	0.22	0.12
2055	0.30	0	0.39	0.21	0.43	0	0.55	0.30
2056	0.03	0	0.04	0.02	0.05	0	0.06	0.03
2057	0.07	0	0.10	0.05	0.11	0	0.14	0.07
2058	0.20	0	0.26	0.14	0.22	0	0.29	0.16
2059	0.06	0	0.08	0.04	0.08	0	0.10	0.06
2060	0.11	0	0.14	0.08	0.14	0	0.18	0.10
2061	0.11	0	0.14	0.08	0.15	0	0.20	0.11
2062	0.24	0	0.32	0.17	0.31	0	0.40	0.22
2063	0.24	0	0.31	0.17	0.31	0	0.41	0.22

Table B.3A. Winter covariate values for total exports, upwelling index and Bend Bridge flows.

	Total Exports (Σ daily exports (cfs), Dec-Jun)				Upwelling Index (36N, 122W, Apr-Jun)		Bend Bridge Monthly Minimum Flow (cfs, Aug-Nov)	
Year	Mean	Zero	Up 30%	Down 30%	Up 10%	Down 20%	Study 9.2	Study 9.5
2007	1250154	0	1625201	875108	199	145	5975	4968
2008	1250154	0	1625201	875108	139	101	4616	4309
2009	1250154	0	1625201	875108	116	84	6284	4737
2010	1250154	0	1625201	875108	136	99	5791	4441
2011	1250154	0	1625201	875108	169	123	5804	4343
2012	1250154	0	1625201	875108	144	105	5881	5458
2013	1250154	0	1625201	875108	158	115	7166	5699
2014	1250154	0	1625201	875108	195	142	10262	6713
2015	1250154	0	1625201	875108	177	129	6383	6500
2016	1250154	0	1625201	875108	318	231	5261	4191
2017	1250154	0	1625201	875108	256	186	7764	6807
2018	1250154	0	1625201	875108	220	160	8409	4863
2019	1250154	0	1625201	875108	173	126	7717	7413
2020	1250154	0	1625201	875108	320	233	5722	5274
2021	1250154	0	1625201	875108	189	138	5521	5071
2022	1250154	0	1625201	875108	186	135	6478	5026
2023	1250154	0	1625201	875108	200	145	6631	4723
2024	1250154	0	1625201	875108	157	114	8097	7236
2025	1250154	0	1625201	875108	314	229	5008	4950
2026	1250154	0	1625201	875108	239	174	5264	5109
2027	1250154	0	1625201	875108	239	174	5638	5641
2028	1250154	0	1625201	875108	223	162	7568	5882
2029	1250154	0	1625201	875108	329	239	5454	4745
2030	1250154	0	1625201	875108	240	174	7893	5639
2031	1250154	0	1625201	875108	267	194	5985	5977
2032	1250154	0	1625201	875108	263	191	9251	6681
2033	1250154	0	1625201	875108	205	149	5422	5516
2034	1250154	0	1625201	875108	270	196	6129	5944
2035	1250154	0	1625201	875108	292	213	9035	5224
2036	1250154	0	1625201	875108	262	190	9760	5488
2037	1250154	0	1625201	875108	209	152	4699	5090
2038	1250154	0	1625201	875108	192	139	4457	4557
2039	1250154	0	1625201	875108	179	130	6642	5340
2040	1250154	0	1625201	875108	282	205	6591	4465

Table B.3A (continued). Winter covariate values for total exports, upwelling index and Bend Bridge flows.

	Total Exports (Σ daily exports (cfs), Dec-Jun)				Upwelling Index (36N, 122W, Apr-Jun)		Bend Bridge Monthly Minimum Flow (cfs, Aug-Nov)	
Year	Mean	Zero	Up 30%	Down 30%	Up 10%	Down 20%	Study 9.2	Study 9.5
2041	1250154	0	1625201	875108	276	201	5831	4908
2042	1250154	0	1625201	875108	297	216	6375	5114
2043	1250154	0	1625201	875108	179	130	11342	3907
2044	1250154	0	1625201	875108	180	131	11658	10590
2045	1250154	0	1625201	875108	309	225	5762	5427
2046	1250154	0	1625201	875108	212	154	6286	5278
2047	1250154	0	1625201	875108	206	150	4686	4327
2048	1250154	0	1625201	875108	191	139	6023	4359
2049	1250154	0	1625201	875108	165	120	6061	4687
2050	1250154	0	1625201	875108	193	140	5220	3852
2051	1250154	0	1625201	875108	186	135	5289	3963
2052	1250154	0	1625201	875108	270	196	3900	4303
2053	1250154	0	1625201	875108	169	123	4743	4086
2054	1250154	0	1625201	875108	173	126	6268	5149
2055	1250154	0	1625201	875108	248	180	6027	4313
2056	1250154	0	1625201	875108	185	134	6689	6797
2057	1250154	0	1625201	875108	222	161	9018	4929
2058	1250154	0	1625201	875108	248	180	5361	5755
2059	1250154	0	1625201	875108	157	114	12261	10749
2060	1250154	0	1625201	875108	378	275	10876	6441
2061	1250154	0	1625201	875108	195	142	8025	6568
2062	1250154	0	1625201	875108	285	207	6552	4070
2063	1250154	0	1625201	875108	339	246	6536	4757

Table B.3B. Winter covariate values for number of days that Verona flow > 56,000 cfs, Bend Bridge water temperatures, Farallon Island ocean temperatures, and proportion of time that the Delta Cross Channel gates are open.

	# Days (Dec-Mar) that Verona Flow > 56,000 cfs		Bend Bridge Average Water Temperature (°C, Jul-Sep)		Farallon Islands Ocean Temperature (°C, Feb-Apr)		Prop. of Time Delta Cross Channel Gates are Open (Dec-Mar)
Year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	+ 0.42° C	+ 1.56° C	Mean
2007	0	0	12.5	13.8	12.3	13.4	0
2008	0	0	13.3	15.4	12.3	13.4	0
2009	6	0	14.0	14.9	12.3	13.4	0
2010	0	0	13.3	15.4	12.3	13.4	0
2011	56	39	13.4	15.6	12.3	13.4	0
2012	68	43	13.2	14.4	12.3	13.4	0
2013	39	28	13.7	15.5	12.3	13.4	0
2014	40	21	13.6	15.0	12.3	13.4	0
2015	0	0	13.6	14.6	12.3	13.4	0
2016	74	60	13.7	15.6	12.3	13.4	0
2017	20	5	13.0	14.3	12.3	13.4	0
2018	69	54	13.7	15.3	12.3	13.4	0
2019	23	9	13.9	14.7	12.3	13.4	0
2020	2	1	14.1	15.6	12.3	13.4	0
2021	8	1	13.6	15.4	12.3	13.4	0
2022	13	4	13.3	15.0	12.3	13.4	0
2023	33	12	13.3	14.7	12.3	13.4	0
2024	0	0	13.8	15.0	12.3	13.4	0
2025	49	35	13.6	15.2	12.3	13.4	0
2026	16	4	13.5	14.9	12.3	13.4	0
2027	51	24	13.2	14.8	12.3	13.4	0
2028	32	17	13.3	14.5	12.3	13.4	0
2029	60	50	14.0	15.2	12.3	13.4	0
2030	76	56	13.2	14.7	12.3	13.4	0
2031	49	28	13.6	15.0	12.3	13.4	0
2032	15	1	13.7	15.3	12.3	13.4	0
2033	62	40	13.4	15.0	12.3	13.4	0
2034	76	61	13.8	14.6	12.3	13.4	0
2035	40	25	13.1	15.5	12.3	13.4	0
2036	0	0	13.5	15.2	12.3	13.4	0
2037	0	0	14.2	15.2	12.3	13.4	0
2038	54	35	16.6	19.2	12.3	13.4	0
2039	14	3	13.4	14.4	12.3	13.4	0
2040	61	45	14.1	16.0	12.3	13.4	0

Table B.3B (continued). Winter covariate values for number of days that Verona flow > 56,000 cfs, Bend Bridge water temperatures, Farallon Island ocean temperatures, and proportion of time that the Delta Cross Channel gates are open.

	# Days (Dec-Mar) that Verona Flow > 56,000 cfs		Bend Bridge Average Water Temperature (°C, Jul-Sep)		Farallon Islands Ocean Temperature (°C, Feb-Apr)		Prop. of Time Delta Cross Channel Gates are Open (Dec-Mar)
year	Study 9.2	Study 9.5	Study 9.2	Study 9.5	+ 0.42° C	+ 1.56° C	Mean
2041	18	4	13.6	14.9	12.3	13.4	0
2042	80	64	14.3	15.6	12.3	13.4	0
2043	94	79	13.3	15.1	12.3	13.4	0
2044	50	43	14.0	14.1	12.3	13.4	0
2045	2	0	14.2	15.8	12.3	13.4	0
2046	53	45	13.8	15.6	12.3	13.4	0
2047	8	0	14.2	15.6	12.3	13.4	0
2048	0	0	14.1	16.1	12.3	13.4	0
2049	12	0	14.2	17.3	12.3	13.4	0
2050	0	0	13.6	16.5	12.3	13.4	0
2051	0	0	14.0	18.0	12.3	13.4	0
2052	2	0	15.0	18.7	12.3	13.4	0
2053	46	24	14.6	19.7	12.3	13.4	0
2054	0	0	13.9	15.0	12.3	13.4	0
2055	70	56	14.4	16.5	12.3	13.4	0
2056	59	40	14.5	15.3	12.3	13.4	0
2057	69	54	14.2	15.5	12.3	13.4	0
2058	79	65	13.5	15.2	12.3	13.4	0
2059	58	42	14.6	14.7	12.3	13.4	0
2060	49	31	13.2	14.7	12.3	13.4	0
2061	4	1	14.8	15.9	12.3	13.4	0
2062	25	13	14.9	17.4	12.3	13.4	0
2063	39	21	15.1	17.0	12.3	13.4	0

APPENDIX C: GROWTH ANALYSIS AND MODELLING

In this appendix we provide a description of the methods we used to collect and analyze length information from various state and federal collection facilities in the Sacramento drainage. We assembled time series of lengths, both upstream and downstream, for both hatchery fish and combined hatchery and wild aggregates. Where possible, we used upstream and downstream lengths to obtain annual growth estimates. In the absence of a downstream growth measurement, we assembled a time series of downstream lengths. We performed regressions on growth and length estimates, evaluating impacts of environmental conditions on growth.

INTRODUCTION

The life-cycle modeling analysis in this project attempts to attribute variability in survival to environmental factors during different parts of the life history. Survival can be affected by the environment in complex ways, and can be mediated through biotic and abiotic processes. We posit that size can play a role in predicting survival, and that growth itself can be an indicator of survival as well. An obvious mechanism for size effects on survival would be that larger fish are less vulnerable to predation than smaller fish. A mechanism for growth being a predictor of survival would be that faster growing fish are likely to be experiencing better feeding conditions and bioenergetic advantages, and therefore should survive better.

In this appendix we look for relationships between environmental conditions and growth, but because growth requires two measurements (a capture and a recapture, or a release and recapture), we are not always able to get an estimate of a growth increment. Some length estimates obtained from survey data cannot be connected to later surveys, and therefore a growth estimate can't be derived from the measurements. An example of this occurs with rotary screw traps operating in tributaries, where juvenile size samples are obtained during rearing and migration. Those sizes are not directly comparable to later samples obtained downstream, because the downstream samples are aggregates of all the independent upstream sampled lengths. We might be able to document a pattern in upstream sizes over the years, but growth to the downstream measurement can't be inferred. We therefore treat size as a surrogate for growth, with the assumption that annual variability in juvenile size is in actual fact a measurement of annual variability in growth since all fish must at some point have emerged from the gravel at roughly the same sizes.

METHODS

We performed an analysis of length and growth patterns for Spring and Fall run Chinook in the Sacramento River in relation to environmental factors. We collected size at release and recapture data from state and federal agencies. We compiled records into average sizes at release for several different stock aggregates that provided adequate sample sizes for the years the data were available. In some case, it was possible to associate the length of a downstream recaptured fish with a known upstream release size to obtain a growth increment estimate, but in other cases only the downstream size record was available. Upstream length records were obtained from hatchery release information, from screw traps operated in tributaries, and from seine surveys operated throughout the Sacramento drainage. The farthest downstream sizes were obtained from Chipps Island, where mid-water trawl surveys collected size information and recorded the race of the fish based on the presence of a CWT or a length based estimated based on the length of the fish at the time the sample was obtained.

Data compilation

Length data

The Pacific States Marine Fisheries Commission manages and supports the Regional Mark Processing Center (RMPC; http://www.rmpc.org/), which in turn manages the Regional Mark Information System (RMIS). Agencies and organizations throughout the Western United States report CWT data directly to the RMIS. The Delta Juvenile Fish Monitoring Program (DJFMP) was initiated in the 1970s and is managed by the US Fish and Wildlife Service (USFWS, 2014). The program has a stated objective to monitor the effects of water projects in the Bay Delta on juvenile Chinook.

The number of juvenile salmon leaving freshwater during the spring has been sampled annually since 1978 by means of mid-water trawling in the estuary near Chipps Island (Brandes and McLain 2001). The Trawl site in Suisun Bay is sampled three days per week year round. It is sometimes sampled daily and at times two shifts per day for a total of 20 tows per day during May and June. During December and January, trawls occur 7 days per week with ten 20 minute trawls conducted daily. Catch limits are imposed when Delta Smelt catches exceed 8 individual Delta Smelt. The trawl survey records fish length at capture and creates a record of the race, origin and release location if a coded wire tag is detected.

We used data that had been collected since 1979 in mid-water boat trawls at Chipps Island, Suisun Bay (Zone 10 S UTM, 4211218N, 595531E). Data from the DJFMP is available online (http://www.fws.gov/stockton/jfmp/). USFWS tables available online contained metrics of juvenile Chinook salmon that had been marked with CWTs, released throughout the Sacramento - San Joaquin Basin and then recovered near Chipps Island in Suisun Bay (Coded *Wire Tag 1978 -2011.xls* and *Coded Wire Tag 2012 -2013.xls*). Survey records not containing CWTs can be found in the spreadsheets *Chipps Island Trawls 1976-2011.xlsx and Chipps Island Trawls 2012-2014.xlsx.*

We used the records from the Chipps Island trawls to create a database of fish lengths and growths increments for all fish with CWTs (referred to as the CWT table). Each fish with a CWT is of a known origin, so the race and the source (hatchery or wild stock origin) are also known. We used the remaining records from the Chipps Island survey to construct a database table of Chinook known to be of a given race, but where the origin is not known. These records were assembled into a table we refer to as the TRAWL table, which only distinguishes between Fall and Spring runs.

We compiled juvenile salmon length data from the Sacramento watershed and the San Francisco Bay Delta into a relational database in order to determine growth of hatchery Fall Chinook and hatchery and wild juvenile Spring Chinook. Wild Spring stocks included Deer, Mill and Butte creeks. Butte Creek fish were release and recaptured in Butte Creek, the Sutter

Bypass or near Chipps Island in Suisun Bay. Release and recovery data were compiled from three sources: California Department of Fish and Wildlife (CDFW), US Fish and Wildlife Service's Delta Juvenile Fish Monitoring Program (DJFMP) and the Regional Mark Processing Center (RMPC).

From 1995 to 2001, the CDFW captured, measured, marked, and released wild spring-run Chinook on Butte Creek (CDFG, 1999; CDFG, 2004-2; CDFG, 2004-3). The purpose of the CDFW program was to estimate adult escapement, monitor timing and abundance of juvenile outmigration, and monitor relative growth rates in the Butte Creek system. Fish were captured and marked with adipose fin clips and coded wire tags at the Parrot-Phelan Diversion Dam (PPDD; Zone 10 S UTM, 4396287N, 611463E). Releases took place at three locations, but varied from year to year. Release sites were: PPDD, Baldwin Construction Yard (approximately one mile downstream of the PPDD) and Adams Dam (approximately 7 miles downstream of PPDD). After release, marked fish were subject to recapture and sacrifice at downstream locations in Butte Creek, the Sutter Bypass and the Sacramento Delta near Chipps Island. Rotary screw traps were used to recapture fish at all locations and an off-stream fish screen outfitted with a trap box was used to collect fish at the PPDD site. Recaptured fish were sacrificed, measured for fork length and their CWTs were extracted and read. We received programmatic data formatted in a Microsoft Access database directly from the CDFW (C. Garman, personal communication, 1/30/2014).

We queried the RMIS database for juvenile Chinook that had been marked and released at any location in the Sacramento drainage. The RMIS table was then related by CWT code to Chipps Island mid-water trawl and Sacramento River recoveries. In this way, we queried recoveries with release locations only within the Sacramento Basin.

We obtained tributary measurements of juvenile lengths from rotary screw traps (RSTs) operating in Butte creek, Mill creek and Deer creek. Rotary screw traps were operated by the US Fish and Wildlife Service in Mill and Deer creeks, and by the California Department of Fish and Wildlife in Butte creek. Screw trap operation spanned 1995-2010 in the records used in this analysis. We used samples obtained from January to June of each year to obtain estimates of tributary outmigration size.

Environmental data

We compiled time series of environmental variables that pertain to the experiences of downstream migration juveniles. For Spring Run, we used discharge at the three creeks (Deer, Mill and Butte), flow, exports volumes and other export indices, and a CPUE index of bass abundance. Flow temperature and discharge were obtained from USGS gauging stations (http://waterdata.usgs.gov/nwis/inventory). Exports and other dayflow parameters were obtained from water project data available on the California department of water resources website (http://www.water.ca.gov/dayflow/output/Output.cfm). Environmental variables were normalized by subtracting the mean and dividing by the standard deviation. The variables are summarized in Table C.1 for Spring run and in Table C.2 for Fall run.

Table C.1 Environmental variables used in length and growth analysis of Spring Chinook.

Covariate	Description	Location	Data Origin
Deer discharge	Average monthly water discharge (cfs) at Deer Creek	Vinna, Deer Creek	USGS 11383500 DEER C NR VINA CA
Mill discharge	Average monthly water discharge (cfs) on Mill Creek	Molinos, Mill Creek	USGS 11381500 MILL C NR LOS MOLINOS CA
Butte discharge	Average monthly water discharge (cfs) on Butte Creek	Chico, Butte Creek	USGS 11390000 BUTTE C NR CHICO CA
Yolo flow	Peak (maximum) streamflow into YOLO Bypass at Woodland, CA	Into Yolo at Woodland, CA	USGS 11453000 YOLO BYPASS NR WOODLAND CA
Bass	Index of Striped Bass abundance as number of striped bass kept. This is NOT effort standardized, but effort data is not available <1980	Delta	Marty Gingris personal comm.
GEO	The amount of water reaching the Mokelumne River system from the Sacramento River via the Delta Cross Channel and Georgiana Slough	Delta cross channel and Georgiana Slough	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO)
EXP	Accounts for all water diverted from the Delta by the Federal and State governments to meet water agreements and contracts. These include Central Valley Project pumping at Tracy (QCVP), the Contra Costa Water District Diversions at Middle River (new for WY 2010; data begin on 01AUG2010), Rock Slough, and Old River (QCCC), the North Bay Aqueduct export (QNBAQ), and State Water Project exports (Banks Pumping Plant or Clifton Court Intake, QSWP).	South Delta	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS).
EXPIN	The Export/Inflow Ratio is the combined State and Federal Exports divided by the total Delta inflow (QTOT). EXPIN = (QCVP+QSWP-BBID)/QTOT (8)	Delta	Dayflow: Export/Inflow Ratio (EXPIN)

CD	The Dayflow parameter net channel depletion (QCD) is an estimate of the quantity of water removed from Delta channels to meet consumptive use (QGCD)	Delta	Dayflow: Net Channel Depletion (QCD)
CVP	Dayflow parameter for Central Valley Project pumping at Tracy (QCVP)	Delta	

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2697 **Table C.2 Environmental variables used in length and growth analysis of Fall Chinook**

Covariate Name	Description	Location	Data Origin
Keswick discharge	Average monthly water discharge (cfs) at Keswick Dam	Keswick Dam	USGS 11370500 SACRAMENTO R A KESWICK CA
Battle discharge	Average monthly water discharge (cfs) on Battle Creek	Cottonwood, Battle Creek	USGS 11376550 BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA
Battle height	Peak gauge height for the water year	Cottonwood, Battle Creek	USGS 11376550 BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA
Feather discharge	Average monthly water discharge (cfs) on the Feather River	Oronville, Feather River	USGS 11407000 FEATHER R A OROVILLE CA
Feather temp	Feather River average maximum temperature from USGS gage with (daily) interpolations from Sacramento, CA air temperature (1992+)	Oronville, Feather River	USGS 11407000 FEATHER R A OROVILLE CA
American temp	American River average maximum temperature from USGS gage with (daily) interpolations from Sacramento, CA air temperature (~1978-1998)	Fair Oaks, American River	USGS 11446500 AMERICAN R A FAIR OAKS CA
Yolo flow	Peak (maximum) streamflow into YOLO Bypass at Woodland, CA	Into Yolo at Woodland, CA	USGS 11453000 YOLO BYPASS NR WOODLAND

			CA
Bass	Index of Striped Bass abundance as number of striped bass kept. This is NOT effort standardized, but effort data is not available <1980	Delta	Marty Gingris personal comm.
GEO	The amount of water reaching the Mokelumne River system from the Sacramento River via the Delta Cross Channel and Georgiana Slough	Delta: DCC and Georgiana Slough	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO)
EXP	Accounts for all water diverted from the Delta by the Federal and State governments to meet water agreements and contracts. These include Central Valley Project pumping at Tracy (QCVP), the Contra Costa Water District Diversions at Middle River (new for WY 2010; data begin on 01AUG2010), Rock Slough, and Old River (QCCC), the North Bay Aqueduct export (QNBAQ), and State Water Project exports (Banks Pumping Plant or Clifton Court Intake, QSWP).	South Delta	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS).
EXPIN	The Export/Inflow Ratio is the combined State and Federal Exports divided by the total Delta inflow (QTOT). EXPIN = (QCVP+QSWP-BBID)/QTOT (8)	Delta	Dayflow: Export/Inflow Ratio (EXPIN)
CD	The Dayflow parameter net channel depletion (QCD) is an estimate of the quantity of water removed from Delta channels to meet consumptive use (QGCD)	Delta	Dayflow: Net Channel Depletion (QCD)
CVP	Dayflow parameter for Central Valley Project pumping at Tracy (QCVP)	Delta	Dayflow: Central Valley Project Pumping (QCVP)
SWP	Dayflow parameter for State Water Project exports (Banks Pumping	Delta	Dayflow: State Water Project Pumping

	Plant or Clifton Court Intake, QSWP)		(QSWP)

Length and Growth analysis

We examined environmental factors affecting length at recapture at Chipps Island of fish with known and unknown release lengths. Where length at release was known, we examined growth rates. We associated each size and growth record with environmental factors experienced by each race of salmon each year the sizes were recorded. We compared fall and spring length at capture at Chipps Island from two separate surveys. The CWT table provided an estimate of growth for fall and spring hatchery releases. The mid-water trawls did not distinguish between wild and hatchery fish, so those analyses pertain to the race as a whole, without distinction about release locations or wild/hatchery distinctions. We also obtained sizes from DJFMP seines in Region 1 (upstream from the Delta) and compared those sizes with Chipps Island size information. Since seine samples do not distinguish between populations, growth obtained from subtracting upstream seine sizes from Chipps Island trawl sizes provide estimates of aggregate Fall and Spring run sizes, but cannot distinguish between release locations or between wild and hatchery releases.

SEINE/TRAWL - growth by race from mid-Sacramento to Chipps Island.

We queried the DJFMP seine database to obtain estimates of growth for Spring and Fall runs. Region 1 of the DJFMP beach seine runs from Colusa State Park to Elkhorn. We averaged lengths of Spring and Fall seine lengths for each year for fish collected between January and June, and compared those to Chipps Island midwater trawl sizes. The trawl survey assigned fish to Fall and Spring runs based on size ranges and records indicated that all collections occurred in May and June. We calculated the growth for each race of fish each year as the difference between the average trawl length and the average seine length. We refer to these growth estimates as the SEINE/TRAWL dataset.

We examined growth patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of growth in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found.

CWT –growth and length by hatchery source.

When hatchery fish are released, the average size of a sample of the release batch is used as the release length of record for fish in the batch. When recaptures occur at Chipps Island, a record for each fish recaptured can be compared to a release length record on the basis of CWT codes. To get reasonable sample sizes for recaptures, we were forced to aggregate hatchery releases such that release locations were ignored. We aggregated all release locations within the Sacramento drainage for each hatchery source. Since a release batch contains a range of lengths, it is possible for the smallest recaptured fish to be smaller than the average released fish. The growth record for each year was calculated as the average of all the recapture lengths minus the average release length. The average of release length was calculated as the weighted release length, weighted by the number released at each location at each time of release. We refer to the length and growth estimates from this method as the CWT dataset.

We tested for statistical relationships between size at recapture and environmental variables for Spring and Fall hatchery releases from Coleman National Fish Hatchery (CNFH) and Feather Fish Hatchery (FFH). We examined growth and length patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of growth and length in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found.

TRAWL – length by race at Chipps Island.

We selected records that were not limited to CWT tagged fish (the TRAWL dataset in this analysis) from Chipps Island, and assembled all records of Spring and Fall chinook to look at the size. By not being limited to CWT matches, the sample size was much larger than for the CWT matched database, but for the TRAWL dataset, the origin of fish could not be determined. The race of the fish was assigned by a length/timing criteria established by the DJFMP (the "Race Table" found at www.fws.gov/stockton/jfmp). Using these records we looked for temporal trends, comparisons between Spring and Fall runs, and relationships between size at capture and environmental factors. Annual average size records for Spring and Fall Chinook do not distinguish between hatchery and wild, and there is no growth estimate because the size at release is not known, and there is no way to distinguish between Butte, Mill, and Deer creeks. The TRAWL dataset provides an aggregate estimate of length at Chipps Island by race alone.

We examined growth patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of length in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found. We treat length as a surrogate for growth on the assumption that some initial length can be treated as a constant across and all variability can be thought of as occurring after that initial length.

RST – Lengths in tributaries

Deer, Mill, and Butte creek rotary screw trap records were queried to obtain estimates of out-migrating juvenile sizes. We took the average size of all samples obtained from the traps between January and June of each migration year. We attempted to match CWT releases from Butte Creek each year to recoveries within the Sacramento basin to obtain growth estimates at various sample locations, but found that recoveries were too few to obtain good estimates of growth. Butte Creek CWT release records with Chipps Island recapture events began in 1996, but recaptures amounted to fewer than 10 fish per year at Chipps Island. It was not possible to relate RST lengths to downstream lengths at Chipps Island for a growth estimate. We therefore limited our examination of RST data to showing temporal trends of sizes of Deer, Mill and Butte creeks.

RESULTS

SEINE/TRAWL - growth by race from mid-Sacramento to Chipps Island.

The average growth of Spring and Fall Chinook are shown in Figure C.1 along with the time elapsed between Seine surveys and mid-water trawls. The temporal trend in growth is shown in Figure C.2. Fall Chinook appear to be slightly larger and on average seen in seine surveys about half of a month later. Predominantly, Fall Chinook appear to grow slightly more between Seine and mid-water trawl surveys, which is noteworthy, since they do so in less time as seen in the average month seined calculation.

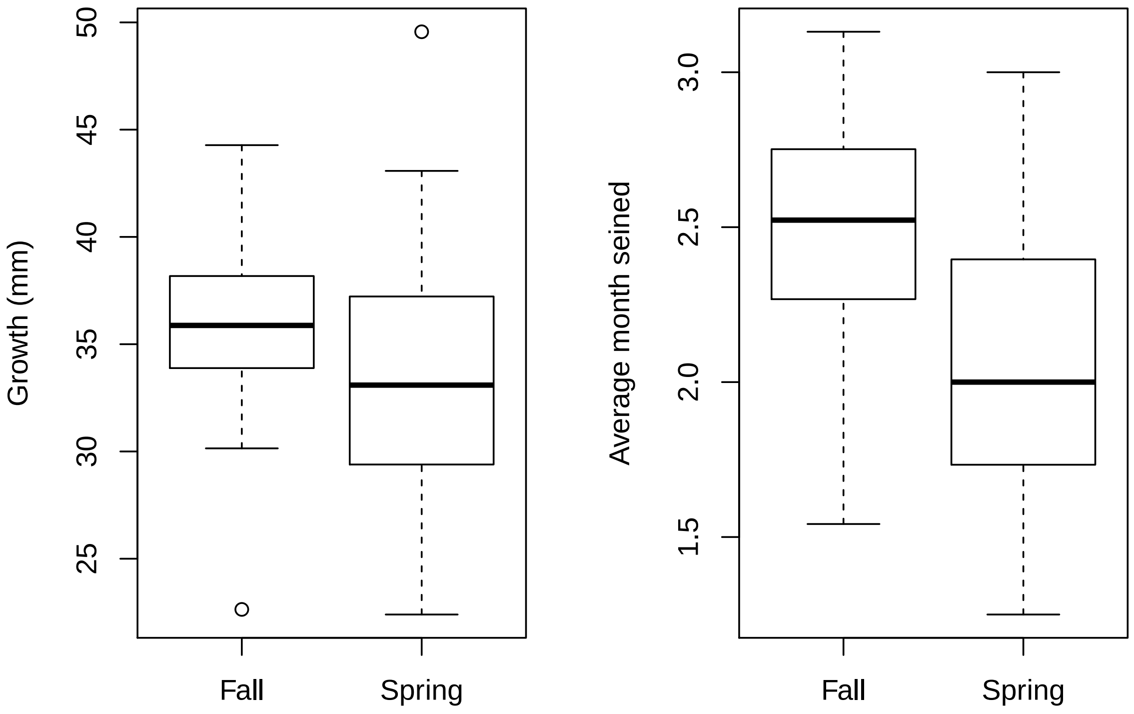

Figure C.1 Growth between release and sampling at Chipps Island (left panel) and month at which Region 1 seine was sampled (right panel).

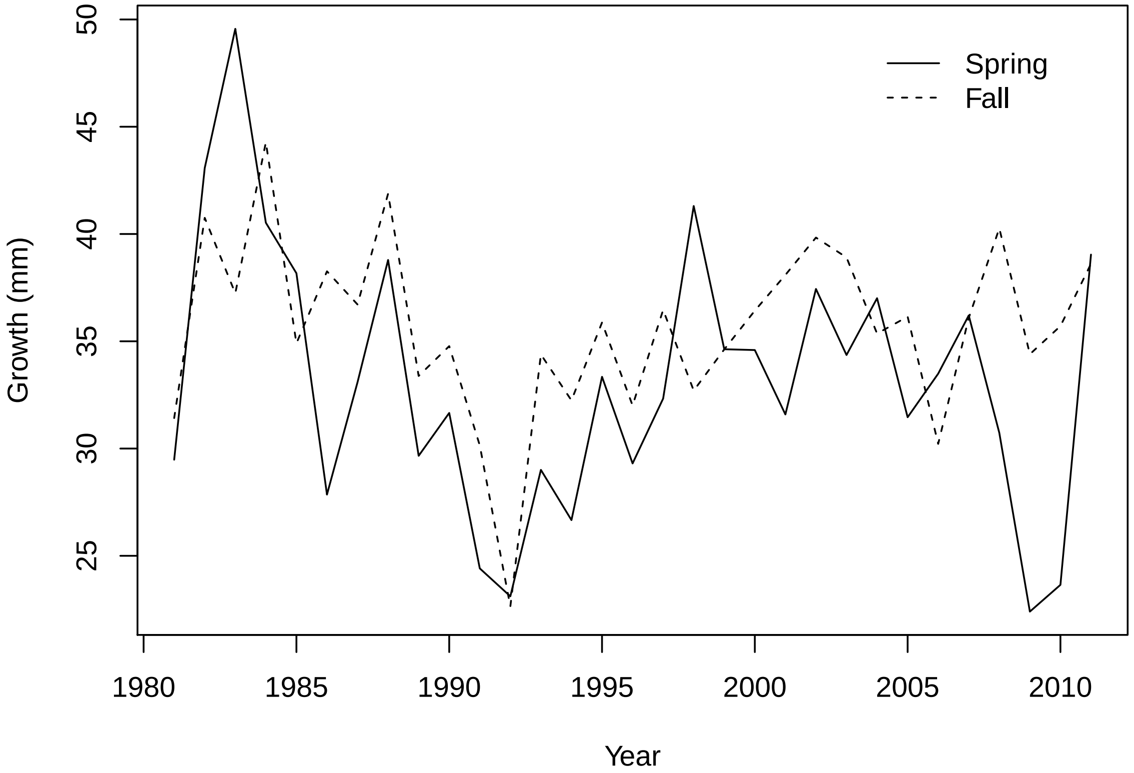

Figure C.2 Temporal trends in Spring and Fall Chinook growth evaluated from beach seine and mid-water trawl surveys.

Table C.3 shows the results of stepwise linear regressions. The regression results show that there are significant effects of Bass, Central Valley Project exports, race (spring or fall run) , and the export to inflow ratio (EXPIN). The bass index shows a positive effect on growth. Central Valley Project exports also show a positive effect, but the export to inflow ratio shows a negative effect. The adjusted R-squared value for the fit was 0.4068. The diagnostic plot of the fit is shown in Figure C.3.

Table C.3 Regression results of growth in SEINE/TRAWL data in relation to environmental variables. Intercept in parentheses.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(int-Fall)	38.3357	0.9227	41.546	<2.00E-16	***
Bass	5.4229	1.3838	3.919	0.000241	***
CVP	3.8959	0.7293	5.342	1.67E-06	***
Spring	-3.5728	1.0712	-3.335	0.001503	**
EXPIN	-1.3115	0.6071	-2.16	0.034961	*

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

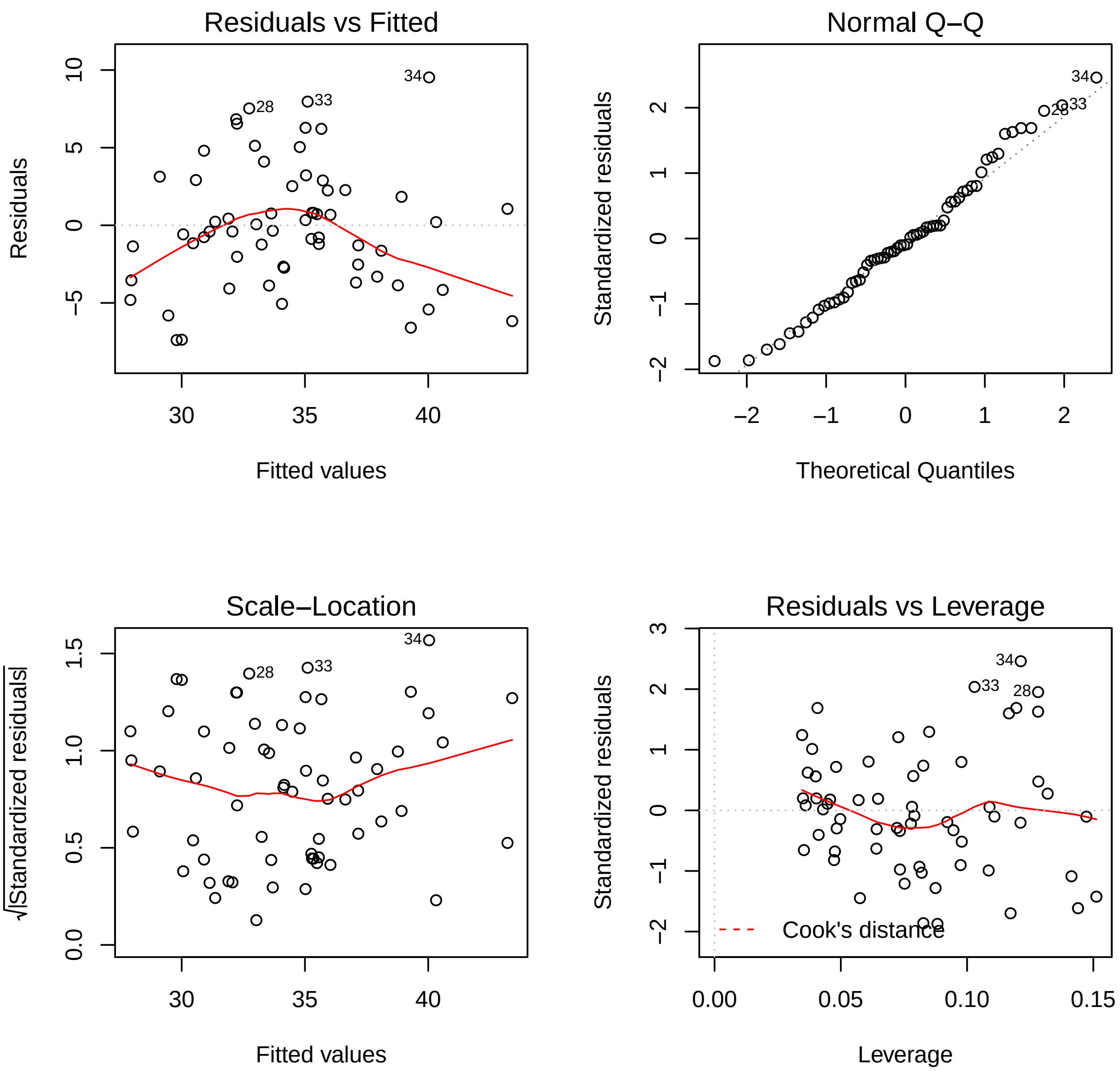

Figure C.3 Diagnostic plot of best fitting model of seine-trawl growth of Spring and Fall chinook.

CWT –growth and length by hatchery source.

Feather Fish Hatchery (FFH) spring Chinook and Coleman National Fish Hatchery (CNFH) fall Chinook growth and lengths at Chipps Island are shown in Figure C.4. We see that there is considerable variability in growth, and that Spring run fish appear to have grown faster than Fall run until the early 1990's, but are now growing less than Fall run (see Figure C.4 upper panel). Table C.4 shows the results of stepwise regressions of length against all Spring and Fall run covariates. The export to inflow ratio was the only significant predictor of catch length in the Chipps Island trawl, with EXPIN having a positive effect. The adjusted R-squared for the best fitting model shown was 0.3414. Diagnostic plots of the best fit are shown in Figure C.5, where we can see that the residuals are normal. Regressions show a hatchery effect, finding that FFH fish arrive at Chipps Island 3.5 mm larger than CNFH fish, but FFH fish included Spring run, which were larger. Despite growth of Spring run recoveries appearing to decline from 1985, the lengths of Spring run fish at Chipps Island appears to be relatively constant. We found no significant relationships between growth and environmental variables.

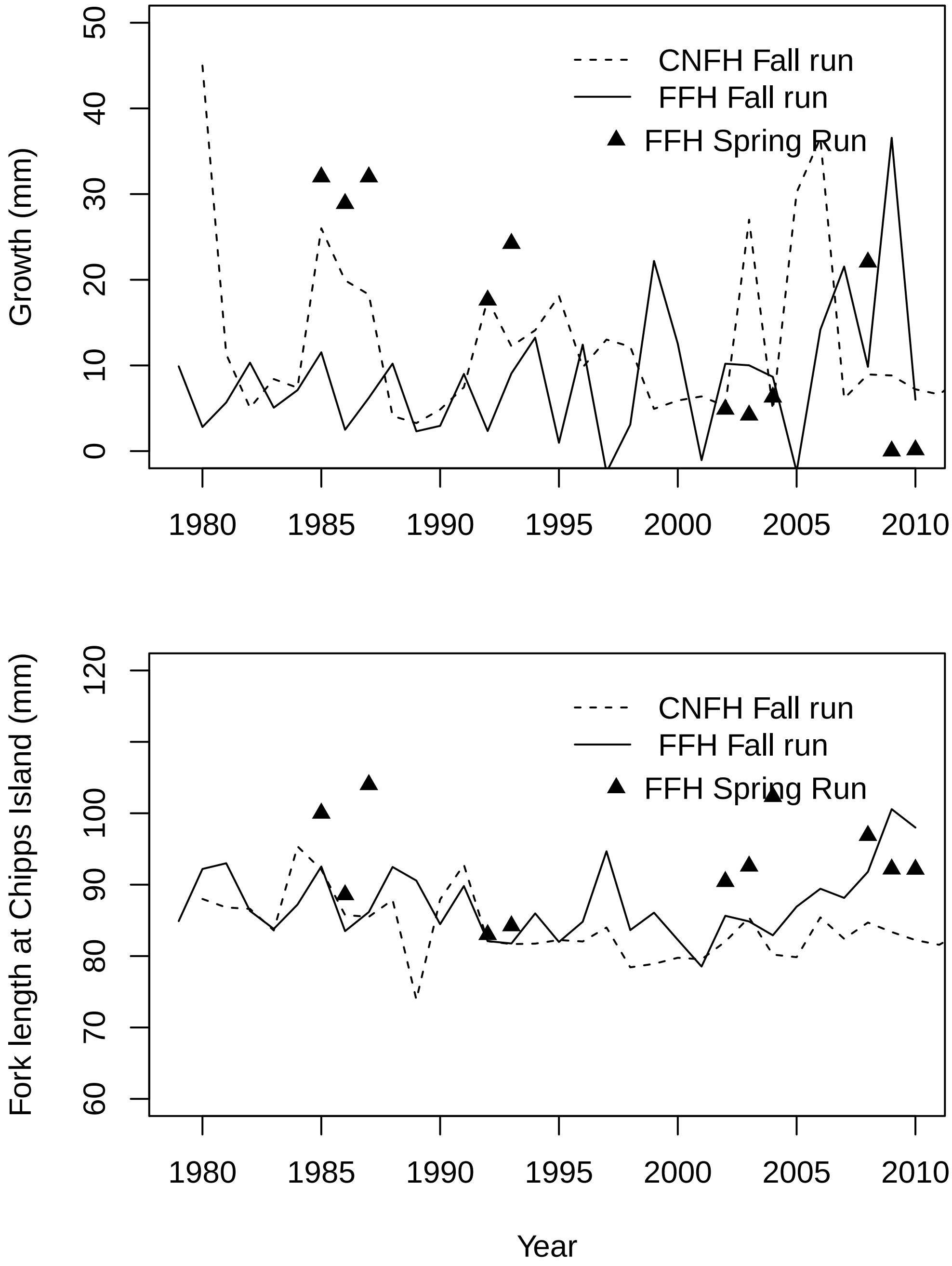

Figure C.4 Growth of CNFH and FFH Fall runs, and FFH Spring run (upper panel) and length at Chipps Island (lower panel).

Table C.4 Regression results of relationship between CWT length at Chipps Island and environmental variables. Intercept in parentheses for Fall CNFH.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(Intercept)	83.8357	0.8361	100.27	<2.00E-16	***
Race Spring	5.6019	1.6816	3.331	0.00137	**
EXPIN	1.7117	0.5764	2.969	0.00405	**
Source FFH	3.4654	1.1919	2.907	0.00484	**

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

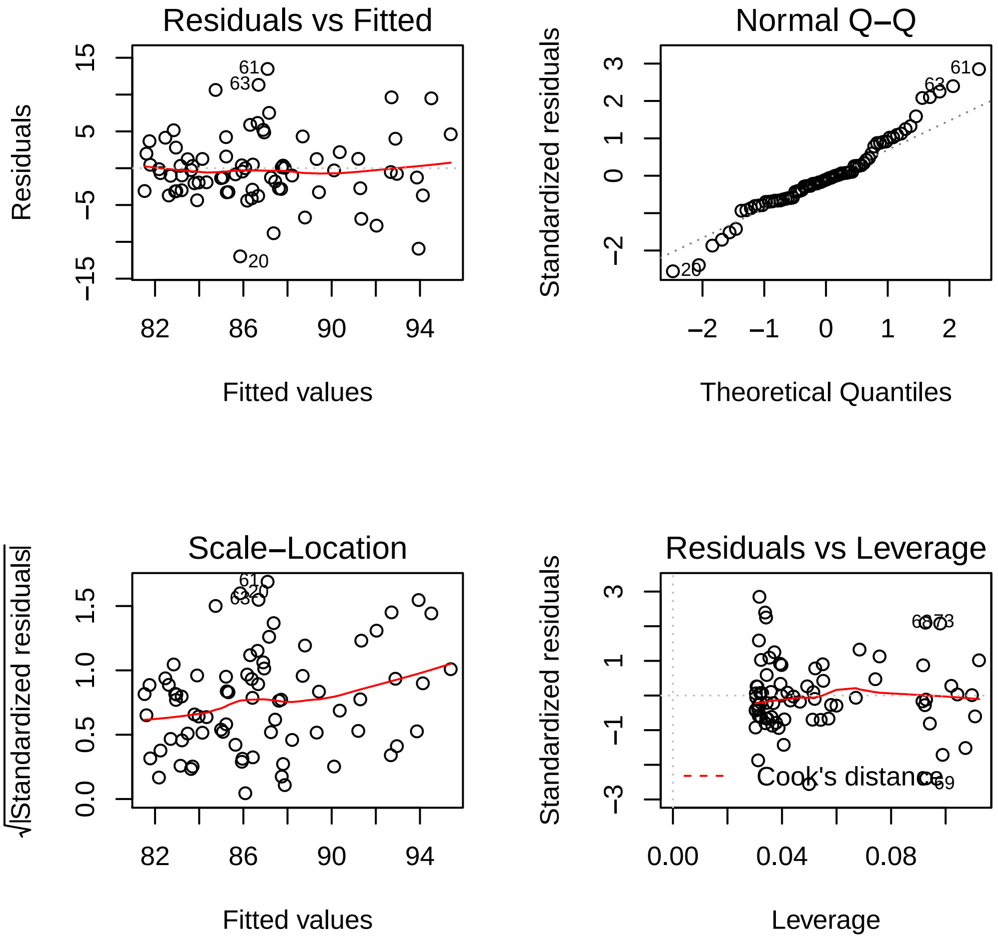

Figure C.5 Diagnostic plots of best fit of length at recapture at Chipps Island to environmental variables.

TRAWL – length by race at Chipps Island.

Unlike the CWT lengths from hatchery specific releases, the aggregated relative Spring and Fall lengths remain consistent from the 1980's until present. Spring run appear to be consistently larger that Fall run (see Figure C.6). Regression results are shown in Table C.5 and indicate that Yolo flow, the Central Valley Project exports, the export to inflow ratio, water passing via the Delta Cross Channel, and the bass index are all significant predictors of size. The Adjusted R-squared of the best fit shown is 0.785. The diagnostic plots of the best fit is shown in Figure C.7. The TRAWL dataset had the largest samples, and despite being aggregated wild and hatchery fish, and despite not identifying source drainages, the regression results yield the highest R-squared. The diagnostics show normality in residuals as well as the majority of residuals concentrated on predicted theoretical quantiles.

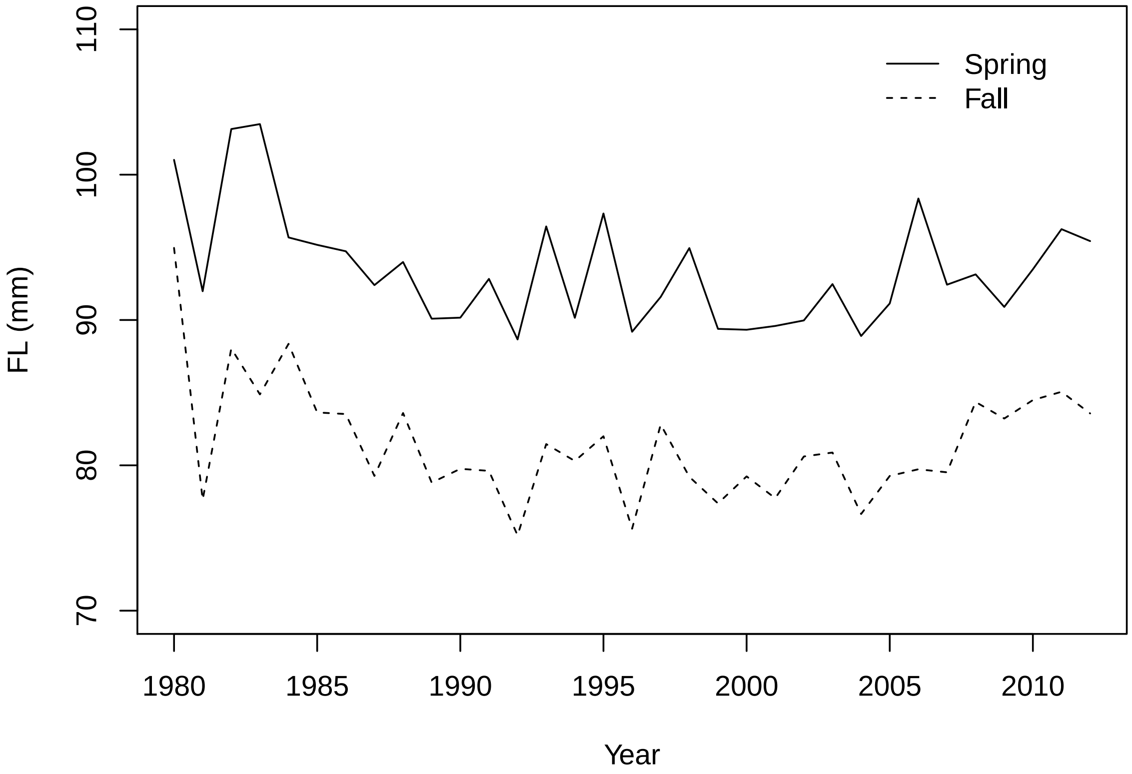

Figure C.6 Lengths of Spring and Fall aggregates at Chipps Island in TRAWL data.

Table C.5 Regression results of best fit of trawl lengths to environmental variables.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(Intercept)	80.9897	0.7322	110.604	<2.00E-16	***
race Spring	11.4344	0.8359	13.678	<2.00E-16	***
Yolo flow	0.99	0.5468	1.811	0.075288	.
CVP	2.6729	0.7082	3.774	0.000375	***
EXPIN	-2.5741	0.7566	-3.402	0.001206	**
GEO	-1.4716	0.6551	-2.246	0.028449	*
BASS	-1.8643	1.0438	-1.786	0.079228	.

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

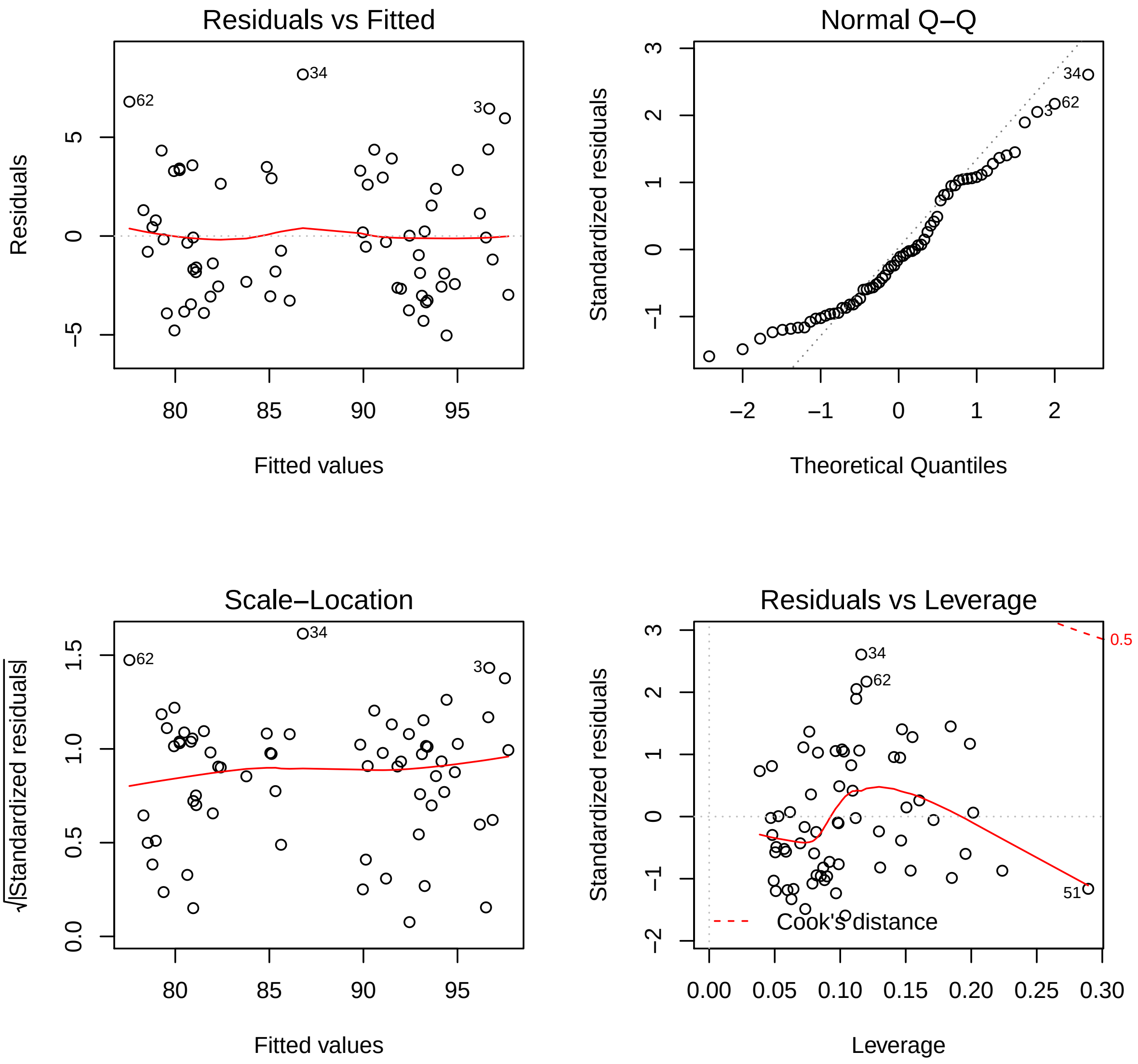

Figure C.7 Diagnostic plot of best fitting model of relationship between length at Chipps Island mid-water trawl and environmental variables.

RST – Lengths in tributaries

Mill, Deer, and Butte creek Spring run average fish sizes from rotary screw trap operations are shown in Figure C.8. We see that Mill, Deer and Butte creeks are on average about 45-55 mm in length between January and June when records were aggregated for outmigration estimates. The temporal pattern in sizes is shown in Figure C.9. We see no major trend in size in tributaries between January and June, only that Butte creek fish appear to run a bit smaller.

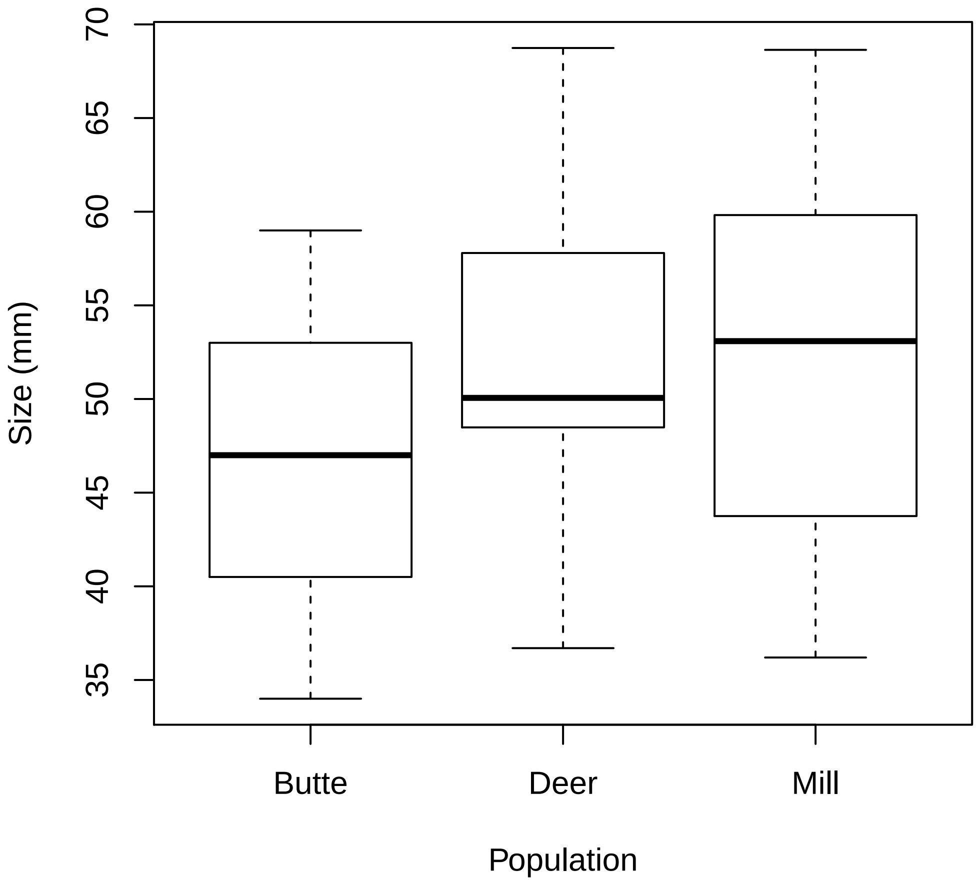

Figure C.8 Average size of juveniles obtained from rotary screw traps operating in Butte, Deer and Mill creeks between January and June.

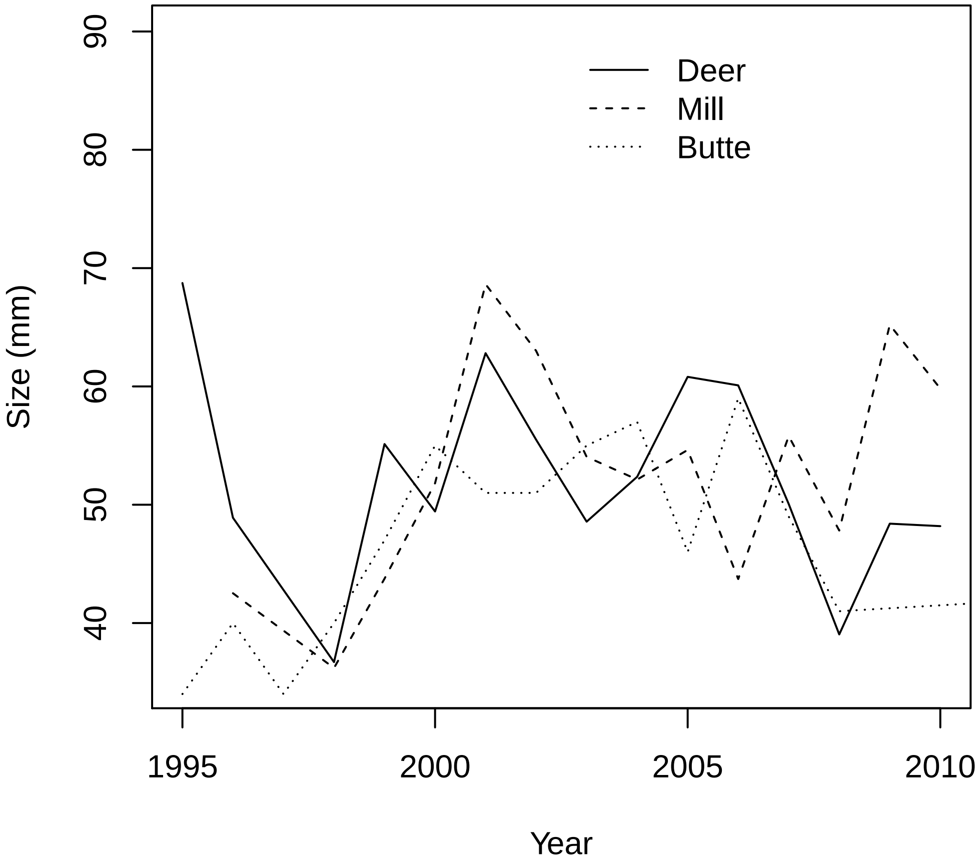

Figure C.9 Temporal trend in juvenile sizes obtained from rotary screw traps operating in Deer, Butte and Mill creeks between January and June.

DISCUSSION

This analysis drew upon varied sources of fish length information in the Sacramento River drainage. The summary of rotary screw trap lengths indicates that Spring run out-migrating Chinook from Deer, Mill and Butte creeks are approximately the same size, and have been stable at approximately 55 mm in recent years. Regression analysis of recoveries from mid-water trawl surveys at Chipps Island indicates that growth of fish from North of the Delta to Chipps Island, as well as the length at recapture in Chipps Island trawls varied in relation to environmental variables. Regression analyses showed that the length at Chipps Island from the perspective of two different types of length statistics proved to be related to environmental variables regardless of the data source of the length estimates.

We used two different growth metrics. One growth metric came from lengths of CWT recoveries and releases of hatchery fish, and the other came from seine and trawl surveys. The CWT growth was derived from average recovery length at Chipps Island and average release lengths at various release locations and times. The average recovery length is a statistic based on a very small sample size relative to the release length statistic. If you consider the how many fish are released relative to recaptured, and if you consider that tagged fish are released at various locations and at different times, it is easy to see how biased the growth estimate might be. The SEINE/TRAWL growth estimate made no distinction between hatchery and non-hatchery fish and it represents an estimate of the growth of all Fall or Spring run fish between Region 1 seines and Chipps Island. In comparison to the CWT estimate, it will be more complex in it's stock composition (with hatchery and non-hatchery fish of all origins), but it is much simpler in upstream capture and release size sampling. All stocks were sampled from the same locations for sizing regardless of origin. We found a relationship between SEINE/TRAWL growth and environmental variables, but no relationship between CWT growth and environmental variables. This may be due to the complexity of how the release length was calculated for the CWT growth estimate.

The environmental predictors that best explained growth were the Central Valley Project exports (CVP), the ratio of combined state and federal exports to the total Delta inflow (EXPIN), and the bass index. CVP and EXPIN are both related to flows in complex ways. CVP is related to flow because exports would tend to be less restricted at higher flows, but would have its highest impact when flows are low. We would expect that juvenile salmon growth could be high when CVP is highest under that logic. EXPIN is related to flow by a similar logic, but since EXPIN is a ratio, we would expect the largest fraction of flows to be exported when flows are low (for a given level of exports). We would expect juvenile salmon growth to be lowest when EXPIN is highest at the lowest flows.

Figure C.10 illustrates some the general patterns in environmental covariation. In the upper left panel we see that CVP has the greatest degree of variability at the lowest flows (with Yolo flow being used as a surrogate for average flow at export locations). Across a range of flow values we can see that the lower bound of CVP increases. This is consistent with a general tendency of reducing exports at lower flows. The relative impact of exports at a given flow is seen with EXPIN, which we see (lower left) diminishes at higher flows. We also see that more water reaches downstream to the Mokelumne river when EXPIN is lower (lower right panel). Finally, there is a general pattern of CVP being larger when EXPIN is higher, but recall that the highest EXPIN may coincide with low flows.

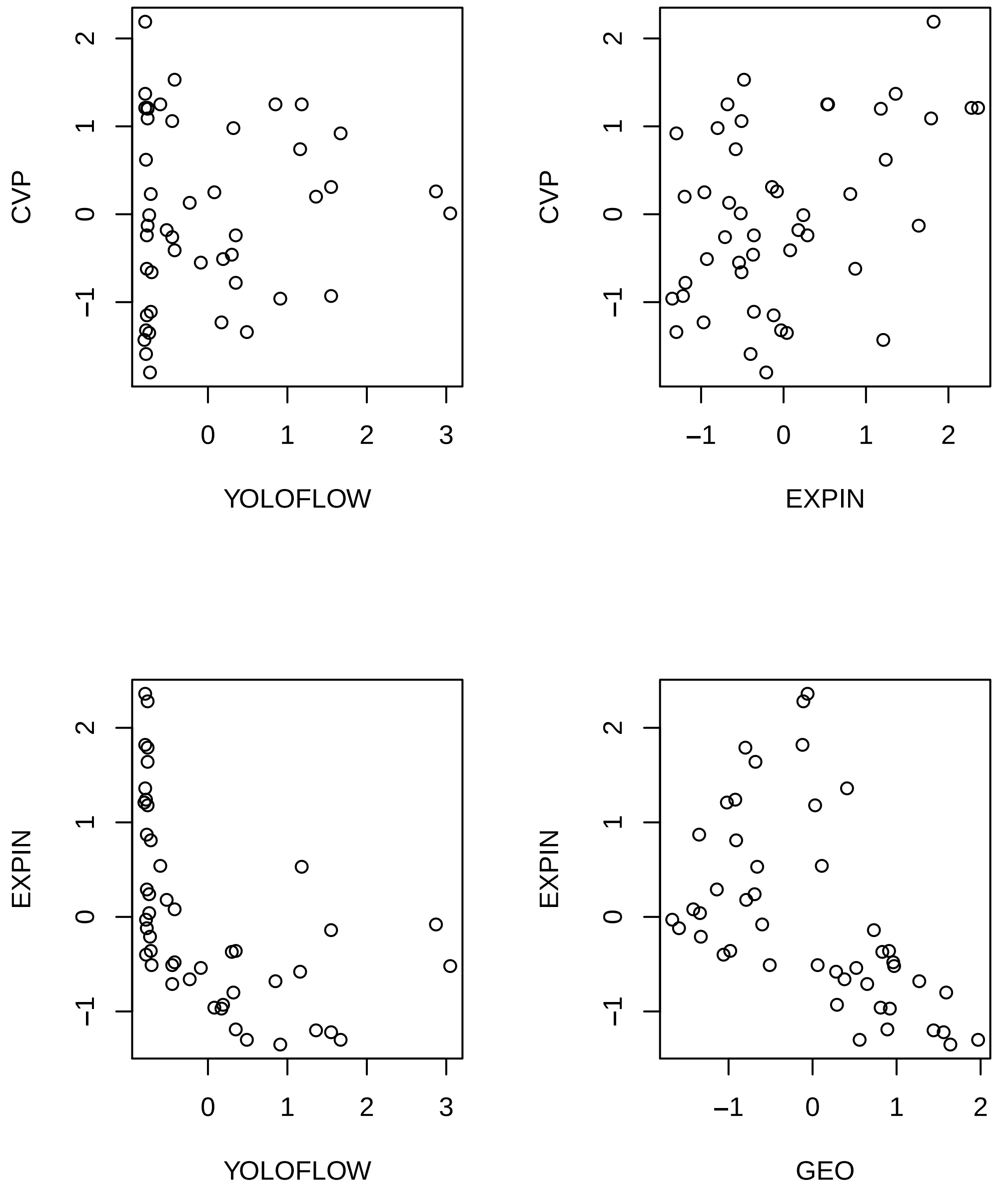

Figure C.10 Covariation between significant environmental predictors.

EXPIN was a significant predictor of length when both CWT and TRAWL datasets were used. It was significant with p<0.01 in both cases. EXPIN was also a significant predictor (p<0.01) of growth estimates of Fall and Spring aggregates obtained from the SEINE/TRAWL dataset. The CWT length regression is in conflict with the SEINE/TRAWL growth regression and the TRAWL length regression though. The CWT result predicts a positive effect of EXPIN, versus a negative effect for the other two regression analyses. A possible reason for this would be that the CWT dataset was exclusively measuring hatchery fish (although hatchery fish would also have been present in the other two analyses). If EXPIN has a positive effect on hatchery fish length at Chipps Island as shown in the CWT length regression, and a negative effect on the aggregate of both hatchery and non-hatchery fish seen in the TRAWL length and SEINE/TRAWL growth analysis, it might suggest that that the negative effect on non-hatchery growth is even stronger than seen in the TRAWL surveys. It could also be a size related issue. If hatchery fish are smaller and more vulnerable to entrainment, removal of the smaller fish from the out-migrating cohort would make it appear as if they grew on average, when in fact it was just the smaller ones that did not make it into the downstream survey sample.

The relationship between flows and exports, and resulting growth and survival are complex. We found that growth and length are negatively related to EXPIN, but positively related to CVP. A possible mechanism, is that there is a threshold flow/export relationship where in smaller fish become more vulnerable to entrainment. Such a mechanism would predict that more larger fish than smaller fish make it downstream to be sampled at Chipps Island, which has the effect of making the growth appear larger on the basis of the average recovery size. This would appear to be favorable growth conditions despite the fact that all individuals did not grow better on those conditions. If a relatively high CVP export year were where to coincide with an average flow year, and if more small fish were entrained, it would appear that fish where larger at Chipps Island.

Results also indicated that Spring run were longer at Chipps Island, despite the fact that the SEINE/TRAWL regression showed that Spring run growth was less than Fall run. Total Central Valley Projects (combined state and federal) exports showed positively effect on growth in the SEINE/TRAWL regression and length in the TRAWL analysis. Since there was a negative effect from the export to inflow ratio, it may be suggest that total flows have a positive effect, and that there may be a relationship between exports and flows that is dictated by water extraction policies.

It is interesting that regression results show that bass has a positive effect on the growth estimates evaluated from the SEINE/TRAWL, yet has a negative effect on lengths estimated from the TRAWL data. Since the bass index is not standardized to effort, it can’t imply a direct predation rate change on a size class of Chinook juveniles, but depending on the relationship between the index and the size of the bass caught, it might imply a shift in the size of Chinook vulnerable to bass predation at a given abundance of bass. It could be that smaller fish are more vulnerable and predation biases the growth estimate by removing smaller fish.

Our examination of length/growth sensitivity to environmental variation points to a few results. First, EXPIN is a statistically significant predictor of size and growth, with a negative effect on both. Our samples conflate the story a bit, but if you consider that the only positive effect was seen in the length of hatchery fish, and if you consider that the CWT dataset had race and hatchery factors, the positive effect of EXPIN in the regression result of the CWT data should not detract from the regression results found in both the SEINE/TRAWL and TRAWL dataset. It should be noted however, that the highest regression coefficient value for an environmental effect in any of our regressions was about 5, meaning that about 5 mm per standard deviation was the maximum variability in size predicted by variability in an environmental effect. This implies that at the extreme of 2 standard deviations, only 10 mm of net difference in size at Chipps Island would be predicted. Still, two standard deviations explains about 95% of the variation in environmental factors, and 10 mm explains 10-15% of the variability in length at Chipps Island (assuming 85 mm length at Chipps Island). Since the same environmental variables explain significant variation in rearing survival, it is feasible that length may be an instrumental in the mechanism of rearing survival.

REFERENCES

Brandes, P.L. and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Pages 39 – 138 *in* R.L. Brown, editor. Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179. California Department of Fish and Game, Sacramento, California.

California Department Of Fish And Game. 1998. Butte Creek Spring-Run Chinook Salmon, *Oncorhynchus Tshawytscha*, Juvenile Outmigration And Life History 1995-1998. Administrative Report No. 99-5.

California Department Of Fish And Game. 2000. Butte And Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha* Life History Investigation 1998-2000. Administrative Report No. 2004-2.

California Department Of Fish And Game. 2004. Butte And Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha* Life History Investigation 2000-2001. Administrative Report No. 2004-3.

Garman, C.E and T. R. McReynolds. 2008. Spring-Run Chinook Salmon, Oncoryhnchus tshawytscha, Life History Investigation. California Department of Fish and Game. Inland Fisheries Administrative Report No. 2009-1.

U.S. Fish and Wildlife Service – Stockton Fish and Wildlife Office. March 2014. Metadata for the Stockton Fish and Wildlife Office’s Delta Juvenile Fish Monitoring Program. http://www.fws.gov/stockton/jfmp/.

APPENDIX C: GROWTH ANALYSIS AND MODELLING

In this appendix we provide a description of the methods we used to collect and analyze length information from various state and federal collection facilities in the Sacramento drainage. We assembled time series of lengths, both upstream and downstream, for both hatchery fish and combined hatchery and wild aggregates. Where possible, we used upstream and downstream lengths to obtain annual growth estimates. In the absence of a downstream growth measurement, we assembled a time series of downstream lengths. We performed regressions on growth and length estimates, evaluating impacts of environmental conditions on growth.

INTRODUCTION

The life-cycle modeling analysis in this project attempts to attribute variability in survival to environmental factors during different parts of the life history. Survival can be affected by the environment in complex ways, and can be mediated through biotic and abiotic processes. We posit that size can play a role in predicting survival, and that growth itself can be an indicator of survival as well. An obvious mechanism for size effects on survival would be that larger fish are less vulnerable to predation than smaller fish. A mechanism for growth being a predictor of survival would be that faster growing fish are likely to be experiencing better feeding conditions and bioenergetic advantages, and therefore should survive better.

In this appendix we look for relationships between environmental conditions and growth, but because growth requires two measurements (a capture and a recapture, or a release and recapture), we are not always able to get an estimate of a growth increment. Some length estimates obtained from survey data cannot be connected to later surveys, and therefore a growth estimate can’t be derived from the measurements. An example of this occurs with rotary screw traps operating in tributaries, where juvenile size samples are obtained during rearing and migration. Those sizes are not directly comparable to later samples obtained downstream, because the downstream samples are aggregates of all the independent upstream sampled lengths. We might be able to document a pattern in upstream sizes over the years, but growth to the downstream measurement can’t be inferred. We therefore treat size as a surrogate for growth, with the assumption that annual variability in juvenile size is in actual fact a measurement of annual variability in growth since all fish must at some point have emerged from the gravel at roughly the same sizes.

METHODS

We performed an analysis of length and growth patterns for Spring and Fall run Chinook in the Sacramento River in relation to environmental factors. We collected size at release and recapture data from state and federal agencies. We compiled records into average sizes at release for several different stock aggregates that provided adequate sample sizes for the years the data were available. In some case, it was possible to associate the length of a downstream recaptured fish with a known upstream release size to obtain a growth increment estimate, but in other cases only the downstream size record was available. Upstream length records were obtained from hatchery release information, from screw traps operated in tributaries, and from seine surveys operated throughout the Sacramento drainage. The farthest downstream sizes were obtained from Chipps Island, where mid-water trawl surveys collected size information and recorded the race of the fish based on the presence of a CWT or a length based estimated based on the length of the fish at the time the sample was obtained.

Data compilation

Length data

The Pacific States Marine Fisheries Commission manages and supports the Regional Mark Processing Center (RMPC; http://www.rmpc.org/), which in turn manages the Regional Mark Information System (RMIS). Agencies and organizations throughout the Western United States report CWT data directly to the RMIS. The Delta Juvenile Fish Monitoring Program (DJFMP) was initiated in the 1970s and is managed by the US Fish and Wildlife Service (USFWS, 2014). The program has a stated objective to monitor the effects of water projects in the Bay Delta on juvenile Chinook.

The number of juvenile salmon leaving freshwater during the spring has been sampled annually since 1978 by means of mid-water trawling in the estuary near Chipps Island (Brandes and McLain 2001). The Trawl site in Suisun Bay is sampled three days per week year round. It is sometimes sampled daily and at times two shifts per day for a total of 20 tows per day during May and June. During December and January, trawls occur 7 days per week with ten 20 minute trawls conducted daily. Catch limits are imposed when Delta Smelt catches exceed 8 individual Delta Smelt. The trawl survey records fish length at capture and creates a record of the race, origin and release location if a coded wire tag is detected.

We used data that had been collected since 1979 in mid-water boat trawls at Chipps Island, Suisun Bay (Zone 10 S UTM, 4211218N, 595531E). Data from the DJFMP is available online (http://www.fws.gov/stockton/jfmp/). USFWS tables available online contained metrics of juvenile Chinook salmon that had been marked with CWTs, released throughout the Sacramento - San Joaquin Basin and then recovered near Chipps Island in Suisun Bay (Coded *Wire Tag 1978 -2011.xls* and *Coded Wire Tag 2012 -2013.xls*). Survey records not containing CWTs can be found in the spreadsheets *Chipps Island Trawls 1976-2011.xlsx and Chipps Island Trawls 2012-2014.xlsx.*

We used the records from the Chipps Island trawls to create a database of fish lengths and growths increments for all fish with CWTs (referred to as the CWT table). Each fish with a CWT is of a known origin, so the race and the source (hatchery or wild stock origin) are also known. We used the remaining records from the Chipps Island survey to construct a database table of Chinook known to be of a given race, but where the origin is not known. These records were assembled into a table we refer to as the TRAWL table, which only distinguishes between Fall and Spring runs.

We compiled juvenile salmon length data from the Sacramento watershed and the San Francisco Bay Delta into a relational database in order to determine growth of hatchery Fall Chinook and hatchery and wild juvenile Spring Chinook. Wild Spring stocks included Deer, Mill and Butte creeks. Butte Creek fish were release and recaptured in Butte Creek, the Sutter

Bypass or near Chipps Island in Suisun Bay. Release and recovery data were compiled from three sources: California Department of Fish and Wildlife (CDFW), US Fish and Wildlife Service's Delta Juvenile Fish Monitoring Program (DJFMP) and the Regional Mark Processing Center (RMPC).

From 1995 to 2001, the CDFW captured, measured, marked, and released wild spring-run Chinook on Butte Creek (CDFG, 1999; CDFG, 2004-2; CDFG, 2004-3). The purpose of the CDFW program was to estimate adult escapement, monitor timing and abundance of juvenile outmigration, and monitor relative growth rates in the Butte Creek system. Fish were captured and marked with adipose fin clips and coded wire tags at the Parrot-Phelan Diversion Dam (PPDD; Zone 10 S UTM, 4396287N, 611463E). Releases took place at three locations, but varied from year to year. Release sites were: PPDD, Baldwin Construction Yard (approximately one mile downstream of the PPDD) and Adams Dam (approximately 7 miles downstream of PPDD). After release, marked fish were subject to recapture and sacrifice at downstream locations in Butte Creek, the Sutter Bypass and the Sacramento Delta near Chipps Island. Rotary screw traps were used to recapture fish at all locations and an off-stream fish screen outfitted with a trap box was used to collect fish at the PPDD site. Recaptured fish were sacrificed, measured for fork length and their CWTs were extracted and read. We received programmatic data formatted in a Microsoft Access database directly from the CDFW (C. Garman, personal communication, 1/30/2014).

We queried the RMIS database for juvenile Chinook that had been marked and released at any location in the Sacramento drainage. The RMIS table was then related by CWT code to Chipps Island mid-water trawl and Sacramento River recoveries. In this way, we queried recoveries with release locations only within the Sacramento Basin.

We obtained tributary measurements of juvenile lengths from rotary screw traps (RSTs) operating in Butte creek, Mill creek and Deer creek. Rotary screw traps were operated by the US Fish and Wildlife Service in Mill and Deer creeks, and by the California Department of Fish and Wildlife in Butte creek. Screw trap operation spanned 1995-2010 in the records used in this analysis. We used samples obtained from January to June of each year to obtain estimates of tributary outmigration size.

Environmental data

We compiled time series of environmental variables that pertain to the experiences of downstream migration juveniles. For Spring Run, we used discharge at the three creeks (Deer, Mill and Butte), flow, exports volumes and other export indices, and a CPUE index of bass abundance. Flow temperature and discharge were obtained from USGS gauging stations (http://waterdata.usgs.gov/nwis/inventory). Exports and other dayflow parameters were obtained from water project data available on the California department of water resources website (http://www.water.ca.gov/dayflow/output/Output.cfm). Environmental variables were normalized by subtracting the mean and dividing by the standard deviation. The variables are summarized in Table C.1 for Spring run and in Table C.2 for Fall run.

Table C.1 Environmental variables used in length and growth analysis of Spring Chinook.

Covariate	Description	Location	Data Origin
Deer discharge	Average monthly water discharge (cfs) at Deer Creek	Vinna, Deer Creek	USGS 11383500 DEER C NR VINA CA
Mill discharge	Average monthly water discharge (cfs) on Mill Creek	Molinos, Mill Creek	USGS 11381500 MILL C NR LOS MOLINOS CA
Butte discharge	Average monthly water discharge (cfs) on Butte Creek	Chico, Butte Creek	USGS 11390000 BUTTE C NR CHICO CA
Yolo flow	Peak (maximum) streamflow into YOLO Bypass at Woodland, CA	Into Yolo at Woodland, CA	USGS 11453000 YOLO BYPASS NR WOODLAND CA
Bass	Index of Striped Bass abundance as number of striped bass kept. This is NOT effort standardized, but effort data is not available <1980	Delta	Marty Gingris personal comm.
GEO	The amount of water reaching the Mokelumne River system from the Sacramento River via the Delta Cross Channel and Georgiana Slough	Delta cross channel and Georgiana Slough	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO)
EXP	Accounts for all water diverted from the Delta by the Federal and State governments to meet water agreements and contracts. These include Central Valley Project pumping at Tracy (QCVP), the Contra Costa Water District Diversions at Middle River (new for WY 2010; data begin on 01AUG2010), Rock Slough, and Old River (QCCC), the North Bay Aqueduct export (QNBAQ), and State Water Project exports (Banks Pumping Plant or Clifton Court Intake, QSWP).	South Delta	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS).
EXPIN	The Export/Inflow Ratio is the combined State and Federal Exports divided by the total Delta inflow (QTOT). EXPIN = (QCVP+QSWP-BBID)/QTOT (8)	Delta	Dayflow: Export/Inflow Ratio (EXPIN)

CD	The Dayflow parameter net channel depletion (QCD) is an estimate of the quantity of water removed from Delta channels to meet consumptive use (QGCD)	Delta	Dayflow: Net Channel Depletion (QCD)
CVP	Dayflow parameter for Central Valley Project pumping at Tracy (QCVP)	Delta	

Table C.2 Environmental variables used in length and growth analysis of Fall Chinook

Covariate Name	Description	Location	Data Origin
Keswick discharge	Average monthly water discharge (cfs) at Keswick Dam	Keswick Dam	USGS 11370500 SACRAMENTO R A KESWICK CA
Battle discharge	Average monthly water discharge (cfs) on Battle Creek	Cottonwood, Battle Creek	USGS 11376550 BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA
Battle height	Peak guage height for the water year	Cottonwood, Battle Creek	USGS 11376550 BATTLE C BL COLEMAN FISH HATCHERY NR COTTONWOOD CA
Feather discharge	Average monthly water discharge (cfs) on the Feather River	Oronville, Feather River	USGS 11407000 FEATHER R A OROVILLE CA
Feather temp	Feather River average maximum temperature from USGS gage with (daily) interploations from Sacramento, CA air temperature (1992+)	Oronville, Feather River	USGS 11407000 FEATHER R A OROVILLE CA
American temp	American River average maximum temperature from USGS gage with (daily) interploations from Sacramento, CA air temperature (~1978-1998)	Fair Oaks, American River	USGS 11446500 AMERICAN R A FAIR OAKS CA
Yolo flow	Peak (maximum) streamflow into YOLO Bypass at Woodland, CA	Into Yolo at Woodland, CA	USGS 11453000 YOLO BYPASS NR WOODLAND

			CA
Bass	Index of Striped Bass abundance as number of striped bass kept. This is NOT effort standardized, but effort data is not available <1980	Delta	Marty Gingris personal comm.
GEO	The amount of water reaching the Mokelumne River system from the Sacramento River via the Delta Cross Channel and Georgiana Slough	Delta: DCC and Georgiana Slough	Dayflow: Delta Cross Channel and Georgiana Slough Flow Estimate (QXGEO)
EXP	Accounts for all water diverted from the Delta by the Federal and State governments to meet water agreements and contracts. These include Central Valley Project pumping at Tracy (QCVP), the Contra Costa Water District Diversions at Middle River (new for WY 2010; data begin on 01AUG2010), Rock Slough, and Old River (QCCC), the North Bay Aqueduct export (QNBAQ), and State Water Project exports (Banks Pumping Plant or Clifton Court Intake, QSWP).	South Delta	Dayflow: Total Delta Exports and Diversions/Transfers (QEXPORTS).
EXPIN	The Export/Inflow Ratio is the combined State and Federal Exports divided by the total Delta inflow (QTOT). EXPIN = (QCVP+QSWP-BBID)/QTOT (8)	Delta	Dayflow: Export/Inflow Ratio (EXPIN)
CD	The Dayflow parameter net channel depletion (QCD) is an estimate of the quantity of water removed from Delta channels to meet consumptive use (QGCD)	Delta	Dayflow: Net Channel Depletion (QCD)
CVP	Dayflow parameter for Central Valley Project pumping at Tracy (QCVP)	Delta	Dayflow: Central Valley Project Pumping (QCVP)
SWP	Dayflow parameter for State Water Project exports (Banks Pumping	Delta	Dayflow: State Water Project Pumping

	Plant or Clifton Court Intake, QSWP)		(QSWP)

Length and Growth analysis

We examined environmental factors affecting length at recapture at Chipps Island of fish with known and unknown release lengths. Where length at release was known, we examined growth rates. We associated each size and growth record with environmental factors experienced by each race of salmon each year the sizes were recorded. We compared fall and spring length at capture at Chipps Island from two separate surveys. The CWT table provided an estimate of growth for fall and spring hatchery releases. The mid-water trawls did not distinguish between wild and hatchery fish, so those analyses pertain to the race as a whole, without distinction about release locations or wild/hatchery distinctions. We also obtained sizes from DJFMP seines in Region 1 (upstream from the Delta) and compared those sizes with Chipps Island size information. Since seine samples do not distinguish between populations, growth obtained from subtracting upstream seine sizes from Chipps Island trawl sizes provide estimates of aggregate Fall and Spring run sizes, but cannot distinguish between release locations or between wild and hatchery releases.

SEINE/TRAWL - growth by race from mid-Sacramento to Chipps Island.

We queried the DJFMP seine database to obtain estimates of growth for Spring and Fall runs. Region 1 of the DJFMP beach seine runs from Colusa State Park to Elkhorn. We averaged lengths of Spring and Fall seine lengths for each year for fish collected between January and June, and compared those to Chipps Island midwater trawl sizes. The trawl survey assigned fish to Fall and Spring runs based on size ranges and records indicated that all collections occurred in May and June. We calculated the growth for each race of fish each year as the difference between the average trawl length and the average seine length. We refer to these growth estimates as the SEINE/TRAWL dataset.

We examined growth patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of growth in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found.

CWT –growth and length by hatchery source.

When hatchery fish are released, the average size of a sample of the release batch is used as the release length of record for fish in the batch. When recaptures occur at Chipps Island, a record for each fish recaptured can be compared to a release length record on the basis of CWT codes. To get reasonable sample sizes for recaptures, we were forced to aggregate hatchery releases such that release locations were ignored. We aggregated all release locations within the Sacramento drainage for each hatchery source. Since a release batch contains a range of lengths, it is possible for the smallest recaptured fish to be smaller than the average released fish. The growth record for each year was calculated as the average of all the recapture lengths minus the average release length. The average of release length was calculated as the weighted release length, weighted by the number released at each location at each time of release. We refer to the length and growth estimates from this method as the CWT dataset.

We tested for statistical relationships between size at recapture and environmental variables for Spring and Fall hatchery releases from Coleman National Fish Hatchery (CNFH) and Feather Fish Hatchery (FFH). We examined growth and length patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of growth and length in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found.

TRAWL – length by race at Chipps Island.

We selected records that were not limited to CWT tagged fish (the TRAWL dataset in this analysis) from Chipps Island, and assembled all records of Spring and Fall chinook to look at the size. By not being limited to CWT matches, the sample size was much larger than for the CWT matched database, but for the TRAWL dataset, the origin of fish could not be determined. The race of the fish was assigned by a length/timing criteria established by the DJFMP (the "Race Table" found at www.fws.gov/stockton/jfmp). Using these records we looked for temporal trends, comparisons between Spring and Fall runs, and relationships between size at capture and environmental factors. Annual average size records for Spring and Fall Chinook do not distinguish between hatchery and wild, and there is no growth estimate because the size at release is not known, and there is no way to distinguish between Butte, Mill, and Deer creeks. The TRAWL dataset provides an aggregate estimate of length at Chipps Island by race alone.

We examined growth patterns in relation to environmental variables listed in Tables C.1 and C.2. We performed stepwise linear regressions of length in relation to each variable, adding variables according to best p-value, and stopping when no further significant variables were found. We treat length as a surrogate for growth on the assumption that some initial length can be treated as a constant across and all variability can be thought of as occurring after that initial length.

RST – Lengths in tributaries

Deer, Mill, and Butte creek rotary screw trap records were queried to obtain estimates of outmigrating juvenile sizes. We took the average size of all samples obtained from the traps between January and June of each migration year. We attempted to match CWT releases from Butte Creek each year to recoveries within the Sacramento basin to obtain growth estimates at various sample locations, but found that recoveries were too few to obtain good estimates of growth. Butte Creek CWT release records with Chipps Island recapture events began in 1996, but recaptures amounted to fewer than 10 fish per year at Chipps Island. It was not possible to relate RST lengths to downstream lengths at Chipps Island for a growth estimate. We therefore limited our examination of RST data to showing temporal trends of sizes of Deer, Mill and Butte creeks.

RESULTS

SEINE/TRAWL - growth by race from mid-Sacramento to Chipps Island.

The average growth of Spring and Fall Chinook are shown in Figure C.1 along with the time elapsed between Seine surveys and mid-water trawls. The temporal trend in growth is shown in Figure C.2. Fall Chinook appear to be slightly larger and on average seen in seine surveys about half of a month later. Predominantly, Fall Chinook appear to grow slightly more between Seine and mid-water trawl surveys, which is noteworthy, since they do so in less time as seen in the average month seined calculation.

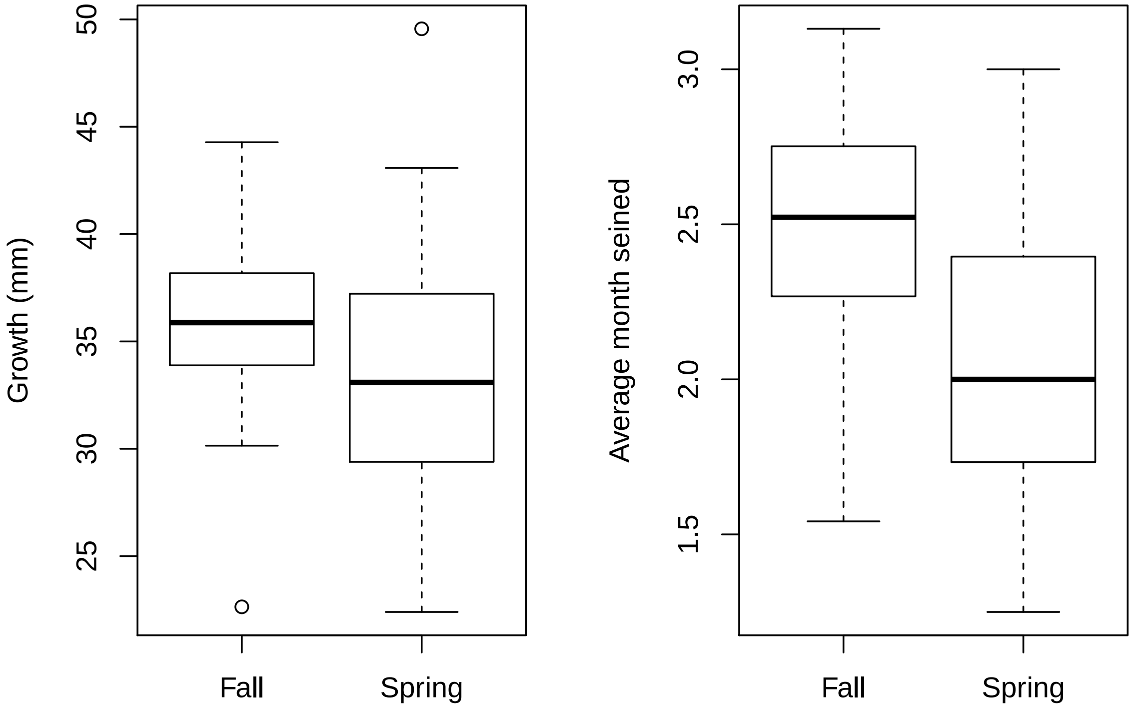

Figure C.1 Growth between release and sampling at Chipps Island (left panel) and month at which Region 1 seine was sampled (right panel).

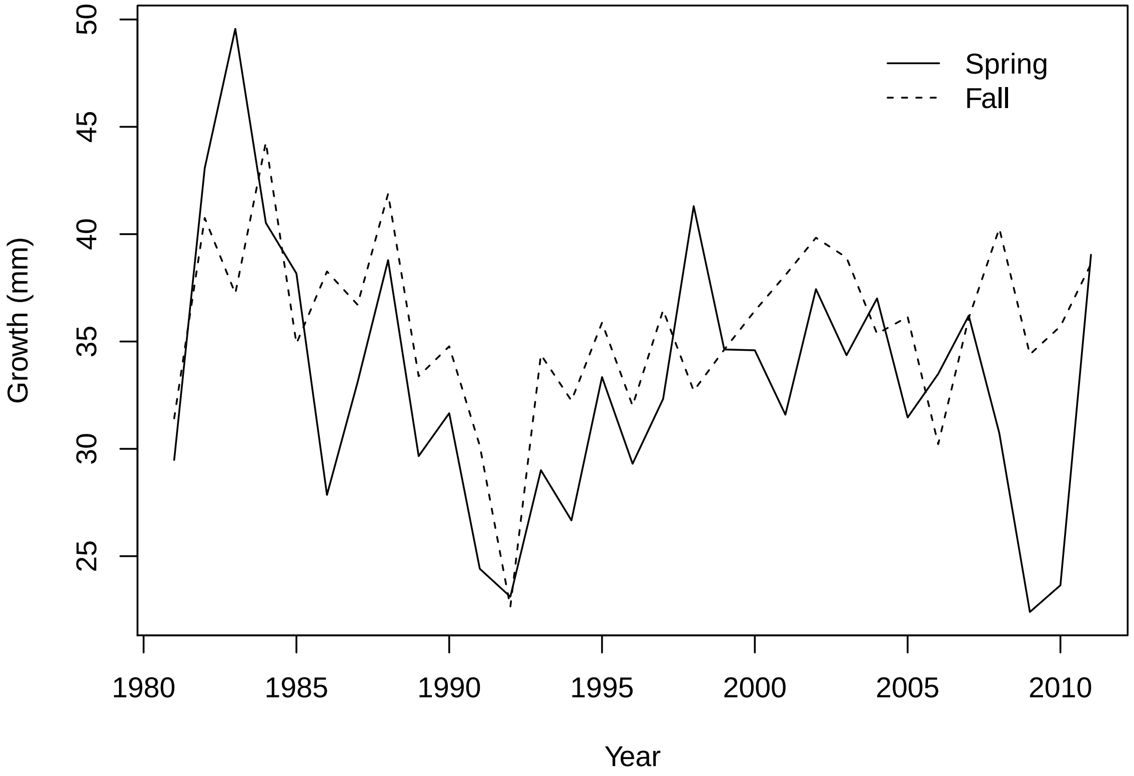

Figure C.2 Temporal trends in Spring and Fall Chinook growth evaluated from beach seine and mid-water trawl surveys.

Table C.3 shows the results of stepwise linear regressions. The regression results show that there are significant effects of Bass, Central Valley Project exports, race (spring or fall run) , and the export to inflow ratio (EXPIN). The bass index shows a positive effect on growth. Central Valley Project exports also show a positive effect, but the export to inflow ratio shows a negative effect. The adjusted R-squared value for the fit was 0.4068. The diagnostic plot of the fit is shown in Figure C.3.

Table C.3 Regression results of growth in SEINE/TRAWL data in relation to environmental variables. Intercept in parentheses.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(int-Fall)	38.3357	0.9227	41.546	<2.00E-16	***
Bass	5.4229	1.3838	3.919	0.000241	***
CVP	3.8959	0.7293	5.342	1.67E-06	***
Spring	-3.5728	1.0712	-3.335	0.001503	**
EXPIN	-1.3115	0.6071	-2.16	0.034961	*

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

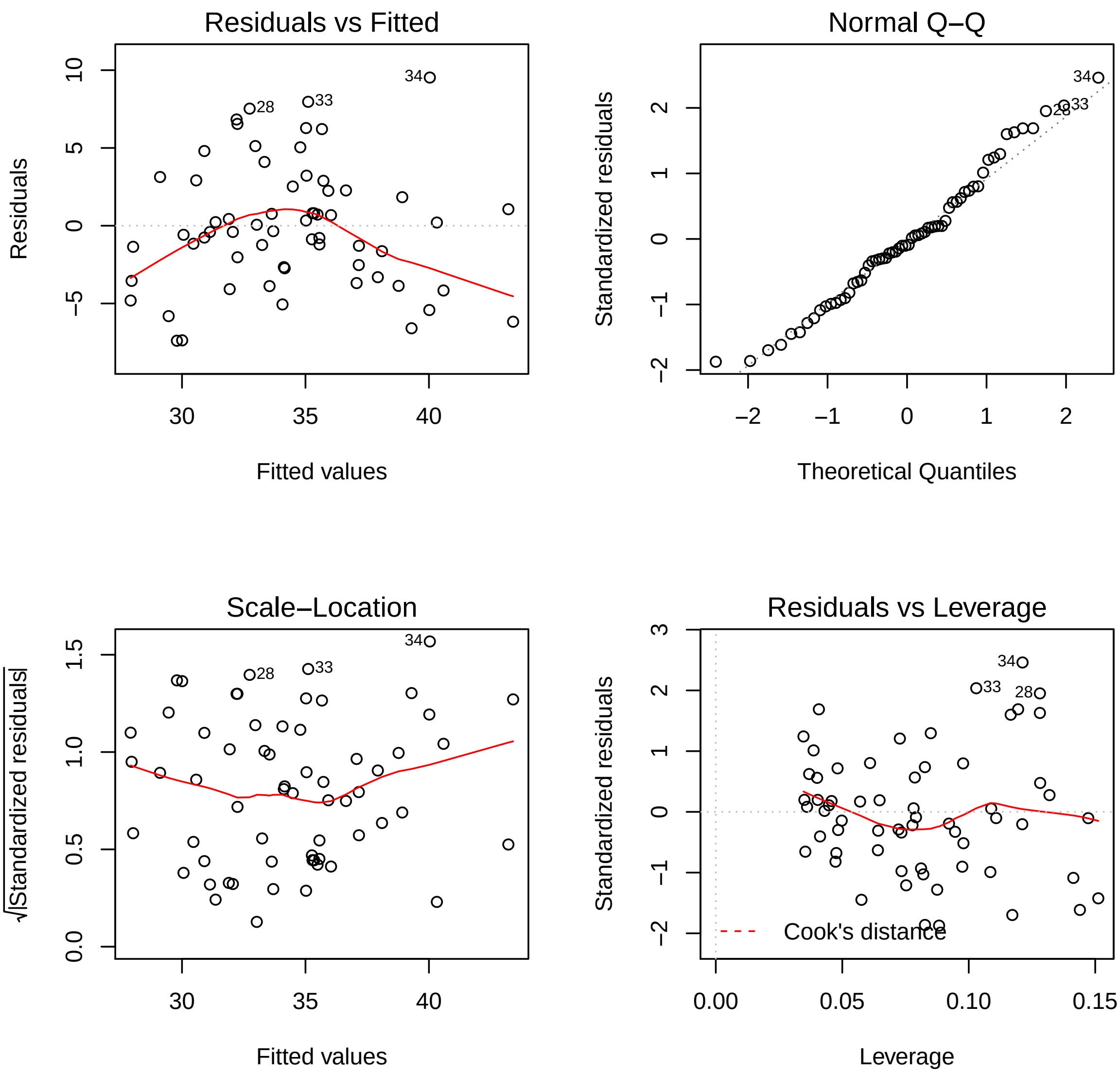

Figure C.3 Diagnostic plot of best fitting model of seine-trawl growth of Spring and Fall chinook.

CWT –growth and length by hatchery source.

Feather Fish Hatchery (FFH) spring Chinook and Coleman National Fish Hatchery (CNFH) fall Chinook growth and lengths at Chipps Island are shown in Figure C.4. We see that there is considerable variability in growth, and that Spring run fish appear to have grown faster than Fall run until the early 1990’s, but are now growing less than Fall run (see Figure C.4 upper panel). Table C.4 shows the results of stepwise regressions of length against all Spring and Fall run covariates. The export to inflow ratio was the only significant predictor of catch length in the Chipps Island trawl, with EXPIN having a positive effect. The adjusted R-squared for the best fitting model shown was 0.3414. Diagnostic plots of the best fit are shown in Figure C.5, where we can see that the residuals are normal. Regressions show a hatchery effect, finding that FFH fish arrive at Chipps Island 3.5 mm larger than CNFH fish, but FFH fish included Spring run, which were larger. Despite growth of Spring run recoveries appearing to decline from 1985, the lengths of Spring run fish at Chipps Island appears to be relatively constant. We found no significant relationships between growth and environmental variables.

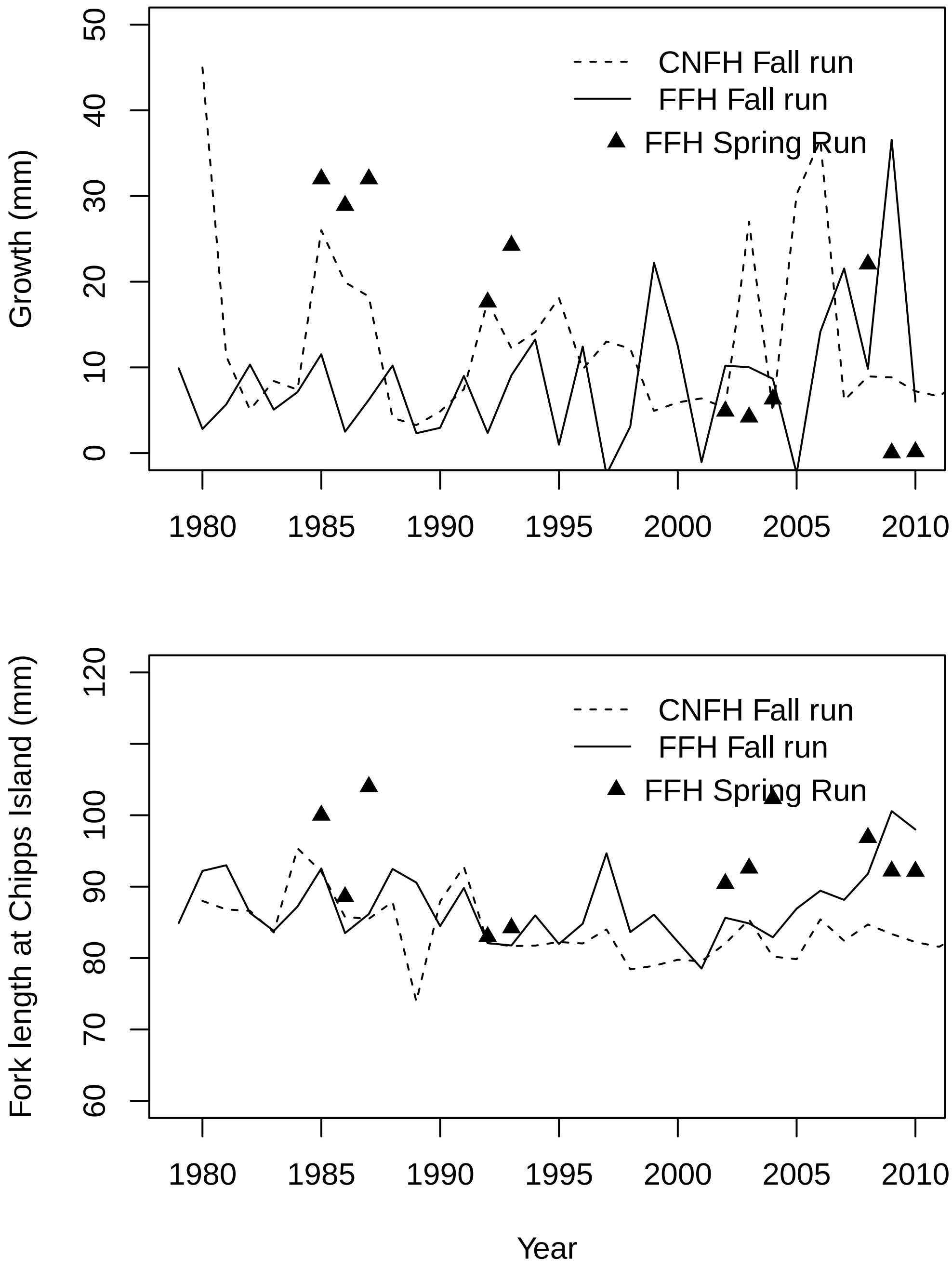

Figure C.4 Growth of CNFH and FFH Fall runs, and FFH Spring run (upper panel) and length at Chipps Island (lower panel).

Table C.4 Regression results of relationship between CWT length at Chipps Island and environmental variables. Intercept in parentheses for Fall CNFH.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(Intercept)	83.8357	0.8361	100.27	<2.00E-16	***
Race Spring	5.6019	1.6816	3.331	0.00137	**
EXPIN	1.7117	0.5764	2.969	0.00405	**
Source FFH	3.4654	1.1919	2.907	0.00484	**

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

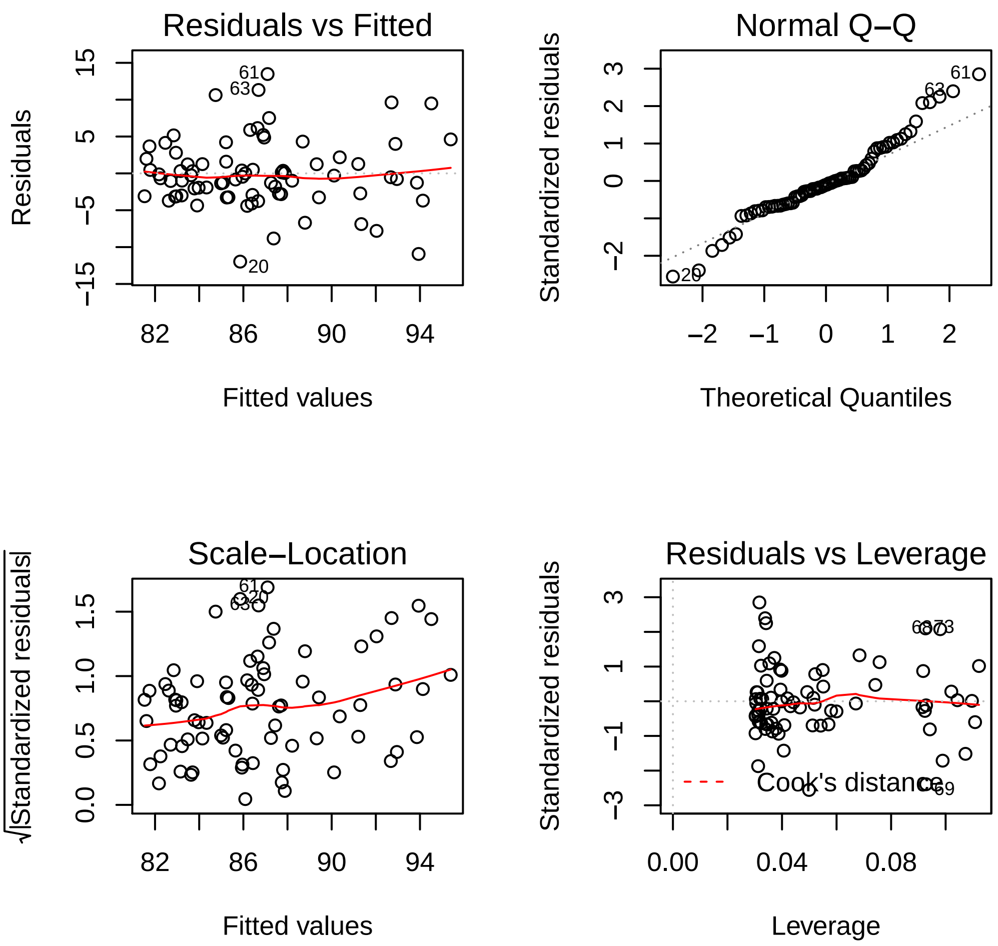

Figure C.5 Diagnostic plots of best fit of length at recapture at Chipps Island to environmental variables.

TRAWL – length by race at Chipps Island.

Unlike the CWT lengths from hatchery specific releases, the aggregated relative Spring and Fall lengths remain consistent from the 1980's until present. Spring run appear to be consistently larger that Fall run (see Figure C.6). Regression results are shown in Table C.5 and indicate that Yolo flow, the Central Valley Project exports, the export to inflow ratio, water passing via the Delta Cross Channel, and the bass index are all significant predictors of size. The Adjusted R-squared of the best fit shown is 0.785. The diagnostic plots of the best fit is shown in Figure C.7. The TRAWL dataset had the largest samples, and despite being aggregated wild and hatchery fish, and despite not identifying source drainages, the regression results yield the highest R-squared. The diagnostics show normality in residuals as well as the majority of residuals concentrated on predicted theoretical quantiles.

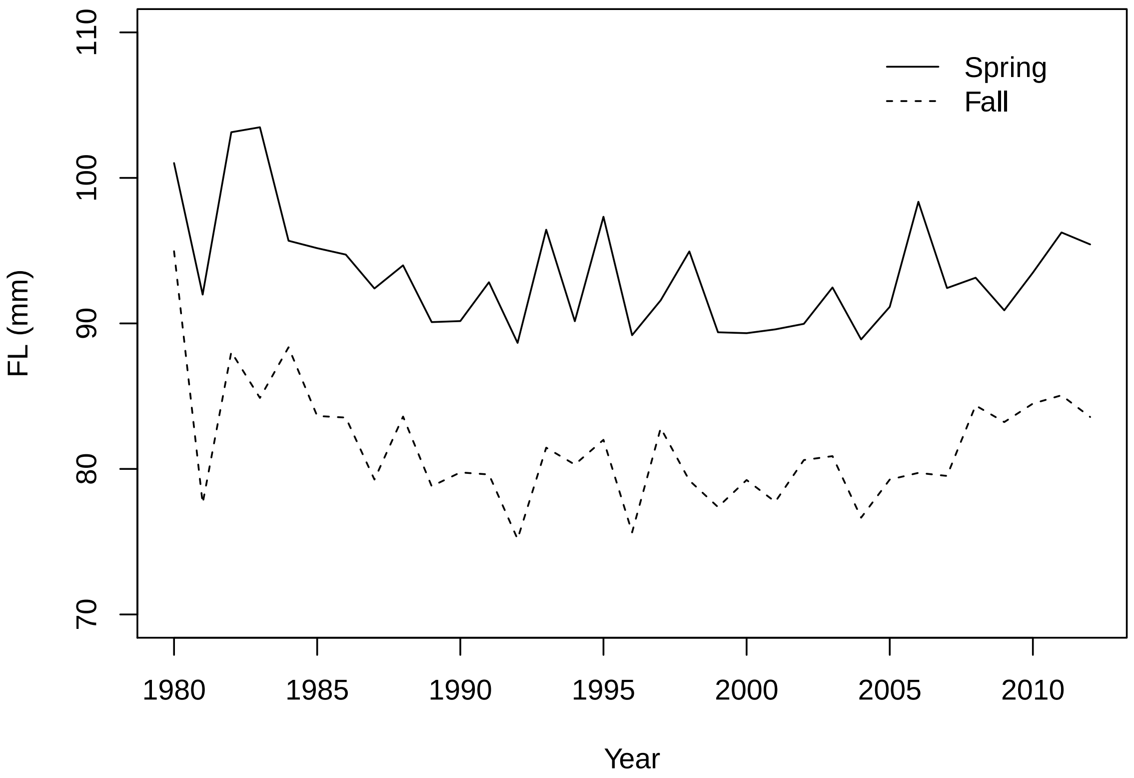

Figure C.6 Lengths of Spring and Fall aggregates at Chipps Island in TRAWL data.

Table C.5 Regression results of best fit of trawl lengths to environmental variables.

Coefficients:	Estimate	Std. Error	t value	Pr(>|t|)	Signif
(Intercept)	80.9897	0.7322	110.604	<2.00E-16	***
race Spring	11.4344	0.8359	13.678	<2.00E-16	***
Yolo flow	0.99	0.5468	1.811	0.075288	.
CVP	2.6729	0.7082	3.774	0.000375	***
EXPIN	-2.5741	0.7566	-3.402	0.001206	**
GEO	-1.4716	0.6551	-2.246	0.028449	*
BASS	-1.8643	1.0438	-1.786	0.079228	.

*** p<0.001, **p<0.01, *p<0.05, . p<0.1

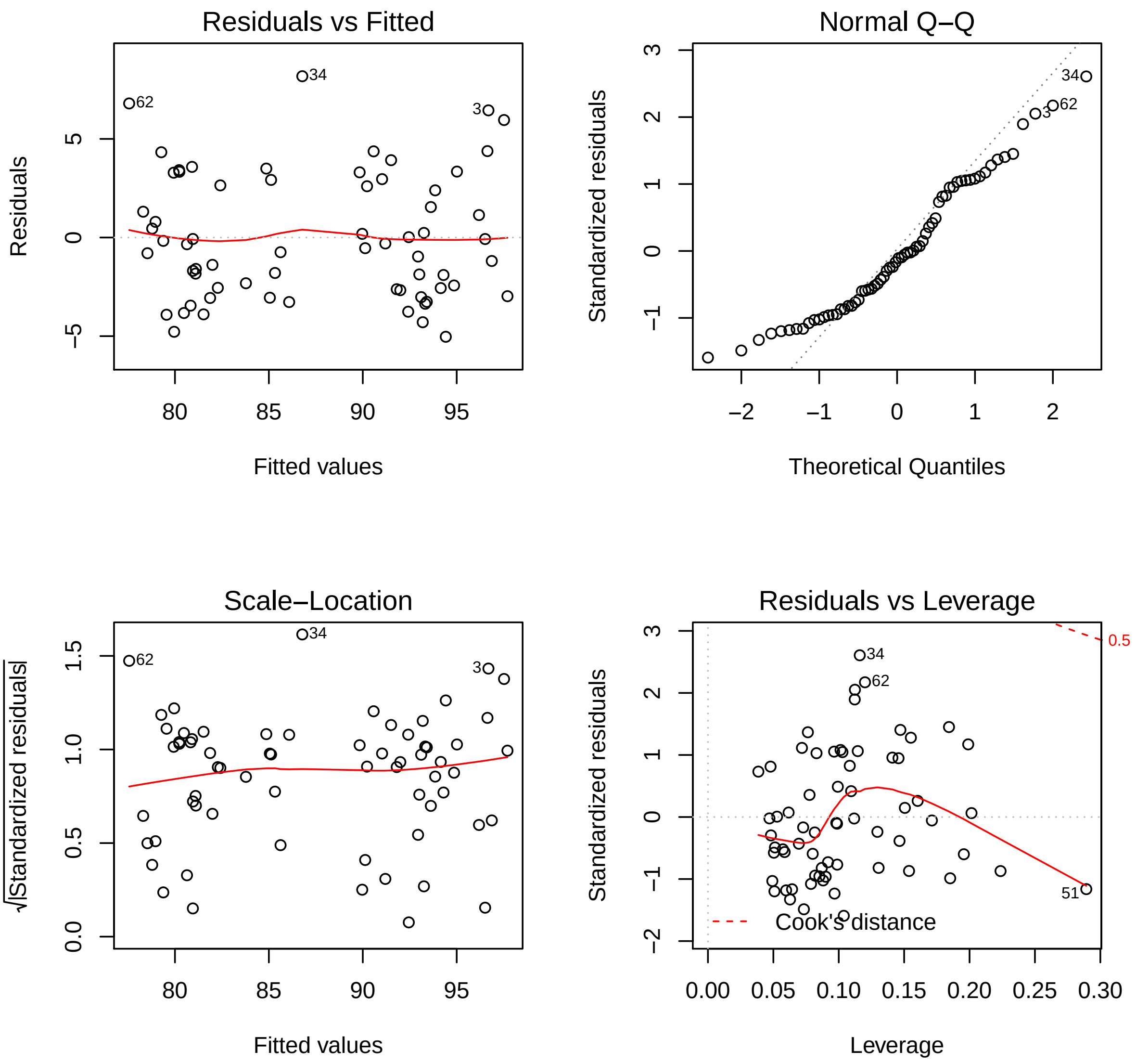

Figure C.7 Diagnostic plot of best fitting model of relationship between length at Chipps Island mid-water trawl and environmental variables.

RST – Lengths in tributaries

Mill, Deer, and Butte creek Spring run average fish sizes from rotary screw trap operations are shown in Figure C.8. We see that Mill, Deer and Butte creeks are on average about 45-55 mm in length between January and June when records were aggregated for outmigration estimates. The temporal pattern in sizes is shown in Figure C.9. We see no major trend in size in tributaries between January and June, only that Butte creek fish appear to run a bit smaller.

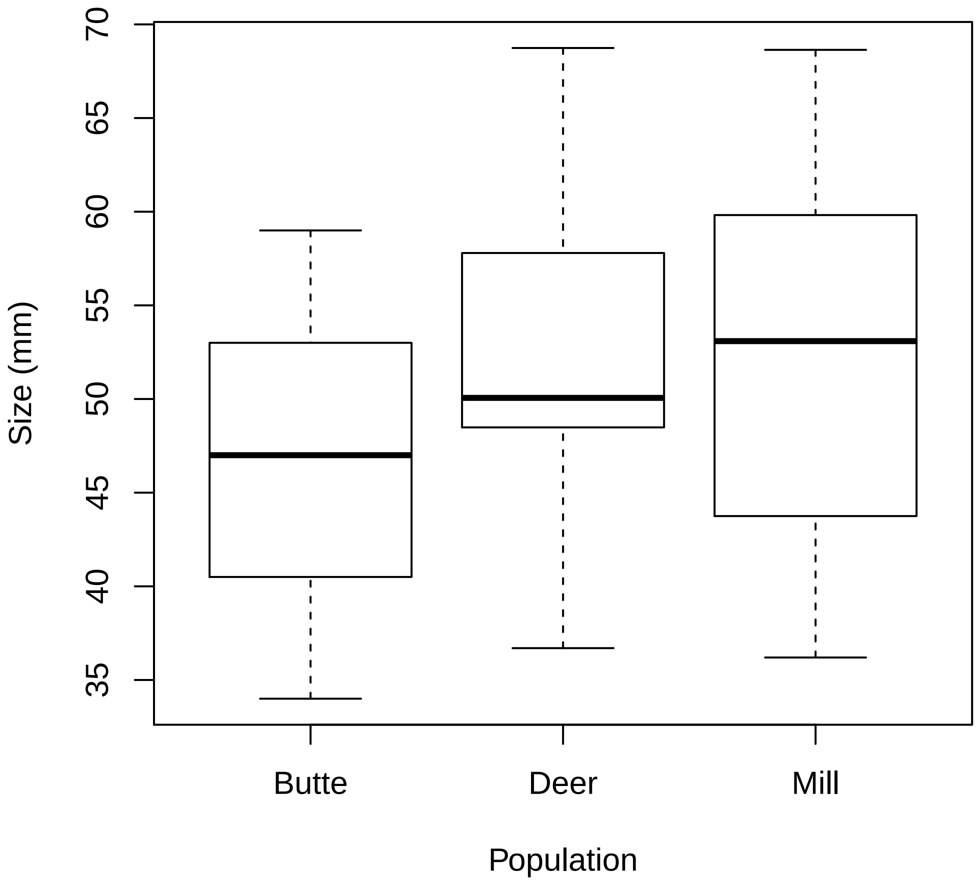

Figure C.8 Average size of juveniles obtained from rotary screw traps operating in Butte, Deer and Mill creeks between January and June.

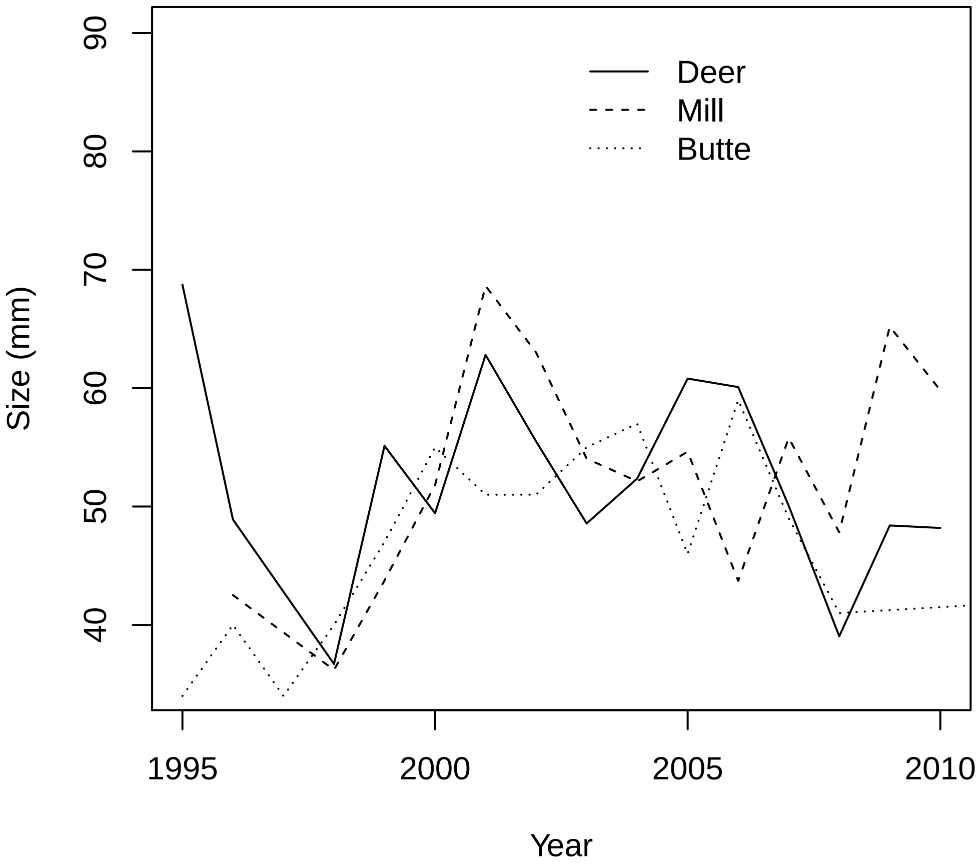

Figure C.9 Temporal trend in juvenile sizes obtained from rotary screw traps operating in Deer, Butte and Mill creeks between January and June.

DISCUSSION

This analysis drew upon varied sources of fish length information in the Sacramento River drainage. The summary of rotary screw trap lengths indicates that Spring run out-migrating Chinook from Deer, Mill and Butte creeks are approximately the same size, and have been stable at approximately 55 mm in recent years. Regression analysis of recoveries from mid-water trawl surveys at Chipps Island indicates that growth of fish from North of the Delta to Chipps Island, as well as the length at recapture in Chipps Island trawls varied in relation to environmental variables. Regression analyses showed that the length at Chipps Island from the perspective of two different types of length statistics proved to be related to environmental variables regardless of the data source of the length estimates.

We used two different growth metrics. One growth metric came from lengths of CWT recoveries and releases of hatchery fish, and the other came from seine and trawl surveys. The CWT growth was derived from average recovery length at Chipps Island and average release lengths at various release locations and times. The average recovery length is a statistic based on a very small sample size relative to the release length statistic. If you consider the how many fish are released relative to recaptured, and if you consider that tagged fish are released at various locations and at different times, it is easy to see how biased the growth estimate might be. The SEINE/TRAWL growth estimate made no distinction between hatchery and non-hatchery fish and it represents an estimate of the growth of all Fall or Spring run fish between Region 1 seines and Chipps Island. In comparison to the CWT estimate, it will be more complex in it's stock composition (with hatchery and non-hatchery fish of all origins), but it is much simpler in upstream capture and release size sampling. All stocks were sampled from the same locations for sizing regardless of origin. We found a relationship between SEINE/TRAWL growth and environmental variables, but no relationship between CWT growth and environmental variables. This may be due to the complexity of how the release length was calculated for the CWT growth estimate.

The environmental predictors that best explained growth were the Central Valley Project exports (CVP), the ratio of combined state and federal exports to the total Delta inflow (EXPIN), and the bass index. CVP and EXPIN are both related to flows in complex ways. CVP is related to flow because exports would tend to be less restricted at higher flows, but would have its highest impact when flows are low. We would expect that juvenile salmon growth could be high when CVP is highest under that logic. EXPIN is related to flow by a similar logic, but since EXPIN is a ratio, we would expect the largest fraction of flows to be exported when flows are low (for a given level of exports). We would expect juvenile salmon growth to be lowest when EXPIN is highest at the lowest flows.

Figure C.10 illustrates some the general patterns in environmental covariation. In the upper left panel we see that CVP has the greatest degree of variability at the lowest flows (with Yolo flow being used as a surrogate for average flow at export locations). Across a range of flow values we can see that the lower bound of CVP increases. This is consistent with a general tendency of reducing exports at lower flows. The relative impact of exports at a given flow is seen with EXPIN, which we see (lower left) diminishes at higher flows. We also see that more water reaches downstream to the Mokelumne river when EXPIN is lower (lower right panel). Finally, there is a general pattern of CVP being larger when EXPIN is higher, but recall that the highest EXPIN may coincide with low flows.

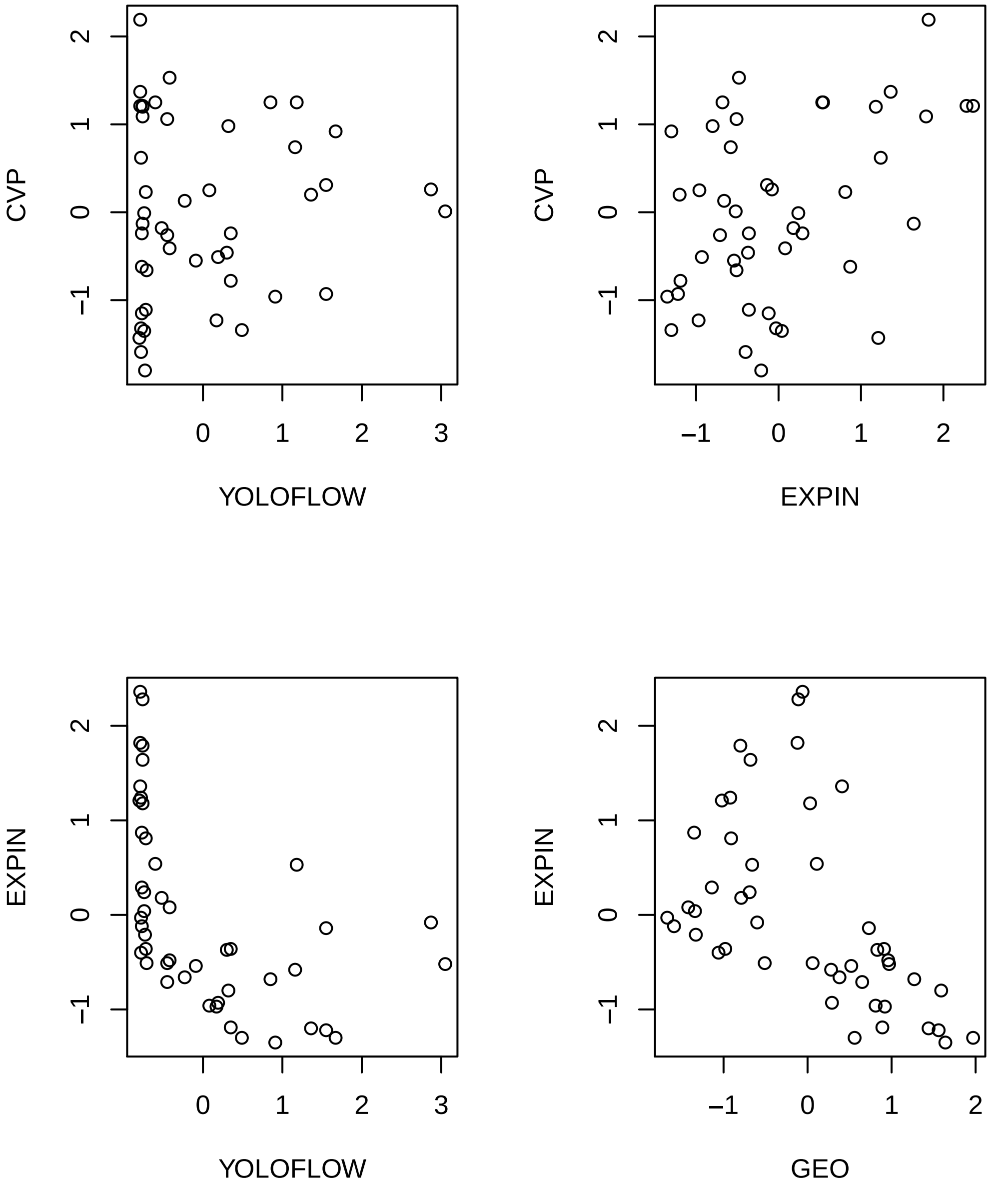

Figure C.10 Covariation between significant environmental predictors.

EXPIN was a significant predictor of length when both CWT and TRAWL datasets were used. It was significant with p<0.01 in both cases. EXPIN was also a significant predictor (p<0.01) of growth estimates of Fall and Spring aggregates obtained from the SEINE/TRAWL dataset. The CWT length regression is in conflict with the SEINE/TRAWL growth regression and the TRAWL length regression though. The CWT result predicts a positive effect of EXPIN, versus a negative effect for the other two regression analyses. A possible reason for this would be that the CWT dataset was exclusively measuring hatchery fish (although hatchery fish would also have been present in the other two analyses). If EXPIN has a positive effect on hatchery fish length at Chipps Island as shown in the CWT length regression, and a negative effect on the aggregate of both hatchery and non-hatchery fish seen in the TRAWL length and SEINE/TRAWL growth analysis, it might suggest that that the negative effect on non-hatchery growth is even stronger than seen in the TRAWL surveys. It could also be a size related issue. If hatchery fish are smaller and more vulnerable to entrainment, removal of the smaller fish from the outmigrating cohort would make it appear as if they grew on average, when in fact it was just the smaller ones that did not make it into the downstream survey sample.

The relationship between flows and exports, and resulting growth and survival are complex. We found that growth and length are negatively related to EXPIN, but positively related to CVP. A possible mechanism, is that there is a threshold flow/export relationship where in smaller fish become more vulnerable to entrainment. Such a mechanism would predict that more larger fish than smaller fish make it downstream to be sampled at Chipps Island, which has the effect of making the growth appear larger on the basis of the average recovery size. This would appear to be favorable growth conditions despite the fact that all individuals did not grow better on those conditions. If a relatively high CVP export year were where to coincide with an average flow year, and if more small fish were entrained, it would appear that fish where larger at Chipps Island.

Results also indicated that Spring run were longer at Chipps Island, despite the fact that the SEINE/TRAWL regression showed that Spring run growth was less than Fall run. Total Central Valley Projects (combined state and federal) exports showed positively effect on growth in the SEINE/TRAWL regression and length in the TRAWL analysis. Since there was a negative effect from the export to inflow ratio, it may be suggest that total flows have a positive effect, and that there may be a relationship between exports and flows that is dictated by water extraction policies.

It is interesting that regression results show that bass has a positive effect on the growth estimates evaluated from the SEINE/TRAWL, yet has a negative effect on lengths estimated from the TRAWL data. Since the bass index is not standardized to effort, it can’t imply a direct predation rate change on a size class of Chinook juveniles, but depending on the relationship between the index and the size of the bass caught, it might imply a shift in the size of Chinook vulnerable to bass predation at a given abundance of bass. It could be that smaller fish are more vulnerable and predation biases the growth estimate by removing smaller fish.

Our examination of length/growth sensitivity to environmental variation points to a few results. First, EXPIN is a statistically significant predictor of size and growth, with a negative effect on both. Our samples conflate the story a bit, but if you consider that the only positive effect was seen in the length of hatchery fish, and if you consider that the CWT dataset had race and hatchery factors, the positive effect of EXPIN in the regression result of the CWT data should not detract from the regression results found in both the SEINE/TRAWL and TRAWL dataset. It should be noted however, that the highest regression coefficient value for an environmental effect in any of our regressions was about 5, meaning that about 5 mm per standard deviation was the maximum variability in size predicted by variability in an environmental effect. This implies that at the extreme of 2 standard deviations, only 10 mm of net difference in size at Chipps Island would be predicted. Still, two standard deviations explains about 95% of the variation in environmental factors, and 10 mm explains 10-15% of the variability in length at Chipps Island (assuming 85 mm length at Chipps Island). Since the same environmental variables explain significant variation in rearing survival, it is feasible that length may be an instrumental in the mechanism of rearing survival.

REFERENCES

Brandes, P.L. and J.S. McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. Pages 39 – 138 *in* R.L. Brown, editor. Contributions to the Biology of Central Valley Salmonids, Volume 2, Fish Bulletin 179. California Department of Fish and Game, Sacramento, California.

California Department Of Fish And Game. 1998. Butte Creek Spring-Run Chinook Salmon, *Oncorhynchus Tshawytscha*, Juvenile Outmigration And Life History 1995-1998. Administrative Report No. 99-5.

California Department Of Fish And Game. 2000. Butte And Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha* Life History Investigation 1998-2000. Administrative Report No. 2004-2.

California Department Of Fish And Game. 2004. Butte And Big Chico Creeks Spring-Run Chinook Salmon, *Oncoryhnchus Tshawytscha* Life History Investigation 2000-2001. Administrative Report No. 2004-3.

Garman, C.E and T. R. McReynolds. 2008. Spring-Run Chinook Salmon, Oncoryhnchus tshawytscha, Life History Investigation. California Department of Fish and Game. Inland Fisheries Administrative Report No. 2009-1.

U.S. Fish and Wildlife Service – Stockton Fish and Wildlife Office. March 2014. Metadata for the Stockton Fish and Wildlife Office's Delta Juvenile Fish Monitoring Program. http://www.fws.gov/stockton/jfmp/.

Appendix D Modeling the influence of historical factors on population dynamics of salmon: the OBAN model

DRAFT

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Abstract

We developed a general state-space modeling framework to evaluate the influence of factors on trends in abundance of multiple life-history stages of salmon. The model utilizes Beverton-Holt transitions among life stages, and incorporates factors into the transitions by modeling the dependence of the Beverton-Holt productivity p (survival) and capacity K parameters as functions of driving factors. We estimated model coefficients in a Bayesian framework to provide inference on factors hypothesized to affect the population dynamics by fitting to indices of abundance. We call the modeling framework Oncorhynchus Bayesian Analysis (OBAN), and we applied it to winter run Chinook in the Sacramento River, California, a salmon run listed as endangered in 1994. Using the OBAN framework we were able to place probability statements on the relationships between certain environmental and anthropogenic factors and winter-run population dynamics. We found that temperatures and minimum flow in the spawning reaches and ocean productivity had a high probability of affecting survival (≥ 0.8), whereas water diversions and water routing had lower probabilities of affecting survival. The OBAN framework provides a means for understanding how historical management of hydrology and harvest coupled with environmental variability shape the trends in abundance, and thus facilitates understanding how future management actions may affect population recovery.

Keywords: state-space, WinBUGS, Bayesian, winter-run, California, water management

Introduction

Recovery of endangered animals requires an analysis of the factors responsible for affecting the population dynamics historically and modifying those factors to facilitate recovery of the population. This is particularly true of salmon populations that have seen decreases in their abundances through the majority of their range, but particularly in the southerly portions of their distribution (NMFS 2014). Understanding what factors have lead to the decline in abundances is an important step toward developing future management actions. Incorporation of uncertainty is important when evaluating these factors to be able to identify the level of confidence that one has in the relationship between historical factors and changes in population abundance. An additional complication arises when abundance measurements are made with relatively poor accuracy. Furthermore, natural variability in the population dynamics (i.e., spawner recruitment relationships) may obfiscate the signal between causative factors and the response of the population to such factors. To address these needs, we developed a state-space modeling framework that is capable of reflecting uncertainty in the factors affecting salmon population dynamics.

The population dynamics uses stages to structure the chronology of factors affecting different portions of the life cycle with density dependence among stages described by Beverton-Holt transitions (Moussalli and Hilborn 1986, Scheuerell et al. 2006, Greene and Beechie 2004). The dynamics incorporate process noise to reflect natural variability in the dynamics of the population and an observation process that describes a state-space modeling framework (Newman et al. 2014). Although the parameters of such models can be estimated using maximum likelihood methods (Maunder et al. 2011) we estimate the model parameters in a Bayesian framework to allow prior knowledge and the observation process to inform the parameter estimates (i.e., using posterior distributions to integrate information from these two sources). Fitting such non-linear state-space models in a Bayesian context is becoming relatively commonplace (King et al. 2010, Newman and Lindley 2006) and this is an extension of those methods.

The development of this modeling framework arises from a practical problem related to a population that may have a moderate probability of extinction (Lindley et al. 2007, Botsford and Brittnacher 1998). The Sacramento River winter-run Chinook (*Oncorhynchus tshawytscha*) currently listed as endangered under the Federal and California Endangered Species Acts, and it has seen a decline in escapement since the 1970's. Like many salmon populations in decline, a list of factors that could potentially affect winter-run (and other salmon transiting the Sacramento River and the San Francisco Delta) have been compiled. Some of these factors include: 1) thermal mortality of eggs and alevin in the spawning reaches; 2) flow related survival after emergence; 3) rearing in off-channel areas such as the Yolo bypass (Sommer et al. 2005); 4) entrapment into the interior delta due to positioning of channel flow gates (Perry et al. 2010); 5) alterations in the outmigration flow vectors due to exportation of water from the system (Newman and Brandes 2010; Newman 2003); 6) predation from piscivorous fishes such as striped bass (*Morone saxatilis*) (Newman and Lindley 2006). Salmon exiting the Bay-Delta ecosystem enter the Gulf of the Farallones and transition to a near-shore environment with annual variability in productivity tied to the strength and location of upwelling (Wells et al. 2007). Once winter-run attain an age of 3 years (2-ocean), they are vulnerable to the west coast salmon fishery that primarily targets fall-run Chinook from the Klamath River, OR and Sacramento Rivers but also catches winter-run (O'Farrell 2012); however, timing and area closures to minimize fishery impacts on winter-run have been in place since the late 1990's (O'Farrell 2012). Yet, the ability to quantitatively evaluate the importance of all of these factors for explaining trends in winter-run escapament has not occurred.

The objectives of our work is to provide a general overview of the Onchorynchus Bayesian Analysis (OBAN) modeling framework and to provide an analyiss of the winter-run Chinook in the Sacramento River as an example of how the framework was utilized.

Methods

Population Dynamics Model

The OBAN modelling framework provides a quantitative tool to evaluate historical patterns in salmon abundance as a function of hypothesized explanatory factors. Specifically, the model: 1) estimates model coefficients by fitting predictions of the population dynamics model to observed indices of abundance; 2) evaluates factors that may explain dynamic vital rates; 3) accounts for mortality during all phases of the salmon life history; and 4) incorporates uncertainty in the estimation of model coefficients by fitting in a Bayesian framework.

The first step to the modeling framework is to define the life-history stages. The OBAN model structure can define life-history stages based on management objectives, such as important locations of anthropogenic or environmental driving factors by the locations where indices of abundance are observed. The number of life-stages is application specific, but it has to incorporate at least two stages for freshwater (egg and juvenile stages), and an ocean stage for each age of returning adult (e.g., a stage for each of the age $2, ..., L$ ages of escaping adults). The OBAN model uses temporally implicit stage durations. Each freshwater stage may be defined such that it reflects the duration that the salmon are within that stage, thus stages do not need to be the same duration. As a consequence, inference on the population vital rates for that stage are predicated on its duration.

The OBAN framework begins with eggs as the first stage and defines the egg abundance as a function of the escapment.

$$N_{1,t} = E_t \times f_t \tag{D.1}$$

where $N_{1,t}$ is the first stage (egg) abundance, E_t is the escapement, and f_t is the fecundity at time t. If only females are being modeled, then the fecundity reflects estimates of eggs per female. Alternatively, if escapement is not sex-specific then fecundity can be defined in terms of fecundity per adult.

The OBAN framework uses Beverton-Holt transitions to calculate the density-dependent transition in abundance among freshwater life stages $(1, ..., M)$ after the egg stage.

$$N_{i,t+1} = N_{i,t} \times \frac{p_{i,t}}{1 + \frac{p_{i,t} N_{i,t}}{K_{i,t}}} \tag{D.2}$$

where $p_{i,t}$ is the productivity parameter, $K_{i,t}$ is the capacity parameter of the Beverton Holt transition and $K_{i,t}$ is the capacity parameter for stage $i = 2, ..., Q$ in year t. Because the production of eggs is captured in equation (1), productivities are equivalent to survival rates in the absence of density dependence and are confined to the range $(0, 1)$. If density dependence is not expected to occur between two stages, the $K_{i,t}$ parameter can be set to a large value to effectively remove the density-dependent portion of the equation.

The productivity parameter ($p_{i,t}$) and capacity parameter ($K_{i,t}$) in a given life stage i from brood year t can be modeled as 1) a constant value; 2) as a constant value with annual variation via random effects; or 3) as a dynamic rate with dependence on a set of time-varying covariates ($X_{j,t}$ for factor j in year t). By using the final formulation, the influence of anthropogenic and environmental factors on specific life history stages can be evaluated. The productivity parameter can be influenced by independent factors acting simultaneously on the life history stage to drive demographic rates, for example environmental variables that represent water conditions such as temperature or flow, biotic factors such as predator abundance, food abundance, or anthropogenic factors such as diking, water diversions, and harvest.

The dynamic productivities are modeled as a function of various factors by using a logit transformation, which ensures that the productivities remain between 0 and 1.

$$\text{logit}(p_{i,t}) = \sum_{j=1}^{F} \beta_j X_{j,t} \tag{D.3}$$

where β_j is the coefficient associated with factor $X_{j,t}$.

Likewise, there may be processes occuring that affect annual stage-specific capacities, such as the amount of available spawning area or the amount of flooded off-channel rearing habitat. To model the dynamic capacities, a log transformation is used, which causes the capacities to remain between 0 and ∞, which is the appropriate parameter space for capacity.

$$\log(K_{i,t}) = \sum_{j=1}^{F} \gamma_j X_{j,t} \tag{D.4}$$

where γ_j is the coefficient associated with factor $X_{j,t}$.

After Chinook enter the ocean, they mature and can return to spawn after a single summer or after overwintering in the ocean for multiple years (Healey 1991). When Chinook enter the ocean, we shift the notation to O_{age} to reflect the fact that some Chinook will remain in the ocean, whiles others will mature and migrate back to freshwater after escaping the fishery. The transition from juvenile rearing to ocean stages occurs via the following transition equation

$$O_{2,t} = N_{M,t} \times \frac{p_{M,t}}{1 + \frac{p_{M,t} O_{i,t}}{K_{M,t}}} \tag{D.5}$$

Maturations of ocean stages for ages $2, ..., L$ are calculated using the following equation:

$$M_{t+age} = O_{age,t} \phi_{age} z_{age} \tag{D.6}$$

where M_{age} is the maturation of the adults at a specific age returning to freshwater according to the conditional maturation rate ϕ_{age}. The number of fish remaining in the ocean $O_{age,t}$ is a function of those that remain and survive to the following year. Because harvest is one of the major sources of mortality in the ocean stages, the above formulation assumes that harvest occurs before maturation; however, this order could be altered to reflect the specific dynamics of the stock of Chinook being modeled.

$$O_{age+1,t} = (1 - h_{age,t})(1 - \phi_{age})O_{age,t} \times \frac{p_{age,t}}{1 + \frac{p_{i,t}O_{age,t}}{K_{age,t}}} \tag{D.7}$$

In the final stage, all Chinook of age L return, thus $M_{t+L} = O_{L,t}$. Survival and capacities can be modelled in the ocean stages just as in the freshwater stages to reflect the effects of localized nearshore productivity. Furthermore the conditional maturation rates may also be modeled as a function of factors using logistic regression. For example, due to differential size at ocean entry or size at release in the case of modeling a hatchery population.

$$\text{logit}(\phi_{age,t}) = \sum_{j=1}^{F} \delta_j X_{j,t} \tag{D.8}$$

where δ_j is the coefficient associated with factor $X_{j,t}$.

Finally, the escapement in calendar year y is the sum of the mature fish returning from the ocean at ages $2, ..., L$ from brood years $y - 2, ..., y - L$.

$$E_y = \sum_{age=2}^{L} M_{age,t} \tag{D.9}$$

Process noise can be added to the stage-specific survivals and capacities by allowing them to vary as a random effect. For example, extra variability could be incorporated through a residual error term in either equation (1) or equation (2) to add variability in the production (fecundity) relationship or in the stage transitions, respectively. To implement process noise, stage-specific random effects, e.g., $Z_{i,t}\ N(0, \sigma^2_{i,p})$ can be added to the equation to express annual variation, where $\sigma^2_{i,p}$ reflects the variance due to process noise in stage i. The amount of process noise may require some additional structure (e.g., through prior specification), otherwise, all the observed data may ostensibly be fitted exactly by allowing the variance in the process noise to be sufficiently large.

Finally, the timing of the influence of factors has to be matched with the timing of the life stages such that the factors are affecting the appropriate cohort. The time subscript t refers to the brood year, thus the covariates, which are typically provided by calendar year y, are lagged appropriately for the population under study.

Bayesian Estimation

Estimation of the model parameters occurs by comparing model predictions to observed data across multiple competing "states of nature" or parameter values. This is achieved through Bayesian estimation of the likelihood of observing the data times the prior probability of the model parameter values (Gelman et al. 2004). The general framework described above is used to compute predicted abundances that are then compared with observed abundances obtained through some sampling method. As a result, a sampling model is defined for each observation. The stage abundances are related to the observed indices of abundance through a sampling model $g()$. The framework is relatively flexible in that any type of sampling data can be incorporated by specifying an appropriate sampling model. Multiple types of abundance indices, $I_{i,k,y}$ for stage i of index type k in year y, can be included in the modeling framework by defining the observation process $g()$ as a function of the sampling model and observation error σ_k^2. For example, the observation process $g()$ could be defined as a lognormal for abundances or biomass, Poisson or negative binomial for counts, or Binomial for capture-recapture studies. Note that if the observation process is modeled with lognormal errors, the variance can be defined in terms of the coefficient of variation (CV = mean/standard deviation) as $\sigma_k^2 = \log(CV_k^2 + 1)$.

$$I_{i,k,t} \sim g(N_{i,t}, \sigma_k^2) \tag{D.10}$$

Priors

Prior probability distributions are required for all model coefficients that are estimated within the modeling framework. For example the coefficients of the logistic regression to define stage-specific survival rates (β_j's) and coefficients of the log-linear model (γ_j 's) to define stage-specific capacities will require prior probability distributions; normal distributions can be used to define the prior probabilities for both of these coefficients due to the transformations used in equations (3) and (4). Care should be taken in specifying the priors for the β coefficients given their inclusion into a logit() transformation, however. King et al. (2010) suggest that N(0,2.5) priors may be used in the coefficients of logistic regression to ensure that excessive mass is not placed in the values near 0 and 1 (as might be the case with a more diffuse normal prior). The conditional maturation rates ϕ_{age} are required to be in the interval $(0, 1)$; therefore, Beta distributions can be used as priors for these coefficients. Finally, the variance of the measurement error on the observation process (σ_k^2) and the variance of any process noise ($\sigma_{i,p}^2$ for stage i) will also require a prior and can be specified as either inverse gamma on the variance or alternatively as a uniform prior on the standard deviation of the variance (Gelman et al. 2006).

Implementation of Bayesian Estimation

The posterior distributions of the model parameters can be estimated by drawing samples from the full conditional distributions of each parameter given values of all other parameters through a Metropolis within Gibbs Markov Chain Monte Carlo (MCMC) approach (Gelman et al. 2004, Gilks and Spiegelhalter 1996). If conjugate priors are used, then the Gibbs sampler can be employed; however, if posterior distributions for the parameters can not be updated using the Gibbs sampler (Roberts and Polson 1994), they can instead updated by using distribution-free adaptive rejection Metropolis steps (Gilks and Spiegelhalter 1996, Spiegelhalter et al. 2003) which is the approach adopted in WinBUGS (Spiegelhalter et al. 2003).

To evaluate if the posterior draws were arising from a stationary target distribution, multiple chains were run from dispersed initial values for each model and the scale reduction factor (SRF, Gelman et al. 2004) was computed for all monitored quantities (model coefficients and abundance estimates). The diagnostics were implemented using the R2WinBUGS package (Sturtz et al. 2005) in R (R Core Team 2013). Monitored parameters in all models had SRF values that indicated samples were being drawn from the target distribution (i.e. SRF $\approx$ 1) by 75,000 samples (Gelman and Rubin 1992). The initial 50% of the samples were used to reach the stationary target distribution and were discarded with the subsequent samples thinned to produce approximately 1,000 draws from the stationary target distributions. The 1,000 draws were used to compute the posterior mean and symmetric 95% probability intervals or credible intervals (95% CrI).

Application of Model to Winter Run Chinook

We defined 7 life-history stages in the winter-run OBAN model including 6 freshwater and marine transition stages and 3 annual ocean stages: 1) eggs, 2) fry 3) juveniles in the Delta (delta), 4) juveniles in the Gulf of the Farallones (gulf) 5) age 2 in the ocean, 6) age 3 in the ocean, and 7) age 4 in the ocean. The escapement was composed of mature individuals that returned at age 2, 3, and 4 (Table D.1).

Fecundity was assumed to vary annually, and the annual values were sampled from probability distribution, i.e., $f_t \sim logN(\mu_f, \sigma_p^2)$. This formulation allowed process noise to be incorporated into the population dynamics, but empirical information on fecundity restricted the range of process noise in the model. Multiple environmental and anthropogenic factors were incorporated into the winter-run model at different stages in the life-history based on hypotheses about factors affecting (Table D.2). The mean fecundity is calculated by assuming that each adult spawner produces 2,450 eggs (Williams 2006, Winship et al. 2014).

Winter Run Abundance Indices

Estimates of winter-run escapement in the Central Valley have been conducted since 1967, and we used an escapement abundance index from 1967 to 2008. Different methods were used to estimate escapement over this period, which may affect the precision of the spawner escapement estimates (Williams 2006, Botsford and Brittnacher 1998). Prior to 1987, all returning spawners passed via a counting ladder at Red Bluff Diversion Dam (RBDD, Figure D.1). From 1987 onward the gates of the diversion dam have been opened to enhance upstream survival of winter-run Chinook salmon, but also likely improved access to areas above RBDD. The current operation of RBDD makes counts of winter-run Chinook salmon after closing the gates on May 15. On average, 15% of the winter run passed RBDD by May 15, but the specific percentage in a given year was as low as 3% or as high as 48% (Snider et al. 2000). Since 2001 the annual escapement estimates have been calculated using a Jolly-Seber estimator derived from the carcass count data (California Department of Fish and Game 2004). Juvenile production indices were calculated from rotary screw trap samples and trap capture probabilities at Red Bluff Diversion Dam for 1995 through 1999 and 2002 through 2008 (Poytress and Carrillo 2011).

Winter Run Factors

Several environmental and anthropogenic factors were used to help describe variability in winter-run juvenile and adult abundance indices (Table D.2). Because the abundance indices occur at RBDD, which coincides with the fry stage, a basal survival rate could be estimated for the egg to fry stages and a second basal rate for the fry to escapement stages. Explanatory factors were incorporated into the survival during the fry stage, delta stage, and gulf stages (Table D.2). We provide a short rationale for the inclusion of each of the factors here.

Water temperatures in the spawning reach above RBDD can sometimes reach stressful levels, thus July through September mean daily water temperature (C) in the Sacramento River at Bend Bridge (TEMP) was used to explain annual variability in egg to fry survival. In addition, low flow can affect survival rates of alevin, so August through November minimum monthly flow in the Sacramento River at Bend Bridge was also used to affect egg to fry survival. In addition, an interaction term of TEMP:FLOW was incorporated into the model to determine if there was some additional mortality associated with either high temperatures or low flow.

In the delta stage, several factors may affect winter-run survival rates. Access to the Yolo bypass, a large floodplain that provides the potential for increased survival and growth of fall-run Chinook (Sommer et al. 2005), may also provide similar benefits for winter-run via bypassing the delta. The Yolo bypass floods when flows on the Sacramento River surpass 56,000 cfs; each day when flows were great enough to enter the Yolo bypass between December and March was a potential opportunity for winter-run to enter the floodplain habitat (YOLO). The Delta Cross Channel is a dual gate structure that conveys water to the interior delta, and late-fall Chinook salmon that enter the interior delta have lower survival rates relative to those that migrate down the Sacramento River (Perry et al. 2010). In the southern delta, the Central Valley Project and State Water Project export water from the delta to supply agricultural and municipal water needs. The levels of exports can vary annually and have been associated with differential survival rates of fall run Chinook (Newman and Brandes 2010, Newman 2003).

Finally, nearshore ocean processes can have important consequences for Chinook salmon (Wells et al. 2007, Woodson et al. 2013), and here we evaluated upwelling in a region south of the entrance to San Francisco Bay (UPW) and the sea surface temperature in the Gulf of the Farallones (FARA).

The ocean stages were modeled as a function of maturation rates and age-3 impact rates. Information for the maturation rates were taken from an analysis of 1998, 1999, and 2000 coded wire tag (CWT) data (Grover et al. 2004) and more recent analyses of maturation rates (O'Farrell et al. 2012). Age-3 impact rates for winter-run were calculated for 1978 - 2011 from a combination of estimated impact rates from CWT returns (1998 - 2008) and from a hindcast of impact rates given spatial allocation of fishing effort (O'Farrell, M., NMFS unpublished data). Until 1987, there was little regulation of the Central Valley Chinook salmon shery and estimates of the mortality rate on winter-run Chinook salmon in the ocean shery were approximately 0.7 of the mortality rate experienced by fall-run Chinook salmon.

Most winter-run Chinook salmon return to spawn as 3-year-olds; however, the winter-run age-4 oceannstages are more likely to be captured in the commercial fishery because of their larger size. Grover et al. (2004) found that the harvest-related mortality of age-4 winter-run Chinook salmon was 2.5 to 3.7 times the rate of age-3. The age-4 impact rate in a calendar year y was assumed to be double the instantaneous rate of age-3 ($h_{4,y} = \exp(\log(h_{3,y}/2))$).

Results

Observed winter-run escapement was on the order of several tens of thousands in the late 1960's and early 1970's and declined to levels in the low thousands during the 1980's with a low abundance estimate of 194 in 1994. Since the mid-1990's the population has recovered to some degree with escapements in the mid 2000's on the order of several thousands. The winter-run OBAN model captured this declining trend and recovery in escapement (Figure D.2). In particular, the model was able to capture the decline in the late 1970's (along with the spike in escapement in 1980), the continued decline through the mid-1990s, and the subsequent increase through early 2000. The three different sampling methods had median estimated CV's ranging from 0.68 for the early period, 1.34 for the middle period, and 0.97 for the later period. As a result, the model was more sensitive to those sampling methods with higher precision (lower CV). In particular, the model fits to the intermediate period (in which counts were expanded assuming 15% passed RBDD by May 15) indicated that the escapement in 1990, 1991, and 1994 was underestimated relative to model predictions (Figure D.2). In contrast, the winter-OBAN model predictions of escapements during the early period (1967 - 1987) and the later period (2001-2008) fit the annual variability in escapement estimates more closely. The winter-OBAN model also fit well to patterns in the juvenile abundance index at RBDD from 1995 to 2007. The median estimated CV on the juvenile index data was 1.2, indicating that the model had intermediate sensitivity to the juvenile indices relative to escapement. The winter-run model predictions of juveniles at RBDD captured the relatively low production of fry during the late 1990's, subsequent increase in early 2000's due to higher escapements, and the declline in the index in 2007 (Figure D.3).

Annual patterns in stage-specific survivals

To predict escapement and juvenile index values, stage-specific survivals were estimated as a function of the environmental and anthropogenic factors. The estimated survival from egg to fry at RBDD averaged 0.24 95%CrI(0.11, 0.48) (Table D.3); however, survival from the 1970's to mid-1990's was highly variable. There were two years in the late 1970's where median survival was predicted to be approximately zero and periods in the early 1980's and early 1990's when survival in the alevin stage was also low (Figure D.4). Since the mid-1990's the survival rates for alevin have been more stable relative to the prior periods. Survival through the delta stage, which spans fry at RBDD to the nearshore ocean, was 0.0097 (95%CrI: 0.0041, 0.022) (Table D.3). Within the delta, annual variability was less pronounced with median survival ranging from a high of 0.017 in 1969 to a low of 0.0063 in 2004. Median delta survivals were relatively stable at approximately 0.009 through the 1980's and 1990's with slightly lower survivals during 2001 to 2004 of approximately

0.006 (Figure D.4). Average survival in the gulf stage was assumed to be 0.5 and variability in survival among years was reflective of ocean productivity. For winter-run Chinook the mid 1980's and mid 1990's were periods of poor survival, whereas 1998 and 2000 - 2001 were years of relatively good survival. Finally, patterns in age-3 survival rates (which were a deterministic function of harvest rates and annual survival rate of 0.8) indicated relatively low survival rates for brood years through the mid-1990's, with improving ocean survival for brood years after 1995 (Figure D.4).

Although the magnitude of the effect from each factor cannot be evaluated directly via the magnitude of the coefficient estimate (due to dependence on the stage-specific intercept), the sign of the coefficients associated with factors provide an indication of the effect of the factor: positive values increase survival relative to the average and negative values decrease survival. Because the winter-run OBAN model was fit in a Bayesian framework, the coefficients are described by posterior distributions and the probability that the coefficent value was positive was calculated (Table D.3). In the egg to fry stage, temperatures in the spawning reaches (TEMP) had a consistent negative effect on survival, whereas minimum flows (FLMIN) had a consistent positive effect on survival (Table D.3). A positive TEMP:FLMIN interaction term of flow and temperature would exacerbate the negative effect of high temperatures and low minimum flows, and the interaction term had a 0.73 probability of being positive. In the delta stage, access to the Yolo bypass (YOLO) and DCC gate position open (DCC) had a positive effect on survival, whereas export levels (EXPT) were negative. Finally, in the gulf stage, high tempeartures in the Farallone Islands (FARA) had a negative effect on winter-run survival, whereas upwelling south of the entrance to San Francisco Bay (UPW) had a positive effect on survival (Table D.3). Several additional parameters were given informative priors to structure the winter-run OBAN model, although if the data were informative on the coefficients, this would be reflected in the posterior. The posteriors on the conditional maturation rates largely reflected the informative priors. as did the CV on the process error (Table D.3).

The magnitude of the effect for each of the factors can not be discerned directly from the magnitude of the coefficient estimate (e.g., in Table D.3), because the coefficients associated with the covariates are dependent upon the intercept terms. To understand how the various factors affect the overall survival of winter-run Chinook, we increased each of the covariates one at a time by 1 standard deviation (SD). The survival rates under the one-at-a-time increases were compared to a baseline case, which was the survival rate with all factors at their mean 1967 to 2008 level. The survival rates began at the egg stage and ended at the end of age 2, prior to harvest affecting survival. To facilitate comparison, we calculated the percent change relative to the baseline survival (i.e., $(alt_k - base)/base \times 100\%$), where alt_k describes a model with factor k increased by 1 SD. Minimum flow had the largest effect per unit SD on winter-run survival with a median increase of 128% (Figure D.5). Temperature also had a strong effect with a negative median effect of -96.7% per unit SD. The other notable factors were exports which had a negative effect of - 12.4% per unit SD, Yolo with a median positive effect of 11.3% and upwelling with a positive effect of 42.3% per unit SD (Figure D.5). The standard deviations are not the same on a percentage basis among factors, however. For example 1 SD of TEMP is equal to 6.8% of the mean, whereas 1 SD of EXPT is equal to 25.6% of the mean. Calculations of the effects of each factor on a percent basis indicated that temperature provides the largest effect with an 11.9% decrease in survival per percent increase in temperature. Minimum flows in the spawning reach provided a median 5.73% change, temperature in the Farallones provided a median -1.55%, and upwelling provided a median 1.78% change, whereas all other factors provided a less than 1% change in survival for a 1% increase in the factor (EXPT -0.48%, YOLO 0.10%, and DCC 0.16%).

Correlation among coefficients was generally low with the exception of the two intercept terms β_{alevin} and β_{delta} (Pearson correlation coefficient on posterior samples = - 0.685). Despite juvenile data being present for the latter portion of the time series, some negative correlation among these two coefficients was expected due to the model structure. This correlation did not inhibit the MCMC algorithm from converging, however. All scale reduction factors on monitored parameters were approximately 1, which indicated that the 3 chains had converged to a stable distribution.

Discussion

The winter-OBAN framework provided a means to evaluate the importance of several anthropogenic and environmental factors hypothesized to affect winter-run Chinook in the Central Valley. The model results support the importance of the environmental conditions in the natal spawning and rearing area and early ocean conditions with important but more subtle effects of delta survival. Our results are comparable with previous models of winter-run Chinook, providing some justification of the overall model structure and its inference. Our estimate of delta survival can be compared with Winship et al. (2014), who estimated the fry to end of age 2 survival rate for 1996 - 2008 of 0.4%. In comparison, our delta survival rate was 0.9% times the average age 2 value of 0.5 equals a 0.45% estimate for our model from fry to the end of age 2.

Median egg to fry survivals were slightly lower than estimated by Winship et al. (2014), in which the median egg to fry survival was 0.30. Furthermore, they found little variability in annual egg to fry survival. Similar fry data were used for both models; however, the winter-run OBAN model was able to use the

1995-2008 survival relationships to improve inference on factors affecting egg to fry survival in the 1970's to mid-1990's, prior to the analysis of Winship et al. (2014). We too found low variability among years in egg to fry survival from 1996 to 2008, but in contrast we found that there was high variability in survival prior to 1995 due to temperature and flow effects, and it played an important role in the decline of winter-run Chinook during the late 1970's and 1980's.

The factors leading to the decline in winter-run abundance during the 1970's can be explained by several periods of poor egg to fry survival tied to low flows and high water temperatures in the spawning reaches. While survival through the delta did not vary dramatically, survival at early ocean entry also had several periods with generally poor survival. Concurrent with this period of episodic recruitment failure and variable ocean conditions, impact rates of age-3 winter-run averaged 0.38 from 1969 to 1997. The recovery of winter run beginning in the late 1990's and early 2000 can be attributed to several managment actions and good ocean productivity from 2001 - 2003. The installation of a temperature control device in 1991 has generally reduced the variability in temperature with subsequent reduction in variability of egg to fry survival since 1993 (Figure D.4). Concurrent with the installation of the temperature control device, harvest rate management reduced the impact rates on winter-run (1998-2009 average of 0.153) (O'Farrell et al. 2012). In addition, survival through the delta was generally better during the 1996 to 1998 period due to lower than average exports and greater than average access to Yolo bypass.

Model Critique

Although the OBAN modeling framework can incorporate density dependence in the model structure, the winter-run implementation here did not include it based on previous work fitting density dependence to winter-run abundance indices. Estimation of the density dependence requires a signal in the data, namely the reduction in survival as a function of abundance. Previous efforts to include density dependence in models of winter-run population dynamics have had mixed results. Newman and Lindley (2006) included density dependence in the egg to fry transition and found little support for density dependence in a model without process noise, but they found strong evidence when process noise was included as a random effect in each stage under a state-space formulation. The information in the data to support the density dependence came from accounting for autocorrelation in the juvenile abundance state variables as well as measurement errors. Winship et al. (2014) found little support for density dependence in the egg to fry stage using a state-space model that estimated process noise, but fixed measurement error based on estimates of CV from sampling design. Based on the similarity of our model design to Winship et al. (2014), we did not include capacity in the model structure. We return to the topic of density dependence below.

We also did not include hatchery output explicitly in the winter-run OBAN implementation. We did, however, incorporate a process noise component to the egg production stage, which was able to vary among years. Hatchery supplementation should be reflected in deviations of recruitment variability, if it was in fact improving the productivity of the population. Hatchery supplementation was initiated in 1991 with some releases in 1994 and 1995; however, production began in ernest in 2000 with between 20 to 57 natural origin females removed from the spawning population for hatchery brood stock (Winship et al. 2014). A more direct approach would be to include a dummy factor in the egg production equation that identified years of hatchery production. The hatchery term could be restricted to have a positive value, reflecting a hypothesized expected benefit of hatchery supplementation, or allowed to be positive or negative reflecting the potential for negative hatchery effects on production of natural origin juveniles.

Recovery

Recovery of winter-run is likely to occur through management of factors under human control while being aware of the influence of uncontrollable environmental conditions (e.g., upwelling). Winter-run appear to be particularly sensitive to temperatures and flows in the spawning reaches. Estimates of the temperature during 1977 indicated that it was 4 standard deviations above the mean (17.6 C) during the July to September period. Mortality in the egg to fry stage was similar in 1976, though, when the temperature was only 1.2 standard deviations (14.6 C) above the mean. The installation of a temperature control device at Shasta Dam provides the ability to decouple water temperatures from flow out of the dam, and manages tempeatures by mixing cold hypolimnetic water with warmer surface water. While this provides a method for controlling temperatures, the operations of the control device may be complicated by the multi-year climate cycles that affect the reservoir storage and thus the amount of cold water available. Still, the winter-run OBAN model results suggest that small deviations in temperature can have substantial impacts on survival from the egg to fry stage, and managing thermal mortality can have important consequences for the population dynamics.

Management of factors in the delta appear to also affect winter-run, but to a lesser degree than the temperature and flow effects during egg to fry survival. Within the delta, increasing access to Yolo bypass and reducing exports can have a positive effect on survival. Water flows into the Yolo bypass over an approximately 1.5 mile weir when flows on the Sacramento River exceed 56,000 cfs at Verona. Winter-run juveniles rear above the weir location and their downstream movement is triggered by flow cues (del Rosario et al. 2013). Access to the Yolo bypass occurs when these flow pulses are also substantial enough to overtop the weir. Given the general lack of off-channel rearing area for salmonids in the Central Valley, improving access to Yolo bypass has been identified as an important management action for recovery of Central Valley salmonids, and winter-run in particular (NMFS 2014).

For the model with a density dependent effect in Newman and Lindley (2006), a Beverton-Holt model was used and the estimated capacity was on the order of 11.5 million fry. Using these values of capacity for fry, estimated fry to age-2 survival of 0.45% and ocean age 2 and age 3 survival rates of 0.5, and 0.8 respectively would suggest a capacity of approximately 20,500 winter-run in the absence of harvest. This capacity level was exceeded every year from 1967 to 1977; thus it may not be an appropriate capacity estimate for that period, but could potentially reflect more recent conditions as the Newman et al. (2006) model focused on 1992 to 2003. More importantly, the existence of a carrying capacity at this level may have important implications for modeling the expected responses to recovery of winter-run. Both the Newman and Lindley (2006) and Winship et al. (2014) models included density dependence in the egg to fry stage, presumably because spawner and juvenile data were available. Yet density dependence could more likely be in the spawning stage given that winter-run are currently spawning below Keswick dam, rather than in their natal tributaries surrounding Mt. Shasta (Yoshiyama et al. 2001). For evaluating the potential for reconnecting winter-run populations to their natal spawning reaches, such an analysis could provide information on potential population sizes under expanded habitat.

The state-space modeling framework has proven to be an important component to ecological modeling due to its ability to reflect uncertainties in the biological processes via process noise and in the observation process via measurement error. In most applications, the process noise is ascribed to random effects (e.g. Newman and Lindley 2006, Winship et al. 2014), but some of the variation in process noise may be explained by realtionships to anthropogenic and environmental factors. Thus, the OBAN framework attempts to move inference toward evaluating hypotheses by formally laying out a framework by which stage-specific variability can be ascribed to explanatory factors rather than to random effects. This linkage can be particularly powerful if some of the factors affecting the population dynamics can be managed for salmonid recovery.

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References

Botsford, L. W. and Brittnacher, J. G. 1998. Viability of Sacramento River winter-run Chinook salmon. *Conservation Biology* **12**(1): 65–79

California Department of Fish and Game. 2004. Sacramento River winter-run Chinook salmon: 2002-2003 biennial report. Tech. rep., California Department of Fish and Game, Native Anadromous Fish and Watershed Branch

del Rosario, R. B., Redler, Y. J., Newman, K., Brandes, P. L., Sommer, T., Reece, K. and Vincik, R. 2013. Migration patterns of juvenile winter-run-sized Chinook salmon (Oncorhynchus tshawytscha) through the SacramentoSan Joaquin Delta. *San Francisco Estuary and Watershed Science* **11**(1). URL `http://www.escholarship.org/uc/item/36d88128`

Gelman, A., Carlin, J., Stern, H. S. and Rubin, D. B. 2004. Bayesian Data Analysis. CRC Press

Gelman, A. and Rubin, D. B. 1992. Inference from iterative simulation using multiple sequences. *Statistical science* 457–472

Gelman, A. et al. 2006. Prior distributions for variance parameters in hierarchical models (comment on article by Browne and Draper). *Bayesian analysis* **1**(3): 515–534

Gilks, W. and Spiegelhalter, D. 1996. Markov chain Monte Carlo in practice. Chapman & Hall/CRC

Greene, C. M. and Beechie, T. J. 2004. Consequences of potential density-dependent mechanisms on recovery of ocean-type Chinook salmon (Oncorhynchus tshawytscha). *Canadian Journal of Fisheries and Aquatic Sciences* **61**(4): 590–602

Grover, A., Lowe, A., Ward, P., Smith, J., Mohr, M., Viele, D. and Tracy, C. 2004. Recommendations for developing fishery management plan conservation objectives for Sacramento River winter Chinook and Sacramento River spring Chinook. Tech. Rep. Progress Report, Sacramento River Winter and Spring Chinook (SRWSC) Interagency Workgroup

Healey, M. 1991. Life history of Chinook salmon (Oncorhynchus tshawytscha). In C. Groot and L. Margolis, eds., Pacific Salmon Life Histories, 311–393. University of British Columbia Press, Vancouver, B.C., Canada

King, R., Morgan, B., Gimenez, O. and Brooks, S. 2010. Bayesian analysis for population ecology. CRC Press

Lindley, S. T., Schick, R. S., Mora, E., Adams, P., Anderson, J., Greene, S., Hanson, C., May, B., McEwan, D., MacFarlane, R. B., Swanson, C. and Williams, J. 2007. Framework for Assessing Viability of Threatened and Endangered Chinook Salmon and Steelhead in the Sacramento-San Joaquin Basin. *San Francisco Estuary and Watershed Science* **5**(1): Article 4

Maunder, M. N., Deriso, R. B. and Waters, C. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (Hyposmesus transpacificus). *Canadian Journal of Fisheries and Aquatic Sciences* **68**(7): 1285–1306

Moussalli, E. and Hilborn, R. 1986. Optimal stock size and harvest rate in multistage life history models. *Canadian Journal of Fisheries and Aquatic Sciences* **43**(1): 135–141

Newman, K. 2003. Modelling paired release-recovery data in the presence of survival and capture heterogeneity with application to marked juvenile salmon. *Statistical Modelling* **3**(3): 157–177

Newman, K., Buckland, S., Morgan, B. J., King, R., Borchers, D., Cole, D. J., Besbeas, P., Gimenez, O. and Thomas, L. 2014. Modelling Population Dynamics. Springer

Newman, K. B. and Brandes, P. L. 2010. Hierarchical Modeling of Juvenile Chinook Salmon Survival as a Function of Sacramento-San Joaquin Delta Water Exports. *North American Journal of Fisheries Management* **30**(1): 157–169

NMFS. 2014. Recovery Plan for the Evolutionarily Significant Units of Sacramento River Winter-run Chinook Salmon and Central Valley Spring-run Chinook Salmon and the Distinct Population Segment of California Central Valley Steelhead. Tech. rep., National Marine Fisheries Service

O'Farrell, M. R., Mohr, M. S., Grover, A. M. and Satterthwaite, W. H. 2012. Sacramento River winter Chinook cohort reconstruction: analysis of ocean fishery impacts. URL `http://swfsc.noaa.gov/publications/TM/SWFSC/NOAA-TM-NMFS-SWFSC-491.pdf`

Perry, R. W., Skalski, J. R., Brandes, P. L., Sandstrom, P. T., Klimley, A. P., Ammann, A. and MacFarlane, B. 2010. Estimating survival and migration route probabilities of juvenile Chinook salmon in the Sacramento-San Joaquin River Delta. *North American Journal of Fisheries Man-*

agement **30**(1): 142–156. doi:Doi 10.1577/M08-200.1. URL `<Go to ISI>://WOS:000277113900013; http://www.tandfonline.com/doi/full/10.1577/M08-200.1`

Poytress, W. R. and Carrillo, F. D. 2011. Brood-year 2008 and 2009 winter Chinook juvenile production indices with comparisons to juvenile production estimates derived from adult escapement. Tech. Rep. Draft Annual Report 2008 and 2009, U.S. Fish and Wildlife Service

R Core Team. 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL `http://www.R-project.org/`

Roberts, G. and Polson, N. G. 1994. On the geometric convergence of the Gibbs sampler. *J. Roy. Stat. Soc. B* **56**: 377–384

Scheuerell, M. D., Hilborn, R., Ruckelshaus, M. H., Bartz, K. K., Lagueux, K. M., Haas, A. D. and Rawson, K. 2006. The Shiraz model: a tool for incorporating anthropogenic effects and fish-habitat relationships in conservation planning. *Canadian Journal of Fisheries and Aquatic Sciences* **63**(7): 1596–1607

Snider, B., Reavis, B. and Hill, S. 2000. 1999 Upper Sacramento River winter-run Chinook salmon escapement survey, May - August 1999. Tech. Rep. Technical Report No. 00-1, California Department of Fish and Game, Stream Evaluation Program

Sommer, T. R., Harrell, W. C. and Nobriga, M. L. 2005. Habitat use and stranding risk of juvenile Chinook salmon on a seasonal floodplain. *North American Journal of Fisheries Management* **25**(4): 1493–1504

Spiegelhalter, D., Thomas, A., Best, N. and Lunn, D. 2003. WinBUGS version 1.4 user manual. Tech. rep., MRC Biostatistics Unit, Cambridge, UK

Sturtz, S., Ligges, U. and Gelman, A. 2005. R2WinBUGS: A Package for Running WinBUGS from R. *Journal of Statistical Software* **12**(3): 1–16. URL `http://www.jstatsoft.org`

Wells, B. K., Grimes, C. B. and Waldvogel, J. B. 2007. Quantifying the effects of wind, upwelling, curl, sea surface temperature and sea level height on growth and maturation of a California Chinook salmon (Oncorhynchus tshawytscha) population. *Fisheries Oceanography* **16**(4): 363–382. doi:DOI 10.1111/j.1365-2419.2007.00437.x. URL `<Go to ISI>://WOS:000247440500005; http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2419.2007.00437.x/full`

Williams, J. G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. *San Francisco Estuary and Watershed Science* **4**(3): Article 2

Winship, A. J., OFarrell, M. R. and Mohr, M. S. 2014. Fishery and Hatchery Effects on an Endangered Salmon Population with Low Productivity. *Transactions of the American Fisheries Society* **143**(4): 957–971. doi:10.1080/00028487.2014.892532. URL `http://www.tandfonline.com/doi/abs/10.1080/00028487.2014.892532`

Woodson, L. E., Wells, B. K., Weber, P. K., MacFarlane, R. B., Whitman, G. E. and Johnson, R. C. 2013. Size, growth and origin-dependent mortality of juvenile Chinook salmon Oncorhynchus tshawytscha during early ocean residence. *Marine Ecology Progress Series* **487**: 163–175. doi:10.3354/meps10353

Yoshiyama, R., Gerstung, E., Fisher, F. and Moyle, P. 2001. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. In R. Brown, ed., Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179(1), 71–176. California Department of Fish and Game, Sacramento, California

Table D.1: Model parameters, state variables, and observable indices of abundance for winter-run OBAN model.

Symbol	Value	Description
Indices		
i	egg, alelvin, fry, delta, bay, gulf	freshwater stages
j		covariate index
k		gear type for observation process
t	1967, .., 2004	brood year
y	1967, .., 2008	calendar year
age	2, 3, 4	ocean age
State Variables		
$N_{i,t}$		abundance of freshwater stage
$O_{age,t}$		abundance of ocean stage
$M_{age,t}$		abundance of mature fish
Parameters		
$\beta_{i,j}$		coefficient relating factor j to survival in stage i
$\gamma_{i,j}$		coefficient relating factor j to capacity in stage i
$\delta_{age,j}$		coefficient relating factor j to maturation at age
ϕ_{age}	(0,1)	conditional maturation in age age
$CV_{E,k}$		coefficient of variation for escapement observation process k
CV_J		coefficient of variation for juvenile observation process k
CV_p		coefficient of variation of process noise
f_t	2450	fecundity per spawner
$h_{age,t}$		impact rate due to harvest
$p_{i,t}$	$(0, 1)$	productivity in stage i and brood year t
$K_{i,t}$	$(0, \infty)$	capacity in stage i and brood year t
z_2	0.5	age 2 average natural survival rate
z_3	0.8	age 3 average natural survival rate
z_4	0.8	age 4 average natural survival rate
Observables		
$I_{y,E}$		Escapement 1967 - 2008
$I_{y,J}$		Juvenile abundance at Red Bluff Diversion Dam 1995 - 1999, 2002-2007

Figure D.1. Map of the Central Valley (black lines), Sacramento River, San Francisco Estuary, and ocean habitats used by winter-run Chinook.

Figure D.2. Model fit to observed winter-run escapement data (squares) from three collection methods: 1) Red Bluff Diversion Dam (RBDD) counts, 2) expansion of RBDD counts assuming 15% passage by May 15, and 3) carcass mark-recapture. Verticle lines indicate 1 standard deviation. Heavy line is the mean winter-run OBAN prediction, whereas thin lines are the 95% credible interval on model predictions of the

Table D.2: Covariates used in the winter-run OBAN model.

Covariate	Mean	Standard Deviation	Stage	Description
TEMP	13.4	0.9	alevin	Jul - Sept mean temperature at Bend Bridge (C)[1]
FLMIN	6605	1477	alevin	Aug - Nov minimum of monthly average flow at Bend Bridge (cfs)[2]
YOLO	22.9	24.7	delta	Dec - Mar number of days where flow is greater than 56,000 on the Sacramento River at Verona[3]
DCC	0.46	0.42	delta	Dec - Mar proportion of time when Delta Cross Channel gates are open[4]
EXPT	1250154	320854	delta	Dec - Jun total exports (cfs)[3]
UPW	210.5	49.8	gulf	Apr-Jun upwelling index[5]
FARA	11.8	0.9	gulf	Feb - Apr mean temperature in the Farallon Islands (C)[6]

[1] Temperature regresssions for 1967 - 1970; modeled temperature data 1970-2005; gage data 2005-2008 CDEC-BND

[2] CDEC-BND station or USGS 11377100 station

[3] Dayflow (http://www.water.ca.gov/dayflow/output/Output.cfm)

[4] US Bureau of Reclamation (http://www.usbr.gov/mp/cvo/vungvari/Ccgates.pdf)

[5] Pacific Fisheries Environmental Laboratory (http://las.pfeg.noaa.gov/LAS/docs/upwell.nc.html)

[6] University of California San Diego (http://shorestation.ucsd.edu/active/index_active.html#farallonstation)

Table D.3: Prior and posterior distributions in the winter-OBAN model.

Parameter	Prior	Mean	Median	95%CrI	Pr > 0
β_{alevin}	N(0, 2.5)	-1.17	-1.21	(-2.09, -0.09)	0.21
β_{delta}	N(0, 2.5)	-4.63	-4.64	(-5.48, -3.79)	0.00
β_{TEMP}	N(0, 2.5)	-2.00	-1.99	(-3.66, -0.35)	0.004
β_{FLMIN}	N(0, 2.5)	1.48	1.42	(0.42, 2.86)	1.00
$\beta_{TEMP:FLMIN}$	N(0, 2.5)	0.52	0.53	(-0.91, 2.06)	0.73
β_{YOLO}	N(0, 2.5)	0.13	0.11	(-0.54, 0.84)	0.65
β_{DCC}	N(0, 2.5)	0.15	0.14	(-0.37, 0.78)	0.70
β_{EXPT}	N(0, 2.5)	-0.13	-0.13	(-0.95, 0.66)	0.39
β_{UPW}	N(0, 2.5)	0.94	0.90	(-0.71, 2.83)	0.83
β_{FARA}	N(0, 2.5)	-0.24	-0.23	(-1.53, 0.91)	0.35
CV_{E1}	U(0,CV_{E3})	0.71	0.68	(0.46,1.12)	NA
CV_{E2}	U($CV_{E3}, 2$)	1.36	1.34	(0.80, 1.96)	NA
CV_{E3}	U(0,2)	1.03	0.97	(0.62, 1.79)	NA
CV_J	U(0,2)	1.20	1.20	(0.42, 1.93)	NA
CV_p	[1]B(2,6)	0.26	0.25	(0.02, 0.59)	NA
ϕ_2	[2]B(1,10)	0.038	0.030	(0.004, 0.128)	NA
ϕ_3	[3]B(10,1)	0.907	0.928	(0.700, 0.997)	NA

[1] Informative prior with a mean of 0.25, 95% interval (0.036, 0.58)

[2] Informative prior with mean of 0.091, 95% interval (0.0025, 0.31)

[3] Informative prior with mean of 0.91, 95% interval (0.69, 0.99)

state variable of escapement.

Figure D.3. Model fit to observed winter-run juvenile abundance index (squares) at Red Bluff Diversion Dam from 1996 to 2008. Verticle lines indicate 1 standard deviation. Heavy line is the mean winter-run OBAN prediction, whereas thin lines are the 95% credible interval on model predictions of the state variable of fry abundance.

Figure D.4. Predicted survival in the egg to fry (alevin) stage above Red Bluff Diversion Dam (A), in the delta (B), in the gulf (C), and as age 3 in the ocean (D). For A - C the dark line represents the median model prediction, whereas thin lines are the 95% credible interval on model predictions. For D the dark line represents the assumed survival rate of age-3 due to natural mortality and harvest.

Figure D.5. Analysis of factors affecting winter-run survival to the end of age 2. Factors were increased by 1 standard deviation and the percent change in survival to the end of age 2 relative to a baseline (all factors at their 1967 2008 mean levels) was calculated for each factor. Please see Table D.2 for a description of each factor.


Red Bluff diversion dam
Yolo bypass
Delta cross channel
Chipps Island

Figure D.1:

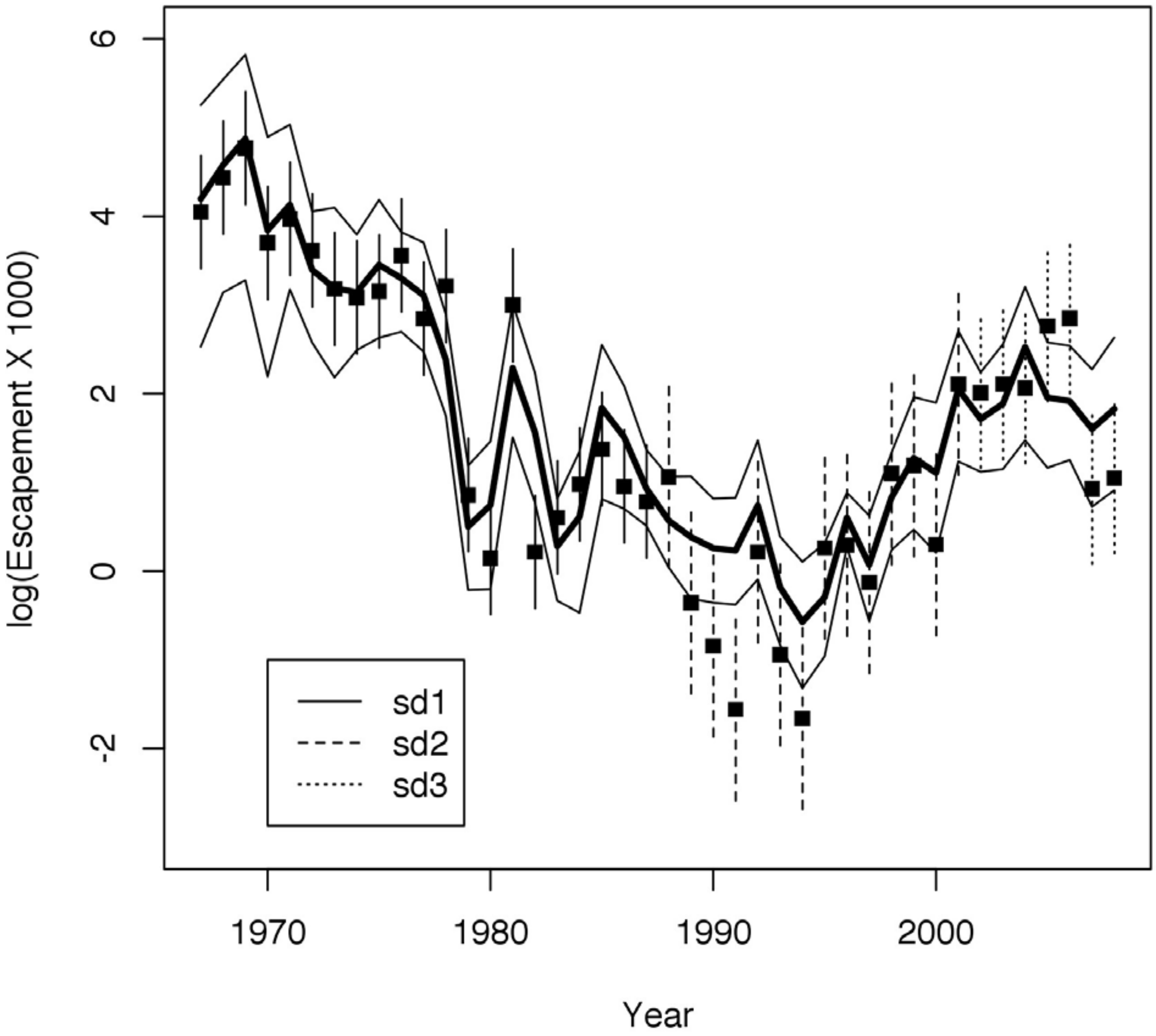
6
4
2
0
-2
log(Escapement X 1000)
1970
1980
1990
2000
Year
sd1
sd2
sd3

Figure D.2:

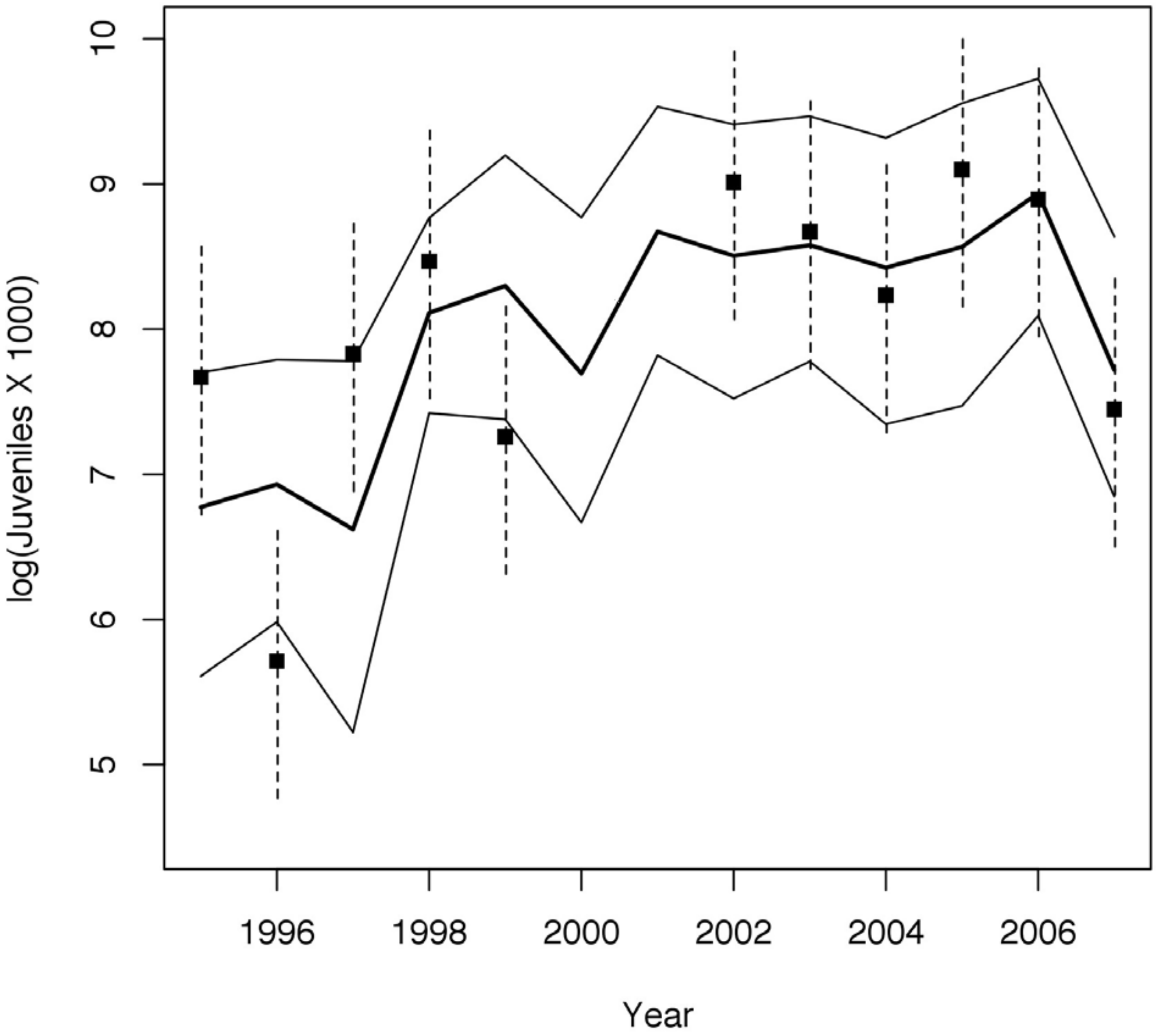
log(Juveniles X 1000)
10
9
8
7
6
5
1996
1998
2000
2002
2004
2006
Year

Figure D.3:

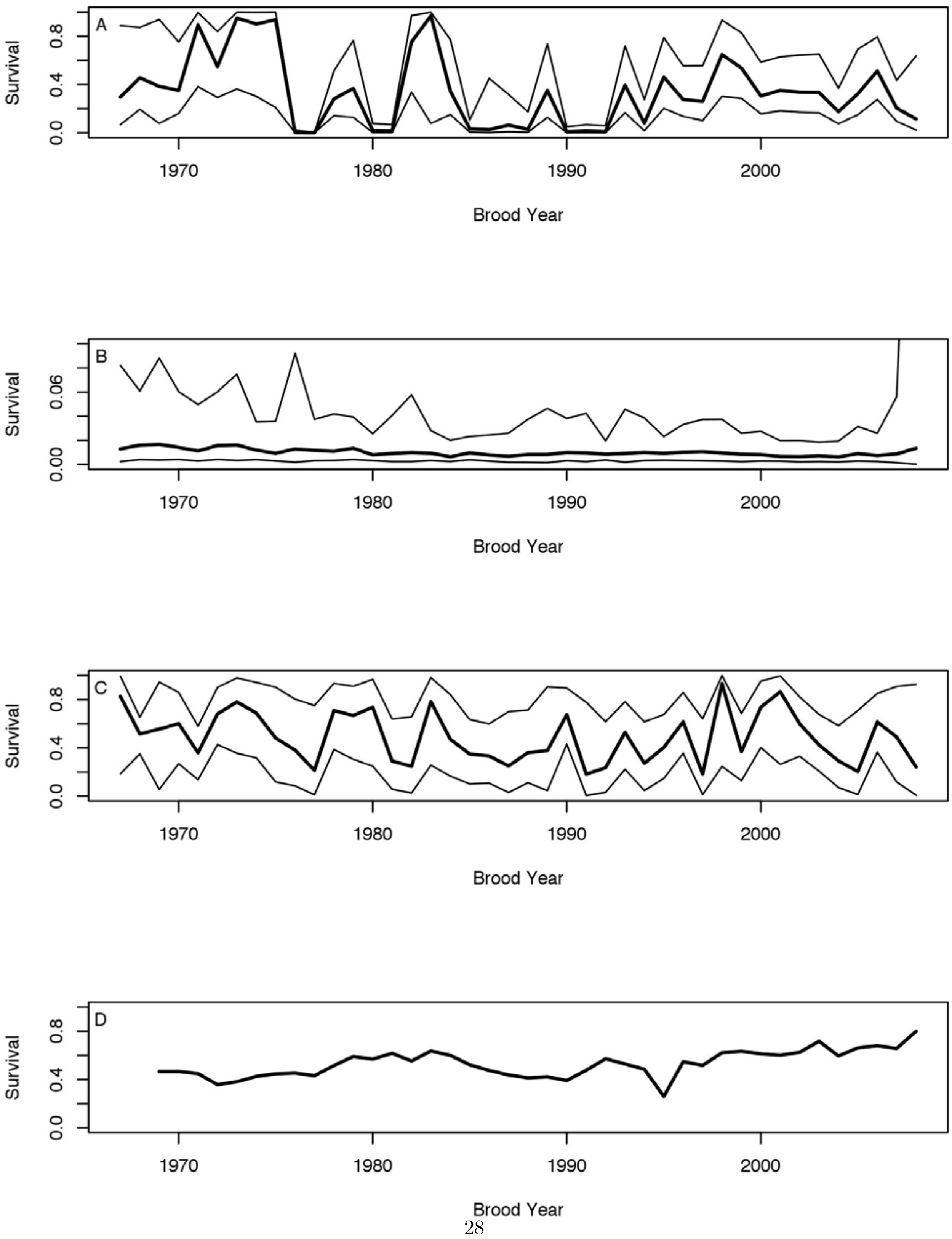

Figure D.4:

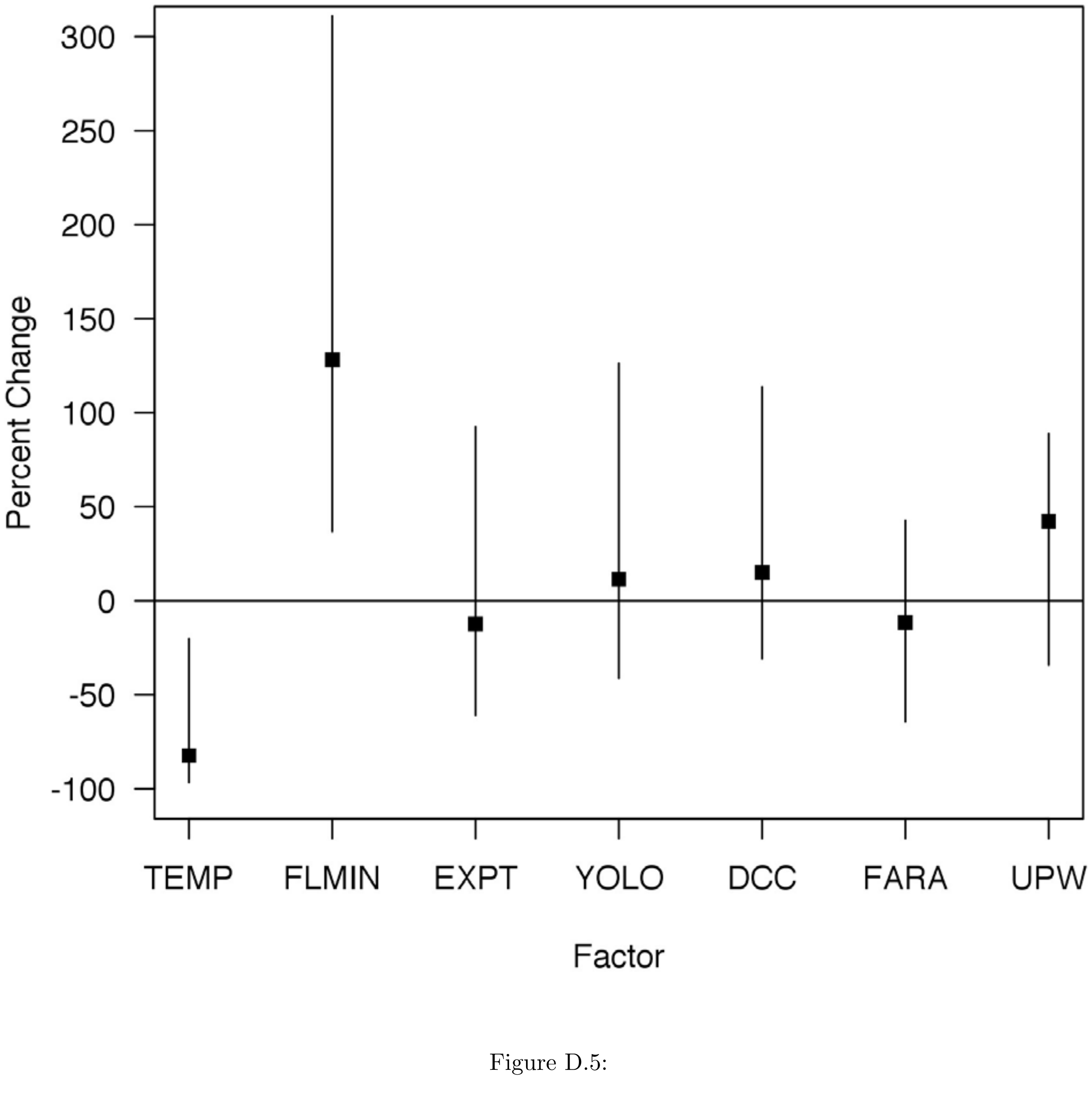
Percent Change
300
250
200
150
100
50
0
-50
-100
TEMP
FLMIN
EXPT
YOLO
DCC
FARA
UPW
Factor

Figure D.5:

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Chinook salmon outmigration survival in wet and dry years in California's Sacramento River

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ABSTRACT

Outmigration survival of acoustic tagged hatchery-origin Sacramento River late-fall run Chinook salmon (*Oncorhynchus tshawytscha*) smolts was estimated for five years (2007-2011) using a receiver array spanning the entire outmigration corridor, from the upper river, through the estuary, and into the coastal ocean. The first four years of releases occurred during below-average river flows, while the fifth year (2011) occurred during above-average flows. In 2011, overall outmigration survival was two to five times higher than survival in the other four years. Regional survival estimates indicate that most of the improved survival seen in 2011 occurred in the riverine reaches of the outmigration corridor, while survival in the brackish portions of the estuary did not significantly differ among the five years. For the four low flow years combined, survival rate in the river was lower in the more anthropogenically-modified upper reaches; however, across all regions, survival rate was lowest in the brackish portion of the estuary. Even in the high flow year, outmigration survival was substantially lower than yearling Chinook salmon populations in other large rivers. Potential drivers of these patterns are discussed, including channelization, water flow, and predation. Finally, management strategies are suggested to best exploit survival advantages described in this study.

INTRODUCTION

Knowing where excessive mortality is occurring is crucial to designing effective conservation measures for salmon populations. Salmon utilize many different habitats during the different stages of their life cycle, but it is the degradation of freshwater or estuarine habitats that is commonly cited as the cause of population declines (Nehlsen et al. 1991). Of particular concern is the high mortality often experienced in these habitats during one of the most vulnerable stages in the salmon life cycle: the downstream migration of juveniles ('smolts') heading to the ocean from their riverine birthplace (Healey 1991).

There has been extensive research on juvenile salmonid smolt survival in large rivers of the west coast of North America, most notably in the Columbia and Fraser Rivers (McMichael et al. 2010; Muir et al. 2001; Rechisky et al. 2013; Skalski et al. 1998; Welch et al. 2009; Welch et al. 2008). These studies have indicated that outmigration survival can vary widely from year to year and population to population, and further research in these rivers has shown that survival rates often correlate with environmental variables such as flow, turbidity and temperature (Giorgi et al. 1997; Gregory and Levings 1998; Smith et al. 2003). This information has proved crucial for improving salmon survival in the Columbia River, through improvements in fish passage structures and changes in dam operations (Connor et al. 2003).

California's Sacramento River, in contrast, is critically lacking in smolt outmigration survival information. The Sacramento River, compared to the Columbia and Fraser Rivers, has an order of magnitude lower discharge, exists in a warm and dry Mediterranean climate, and yet is the primary source of water to the state's industrial, domestic and agricultural sectors. The Sacramento River and its estuary are currently the objects of intense conservation concern due to the poor status of some of its salmon and steelhead populations (among other native species) and habitats. In spite of these problems, the Sacramento River is still an important contributor to west coast Chinook salmon (*Oncorhynchus tshawytscha*) fisheries, largely due to extensive hatchery propagation efforts (O'Farrell et al. 2013). Several very large water and habitat management projects are under consideration that are expected by their proponents to contribute to the restoration of Chinook salmon populations, yet survival rates across the life cycle of these populations are poorly known. Several coded-wire and acoustic tagging studies have assessed Chinook salmon smolt survival in the Sacramento-San Joaquin Delta (the freshwater portion of the estuary), which is the hub of water infrastructure for the majority of southern California and a location where anthropogenic modifications are extensive and salmonid losses are great (Baker and Morhardt 2001; Brandes and McLain 2001; Perry et al. 2010). However, no study has assessed smolt survival through the entirety of the outmigration corridor, from the upper limit of anadromy to the Pacific Ocean.

In this study, we quantify the spatial and temporal patterns of hatchery late-fall run Chinook salmon smolt survival in the Sacramento River system. Utilizing an extensive network of acoustic receivers, we estimated survival through the river and estuary over 5 years at a fine-scale spatial resolution previously not possible. This resolution allowed us to discern regional and temporal differences in survival that cannot be obtained using traditional tagging methods.

METHODS

Study area

The Sacramento River is the longest and largest (measured by flow discharge) river that is fully contained within the state of California, and is the third largest river that flows into the Pacific Ocean in the contiguous United States (Fig. 1). The headwaters are located just south of Mount Shasta in the lower Cascade Range and the river enters the ocean through the San Francisco Estuary at the Golden Gate. The total catchment area spans approximately 70,000 km^2. The Sacramento River and its tributaries have been heavily dammed and otherwise impacted by human activities; it is estimated that 47% of the historic spawning, migration and/or rearing area is no longer accessible to Chinook salmon (Yoshiyama et al. 2001).

The Sacramento River watershed includes diverse habitats, from relatively pristine run-riffle reaches in the north, to a heavily channelized and impacted waterway further south, and finally to the San Francisco Estuary, the largest and most modified estuary on the west coast of North America (Nichols et al. 1986). The San Francisco Estuary is comprised of an expansive tidally-influenced freshwater delta upstream of its confluence with the San Joaquin River and a series of increasingly saline bays. The sheer size and physical differences between these two sections of the estuary merit separate consideration with respects to their influence on salmon survival, therefore, we use the terms “delta” and “bays” to differentiate between the two.

The annual mean daily discharge for the Sacramento River from 1956 to 2008 was 668 m^3s^{-1} (Interagency Ecological Program, 2004). However, this water does not continue downstream unimpeded; due to one of the world’s largest water storage and water transportation infrastructures, replete with abundant dams, reservoirs, diversions and aqueducts, it is estimated that current discharge of the Sacramento and San Joaquin Rivers combined is less than 40% of the pre-development discharge (Nichols et al. 1986). The damming and water diversions of the Sacramento River and its tributaries have also homogenized river flows throughout the year, reducing winter high flows and flooding while increasing flows in the summer and fall (Buer et al. 1989).

The study area included approximately 92% of the current outmigration corridor of late-fall run Chinook salmon, from release to ocean entry. Specifically, the study area’s furthest upstream release site at Jelly’s Ferry (518 km upstream from the Golden Gate Bridge) is only 47 km downstream from Keswick Dam, the first impassable barrier to adult salmon returning to spawn on the Sacramento River.

Central Valley late-fall run Chinook salmon

The late-fall run is one of the four Chinook salmon runs occurring in the Sacramento River drainage, and is the only run to exhibit a predominately yearling migrant life history (Moyle 2002). Following emergence from the gravel, wild late-fall run juveniles exhibit a river residency of 7 to 13 months, after which smolts (juvenile salmon that are actively migrating to the ocean) will migrate to the ocean between the months of October and May at a fork length of 90 to 170 mm (Fisher 1994; Snider and Titus 2000a, b). In contrast, the subyearling life history demonstrated by a 4 to 7 months freshwater residency is the more common life history strategy used by the other salmon populations in the Sacramento River. Moyle et al. (1995) outlined six major threats to the late-fall run Chinook salmon population, one of which was mortality during outmigration, potentially due to water diversions and increased predation in bank-altered areas. In 2004, the fall/late-fall run Chinook salmon Evolutionarily Significant Unit (ESU) was designated a “species of concern” by the United States Endangered Species Act.

The United States Fish and Wildlife Service’s (USFWS) Coleman National Fish Hatchery (Anderson, CA) is the only hatchery to produce late-fall run Chinook salmon, releasing approximately one million smolts a year between mid-December and mid-January. Annual escapement for this population can vary from just several hundred to 42,000; the average annual escapement from the winter of 1973/1974 to the winter of 2007/2008 is 12,386 individuals (Azat 2015). Little information exists regarding what proportion of the late-fall run adult population is of hatchery origin versus wild origin. Palmer-Zwahlen and Kormos (2013) estimated that in 2011, 100% of late-fall run adults returning to Coleman National Fish Hatchery were hatchery fish while 44% of late-fall adults recovered during carcass surveys on the Sacramento River were hatchery origin.

Fish Tagging and Releases

For five consecutive winters, from January 2007 to December 2010/January 2011 (henceforth referred to as 2007, 2008, 2009, 2010 and 2011 seasons, based on the year during which January tagging occurred), 200 to 304 late-fall run Chinook salmon smolts from Coleman National Fish Hatchery were implanted with acoustic tags and released into the Sacramento River. Release times were scheduled to be within a few days of the release times of the general production of hatchery fish. Only smolts 140 mm or larger were tagged to keep the tag weight to less than 6% of the fish weight. Therefore, tagged smolts were representative of the larger hatchery individuals; specifically, from 2007 to 2011, smolts at or above the 140 mm cutoff represented 23.5%, 38.4%, 50.2%, 29.6, and 50.9% of the total hatchery production. In the rare instance that a smolt had severe descaling, fin erosion, or other obvious injuries, the smolt was discarded and not tagged.

Acoustic tags were surgically implanted into the peritoneal cavity of anesthetized fish. The tag was inserted through a 12 mm incision anterior to the pelvic girdle and 3 mm to the side of the *linea alba*. The incision was then closed with two simple interrupted stitches tied with square knots of non-absorbable nylon cable-type suture. All fish were allowed to recover for a minimum of 24 hours before release. Additional surgery details can be found in Ammann et al. (2013). In study years 2008 and 2009, an additional group of smolts from the same hatchery were tagged with dummy acoustic transmitters to monitor tag effects and tag retention in laboratory trials. No fish shed their tags over 221 and 160 days (the entire length of the trial in both years respectively) and tagged fish growth and survival was not significantly different than untagged fish (Ammann et al. 2013). Since fish in the field and captive studies had similar tag burdens (1.6 to 6.3% for field study, 2.6 to 5.6% for captive study), we assumed that mortality in the field study was not tag related.

In the first year (2007), a total of 200 fish were released in small batches (13-14 fish each) every weekday afternoon for the third, fourth and fifth weeks of January 2007 at the Coleman National Fish Hatchery into Battle Creek (river km 534 - “rkm” is distance from ocean), a tributary to the Sacramento River (Table 1). In the following four years, fish were released in two groups. In 2008-2010 a total of approximately 300 fish was released: ~50 fish were simultaneously released at dusk at three release sites in the upper 150 km of the mainstem Sacramento River (rkm 518, 412, 363) in mid-December and early January allowing the lower release groups to reach the lower river and estuary in larger numbers, which improved statistical precision of the survival estimation. In 2011, 240 fish were released: 120 fish were released in mid-December and early January at dusk at Jelly’s Ferry (rkm 518), a site on the mainstem Sacramento River, only 7.3 kilometers downstream of the confluence with Battle Creek. Fish were transported to the release sites by truck at low densities (~ 10 $g•l^{-1}$) in coolers with aerators. In years with multiple release sites, transport times were extended for closer sites to keep potential transport stress equal among all release groups.

Acoustic Telemetry

Acoustic tagging technology was used to acquire high-resolution movement data and survival estimates. Uniquely coded Vemco 69 kHz V7-2L acoustic tags (1.58g ± 0.03 S.D. in air, 7mm diameter by 20mm long; Amirix Systems, Inc., Halifax, Nova Scotia, Canada) and Vemco

VR2/VR2W receivers were used to tag and track fish. The tags transmitted every 30 to 90 seconds (with a mean of 60 seconds) in the first year of the study, then transmitted every 15 to 60 seconds (with a mean of 45 seconds) in the following four years. Battery life tests were conducted in 2007, 2010, and 2011 with a subset of tags from the same batch used for tagging smolts. In 2007, tag life of 11 test tags ranged from 138 to 749 days with a mean of 513; in 2010, tag life of 20 test tags ranged from 127 to 297 days with a mean of 194; in 2011, tag life of 25 test tags ranged from 98 to 214 days, with a mean of 172. For the purposes of verifying that tag life was sufficient to last the entire migration of all smolts, the time elapsed from release to last known detection was calculated for each smolt for all five years of the study. Last known detection for smolts was either last known detection before disappearance, or time of arrival to the Golden Gate receiver location (considered the end of the outmigration in this study). The longest outmigrating individual per year took 32, 89, 67, 97, and 79 days respectively for the years 2007-2011, with 99.2% of smolts successfully outmigrating or disappearing within the first 60 days after release. Therefore, we believe the battery life for our tags were sufficient to last the entire outmigration period of our tagged smolts.

The receiver array spanned 550 km of the Sacramento River watershed from below Keswick Dam to the entrance to the ocean (Golden Gate) and beyond to Point Reyes. This network of approximately 300 receivers at 210 receiver locations was maintained by the California Fish Tracking Consortium (http://californiafishtracking.ucdavis.edu), a group of academic, federal and state institutions, and private consulting firms. We selected a subset of these receiver locations for the final survival analyses, as per the selection criteria described in the Data Analysis section of the methods.

The acoustic receivers automatically process all detection data and drop most false detections or incomplete codes from the detection file. All detections were then subject to standardized quality control procedures to remove any remaining false detections (see Michel et al. (2013)).

Data Analysis

Survival in each reach

Juvenile Chinook salmon express obligate anadromy, meaning that they will travel toward the ocean once the emigration has begun with scarce exceptions (Healey 1991). Therefore, in a linear system such as the Sacramento River, if receiver locations were capable of detecting every passing tag, then if a fish is detected at one receiver location but is never detected thereafter, we could assume that the fish has died somewhere in the reach between the receiver location where it was last detected and the next downstream receiver location.

However, receiver locations rarely operate perfectly, necessitating the estimation of detection and survival probabilities at each receiver location. We used the Cormack-Jolly-Seber (CJS) model for live recaptures (Cormack 1964; Jolly 1965; Seber 1965) within Program MARK (White and Burnham 1999) using the RMark package (Laake and Rexstad) within program R (v. 3.0.1; R Development Core Team 2013). The CJS model was originally conceived to calculate survival of tagged animals over time, by re-sampling (recapturing) individuals and estimating survival and recapture probabilities using maximum likelihood. For species that express an obligate migratory behavior, a spatial form of the CJS model can be used, in which recaptures (i.e., tagged fish detected acoustically downstream from release) occur along a migratory corridor (Burnham 1987). The model determines if fish not detected at certain receivers were ever detected at any receiver downstream of that specific receiver, thus enabling calculation of maximum-likelihood estimates for detection probability of all receiver locations (p), survival (Φ), and 95% confidence intervals for both (Lebreton et al. 1992).

An initial run of the model with all possible river receiver locations together with the major estuary receiver locations was performed for each individual year separately, after which a subset of the river receiver locations that had consistently high tag detection probabilities through the years and that were strategically located were chosen to delimit the river reaches that were used in the spatial survival analysis. Additionally, because survival between the Battle Creek release site and Jelly's Ferry receiver location was only estimated in 2007, and because Jelly's Ferry was the furthest upstream release site for all following years, only fish known to have reached the Jelly's Ferry receiver location in 2007 were included in all survival analyses, and Jelly's Ferry was considered to be their release location. In total, 145 of the 200 smolts released in 2007 were known to have reached the Jelly's Ferry release location and were included in survival analyses. A total of 19 receiver locations were chosen, extending from just below the most upstream release site, Jelly's Ferry, to the Golden Gate (Fig. 1; Table 2). Between them, we delineated 17 reaches in which mortality can be accurately estimated (the detection probability and survival of the 18th and last reach can only be estimated jointly as there is no detection information beyond this point in which to assess the final receiver location).

Parallel receiver lines were installed at the Golden Gate approximately 1 km apart in order to estimate detection probability and survival at the inner (East) Golden Gate receiver line by using the western line to assess performance of the eastern line. After the 2008 outmigration season, a coastal ocean receiver line was deployed across the continental shelf at Point Reyes, approximately 60 km north of the Golden Gate. Detections from this receiver line were included in the encounter history for the Golden Gate West line to improve accuracy in the estimation of survival and detection probability to the Golden Gate East line. However, because the Point Reyes receiver location did not exist in the 2007 or 2008 season, and few fish were detected there in subsequent years, it was not formally included as a receiver location in the survival analyses.

Survival per 10 km, regional survival and overall survival

For each year, we used the 18 receiver locations to estimate reach survival (“ϕ_R”) for 17 reaches, using the fully time-varying CJS model, which in this case actually varies over space, specifically each reach has a parameter (“reach model”). Detection probabilities were also allowed to vary by reach. These survival estimates were then standardized by reach lengths *l* (giving survival per 10 km, “ϕ_{10}”) to allow inter-reach survival comparisons. This was done by setting the time intervals (in reality, space intervals for this application) in the process.data() function of RMark package to a vector of reach lengths (in units of 10 km). The per 10 km survival estimates are calculated by RMark according to this formula (Eqn 1):

$$(1) \qquad \phi_{10} = \sqrt[l]{\phi_R}$$

To account for the propagation of error, standard errors for *n*th root parameter estimates were calculated by the RMark package using the delta method (Powell 2007; Seber 1982).

Regional (river, delta, and bays) and overall (from the release site to the Golden Gate) survival was then assessed for each year. We did this by taking the product of the reach survival estimates that fall inside the spatial extent of interest, and we present this as percent survival. To account for the propagation of error, standard errors of the cumulative products of survival estimates were also calculated using the RMark package, using the deltamethod.special() function. When using the delta method for estimating the variance of the product of survival estimates, the variance-covariance matrix for the survival estimates must be included in the estimation. Confidence intervals for the product of survival estimates must be calculated on the logit scale, then back-transformed to the real probability scale. Therefore, to estimate 95% confidence intervals, we used our product of survival estimates ($\widehat{\phi}$) along with its respective standard error of the beta estimate ($\widehat{SE}logit(\widehat{\phi})$) by using the formula (Eqn 2):

$$(2) \qquad expit[logit(\widehat{\phi}) \pm 1.96 \times \widehat{SE}logit(\widehat{\phi})]$$

The influences of different spatial and temporal factors on survival rates were assessed by modeling ϕ_R as a function of the factor in question. Specifically, the influence of these factors was assessed by allowing each release group (e.g., five groups for the release year model: 2007, 2008, 2009, 2010 and 2011) within each model to have its own set of survival parameters. Each factor-specific survival model was compared to one another and to a base model (a model with no factor-specific parameters) using Akaike's Information Criterion corrected for small sample sizes (AICc). Goodness-of-fit was assessed by estimating the $\hat{c}$ variance inflator factor of the base model. For this we used two different methods, and adopted the more conservative estimate. Firstly, we simulated $\hat{c}$ and deviance from 100 simulations using the bootstrap procedure. Then, we estimated $\hat{c}$ in two ways, first by dividing the deviance estimate from the original data by the mean of simulated deviances, giving a $\hat{c}$ of 1.309, then by dividing the $\hat{c}$ from the original data by the mean $\hat{c}$ from the bootstraps, giving a $\hat{c}$ of 1.494. We therefore adopted the more conservative $\hat{c}$ of 1.494 and used it to adjust all AIC values for overdispersion (herafter called QAICc). As a rule of thumb, if a test model lowered QAICc relative to the base model by a difference of more than seven, the test model was deemed substantially more parsimonious, and therefore supported over the base model.

The effects of reach (n=17), release year (n=5), release site (n=3), and all interactions of those factors were tested (Table 3 for models). This was done by comparing the QAICc score of each model to the QAICc score of a version of the "reach model" that combines data from all five years, which henceforth will be considering the "*base* model". We used the reach model as our base model under the assumption that survival must vary through space given the spatial heterogeneity of the study system. To test this assumption, a "null model" was also included for comparison. This model only allowed one parameter for survival (representing the null hypothesis: constant survival through space and time). An initial run of several models that allowed for different parameterization of the detection probability terms, while keeping the survival terms the same, indicated that the model allowing for detection probability to vary by reach and year was the best supported. Therefore, all survival models presented in Table 3 allow detection probability to vary by reach and year [*p(*reach*year)].

In order to better understand whether annual fluctuations in survival occurred on a regional scale, we also included three models that allowed survival to vary per reach and per year (reach*year) in only the river, the delta (the delta being the freshwater portion of the estuary) or the bays (Suisun, San Pablo and San Francisco Bays, i.e. the brackish portion of the estuary). These models allowed survival to vary by reach in the remaining regions, and are therefore also comparable with the base model.

Finally, the influence of individual covariates (fork length (mm) and weight (g)) on survival was assessed. The model selected *a priori* to include these covariates was the base model. The individual covariates were added both as an additive factor (different intercept per reach, but common slope), and as factor including the interaction term (different intercept and different slope). These models were then compared using QAICc to the base model without any individual covariates to determine whether fish size and weight affects survival.

For the purpose of considering migration rate as a potential driver for survival rates, mean successful migration movement rate (km/day MSMMR; (Michel et al. 2013)) was calculated per year. Migration movement rate from release site to the West Golden Gate receiver line (i.e., entry to the Pacific Ocean) was calculated for every fish that was detected (i.e., successfully reached the ocean) at either of the Golden Gate receiver lines. These values were then averaged per year and compared to the overall survival for that year in Table 4.

RESULTS

Overall survival of late-fall run Chinook through the entire migration corridor (rkm 518 to rkm 2) per year ranged from 2.8 to 15.7%, with 2011 having the highest survival (Table 4). The MSMMR values indicate that the first four years of the study had relatively similar migration rates, ranging from 17.5 to 23.5 kilometers per day, whereas 2011 had a faster migration rate of 36 kilometers per day.

Survival rate on a reach-by-reach basis was quite variable. During the first four years of the study, the upper river reaches (reaches 1 through 8; rkm 518 to 325) had some of the lowest survival per 10 km and the lower reaches of the river (reaches 9-12; rkm 325-169) had the highest. The delta was comparable to the upper river, and the San Francisco and Suisun Bays (reaches 13-17; rkm 169-2) had the lowest survival rates (Fig. 2). During these same four years, detection probabilities per year and per receiver location throughout the watershed ranged from

4% to 100%, with 90% of all detection probabilities being larger than 50%. In the fifth year, river flows at the time of release were much higher than in the previous four years (Fig. 3), and as a result detection rates were much lower in the river, with only three of the twelve river receiver locations having a detection probability higher than 1%. Therefore 2011 reach-specific survival in the river was not estimable.

Region-specific survival estimates were calculated using the product of all reach-specific survival estimates within the region of interest (Fig. 4; Table 4). Although reach specific survival parameters could not be estimated for the river region in 2011, detection probability improved downstream as water velocity decreased, allowing the estimation of reach specific and region specific survival estimates downstream of the river region. To estimate river region survival in 2011, and to further investigate differences in survival between 2011 and the previous years, the detection data was simplified for a post-hoc CJS modeling exercise that would allow the inclusion of 2011. We simplified the detection data by only including detections from four receiver locations separating the major watershed regions: Freeport at the downstream end of the river region, Chipps Island at the downstream end of the delta region, and the two parallel Golden Gate receiver lines at the downstream end of the bays region. Additionally, only fish released at the Jelly's Ferry site were included for all years since the other release locations did not have associated receiver locations. A preliminary model that allowed survival and detection probability to vary by region and by year (region*year) allowed us to estimate survival in the river region in 2011 (Fig. 4; Table 4). This estimate revealed that survival in the river in 2011 was much higher than in all previous years, while survival in the delta and bays was similar among all five years. We also constructed a set of similar models where one year was given its own set of region specific survival parameters, while the remaining four years shared the same region specific survival parameters. These models allowed detection probability to vary by region and by year. Five models were constructed, each one allowing a different year to have its own survival parameters. The model allowing 2011 to have its own region-specific survival parameters while the other four years shared the same region-specific parameters was substantially better supported (ΔQAICc >7) than all the other models of the same type, as well as the preliminary model (permitting all years to have different region-specific survival parameters).

In the analysis of the effect of different spatial and temporal factors on survival, 2011 data was omitted due to the lack of detection data available in the river portions of the watershed. The influence of reach on survival rates (base model) was found to have substantially better support (ΔQAICc >>7) than the null model (constant survival through space and time; Table 3). The reach models that included release site or year ("Reach*release" and "Reach*year", respectively), as well as the interaction model ("Reach*year*release"), did not improve their support over the base model. The year model was better supported than the release model. The only model that had substantially better support than the base model was the model that allowed for river survival to have a year effect, while delta and bays survival was held constant through time. ("(River survival*year)*reach"). The model allowing only the delta reach to have a year effect ("(Delta survival*year)*reach") was marginally better supported than the base model (ΔQAICc <2).

Tagged fish weight and fork length varied significantly among years (P<0.001), and pairwise hypothesis testing using Bonferroni and Tukey's honestly significant difference tests both indicate that fish sizes were statistically different among all years (with the exception of the 2009/2010 pair) (Table 1). However, the addition of individual covariates (weight, length) as factors to the base model did not improve parsimony in any circumstance, although the length model did fit the data better than the weight model. A model adding length as an additive factor had more support than the other covariate models, and had approximately equal support with the base model (ΔQAICc <0.1; Table 3). Therefore the significant differences in weight and fork length among years did not appear to affect survival.

DISCUSSION

This study used high resolution fish tracking and environmental data to provide the first reach-specific survival estimates of Chinook salmon smolts in the Sacramento River over the entire migration corridor. Survival was relatively high in the lower river compared to other areas, a somewhat unexpected finding given that this reach is channelized and rip-rapped. Also, and in contrast with the commonly-held belief that mortality during the Central Valley smolt outmigration is greatest in the delta (Williams 2006), we observed relatively high mortality in the upper river and especially in the bays downstream of the delta. We found that survival over the entire migration route was much lower in four low-discharge years (2.8 – 5.9%) than in one high-discharge year (15.9%; Fig. 3); higher survival in the high-discharge year was due mainly to increased survival in the river region. This suggests that riverine survival dynamics may be playing an underappreciated role in determining annual salmon stock abundance, as shown with Cheakamus River steelhead stock in British Columbia (Melnychuk et al. 2014).

One potential reason why the lower Sacramento River had higher survival than expected may be due to channelization. Levees, riprap, and channelization have been considered detrimental for salmon populations due to their degradation of spawning grounds (reduced input of gravel), the paucity of prey to feed upon, and an absence of cover that results in a greater frequency of predation on juveniles (Buer et al. 1989; Chapman and Knudsen 1980; Garland et al. 2002; Schmetterling et al. 2001)). However, Michel (2010) found a strong positive correlation between channelized reaches and smolt survival. Given limited rearing potential, smolts likely migrate through channelized reaches, reducing the period of exposure to sources of mortality. The majority of potential predator species in the watershed are typically found associated with submerged structure and vegetation, which in the lower Sacramento River are mostly limited to the riprapped littoral zone. A smolt travelling downstream in the lower Sacramento River only needs to avoid the channel margins to minimize exposure to predators. Outmigrating Chinook salmon smolts in the Sacramento River travel disproportionally more in the center of the channel (Sandstrom et al. 2013). Similarly, smolt survival was higher in deep impoundments compared to shallower undammed reaches of the Columbia River (Welch et al. 2008).

Previous studies of salmon survival in the Sacramento River and estuary, based primarily on coded-wire tags, suggested significantly lower mortality in the bays, but higher mortality in the river. Brandes and McLain (2001) found survival of sub-yearling fall-run Chinook salmon smolts from Port Chicago to the Golden Gate (roughly equal to our bays region) during the 1984-1986 years to vary between 76% and 84%, compared to a range of 26% to 43% in this study. California Department of Fish and Wildlife monitored survival rates of late-fall Chinook salmon from Battle Creek to rkm 239 (within the river region) during the 1996-2000 years using coded-wire tag recoveries at rotary screw traps. They estimated survival rates to vary between 1.1% and 2.7% (Snider and Titus 1998, 2000a, b, c; Vincik et al. 2006), compared to a range of 15.5% to

63.2% over a longer distance in this study. Reasons for these discrepancies could lie in the conditions during the years compared, or could have to do with the difference in sampling protocol and survival estimation.

Overall survival of outmigrating late-fall run Chinook salmon smolts in the Sacramento River is low in comparison to the Columbia and Fraser rivers, in spite of those rivers having substantially longer migration corridors. Welch et al. (2008) found that yearling Chinook salmon smolts from the Snake River (a tributary to the Columbia River) had an overall survival of 27.5% (± 6.9% S.E.) to the ocean over a distance of 910 km in 2006. That study also found that overall survival for yearling Chinook salmon smolts from various tributaries of the Fraser River to the ocean over distances ranging from 330.8 to 395.2 km had an overall survival varying from 2.0% (± 3.6 S.E.) to 32.2% (± 20.7 S.E.), with the majority of the tributary and year-specific survival estimates above 15%. Rechisky et al. (2009) found that outmigrating yearling Chinook salmon smolts from the Yakima River (a tributary to the Columbia River) had an overall survival of 28% (± 5 S.E.) to the ocean over a distance of 655 km.

There are also striking differences in the spatial patterns of survival between the Sacramento River and the Columbia and Fraser Rivers. Columbia River tagging studies have found survival for yearling Chinook salmon through the lower river and estuary to vary between 82% and 100% (or between 98.3% and 100% per 10km), depending on the year and population (Harnish et al. 2012; Rechisky et al. 2013). Similarly-sized sockeye salmon (*Oncorhynchus nerka*) smolts experienced little to no mortality during outmigration through the mainstem Fraser River (including the estuary) during the years 2010-2013 (Rechisky et al. 2014). In our study, survival through the estuary (delta and bays region combined) ranged from 15.1% to 23.4% (89.3%-91.7% per 10 km).

There are a number of possible explanations for why the survival of Chinook smolts in the Sacramento River is generally lower than in other west coast rivers. Flows in the Sacramento River are highly regulated by large water storage dams, and peak discharge is typically much reduced in the outmigration period (Buer et al. 1989; Larry and Marissa 2009). In contrast, no dams exist on the mainstem Fraser River, and the dams on the Columbia River are used for hydropower and do not reduce or homogenize flows to the same extent as water storage dams. It is only in wet years such as 2011 that water flows are high enough for water managers to allow significant dam releases in the Sacramento River. We observed much higher in-river survival during 2011, and other studies have shown positive relationships between survival and river flow (Connor et al. 2003; Smith et al. 2003). Higher flows correspond to higher velocities and faster travel times, reducing the time smolts are exposed to predators (Hogasen 1998). High flows may also be correlated to higher turbidities, which can reduce the effectiveness of visual predators (Ferrari et al. 2014; Gregory and Levings 1998).

Differences in the condition of estuaries offer another explanation. Magnusson and Hilborn (2003) found that in comparing the survival of subyearling Chinook salmon smolts in 27 different small to medium sized estuaries in the U.S. Pacific Northwest, there was a significant positive relationship between survival and the percentage of the estuary that was in pristine condition. They also note that according to MacFarlane and Norton (2002), estuary use by subyearling Chinook salmon smolts was less in the brackish portion of San Francisco Estuary than other estuaries in the Pacific Northwest, potentially due to the poor condition of the estuary.

Nichols et al. (1986) posited that the San Francisco estuary is the most modified estuary on the west coast of the United States, which suggests that the low survival estimates seen in this study are consistent with Magnusson and Hilborn's findings. Cohen and Carlton (1998) suggested that the extensive modification of the San Francisco Estuary contributes to it being perhaps the most invaded estuary in the world. Invaders include a number of piscivorous fish species that likely prey on migrating juvenile salmon. The role of predation clearly warrants study.

Survival rates during drought years observed in this study, if applicable to natural populations, suggest that populations are likely contracting. Bradford's (1995) review of Pacific salmon mortality rates suggested that typical fished Chinook salmon populations have a total mortality rate of 6.76 (based on fecundity) and an average observed egg-to-smolt mortality rate of 2.56. Average smolt mortality rate ($-\log_e(\mathit{survival})$) during the first four years of our study was 3.23. A stable population subject to these mortality rates would require total mortality to be no more than 0.97 (or no less than 38% survival) for the period between ocean entry and reproduction, a period of two to four years for late-fall Chinook subject to significant ocean harvest rates.

Our results have implications for the management of Central Valley salmon hatcheries. Much of the hatchery production in the Central Valley is transported by tanker truck to the bays in order to avoid mortality incurred during the migration through the river and delta. Offsite release leads to undesirable levels of straying, and a recent independent review of California salmon hatchery practices recommends on-site release of hatchery production (CHSRG 2012). Salmon smolts have long been known to migrate during peak flows (Healey 1991; Hogasen 1998; Kjelson et al. 1981). Our study has shown that fish migrating during high flows have higher survival. Hatcheries could employ a “release window” strategy during which they wait for a peak flow, or coordinate their operations with releases from upstream reservoirs that could create artificial pulse flows. Reservoir releases have been shown to improve subyearling Chinook salmon smolt survival (Zeug et al. 2014), although evidence for improved yearling survival is not as clear (Giorgi et al. 1997; Young et al. 2011). The efficacy of reservoir release will depend on the degree to which survival benefits of migrating during freshets are due to decreased travel time versus higher turbidity, which may not be easily manipulated through reservoir operations.

Our study has demonstrated remarkably low survival rates for late-fall run Chinook salmon smolts in the Sacramento River. The Sacramento River is also home to three other runs of Chinook salmon that migrate at smaller sizes and later in the season (Fisher 1994), when water temperatures are higher and predators may be more active. These other runs may therefore be experiencing even lower survival. Furthermore, most mortality in this study occurred in a 1-2 week period for hatchery fish. This has disconcerting implications for wild fish that must spend several months to a year rearing in the watershed. As tags become smaller, the study design utilized here can be applied to document spatial and temporal patterns of survival in these other runs that are of significant conservation and fishery concerns, providing resource managers with valuable information on where and when survival problems are occurring - information necessary to effective mitigation of survival problems.

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REFERENCES

Ammann, A.J., Michel, C.J., and MacFarlane, R.B. 2013. The effects of surgically implanted acoustic transmitters on laboratory growth, survival and tag retention in hatchery yearling Chinook salmon. Environmental Biology of Fishes **96**(2-3): 135-143.

Azat, J. 2015. GrandTab 2015.04.15 California Central Valley Chinook Population Database Report. CA Department of Fish and Wildlife.

Baker, P.F., and Morhardt, J.E. 2001. Survival of Chinook Salmon Smolts in the Sacramento-San Joaquin Delta and Pacific Ocean. *In* Contributions to the Biology of Central Valley Salmonids. *Edited by* L.R. Brown. California Department of Fish and Game, Sacramento, California. pp. 163-182.

Bradford, M.J. 1995. Comparative review of Pacific salmon survival rates. Canadian Journal of Fisheries and Aquatic Sciences **52**(6): 1327-1338.

Brandes, P.L., and McLain, J.S. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. *In* Contributions to the Biology of Central

Valley Salmonids. *Edited by* L.R. Brown. California Department of Fish and Game, Sacramento, California. pp. 39-138.

Buer, K., Forwalter, D., Kissel, M., and Stohler, B. 1989. The Middle Sacramento River: Human impacts on physical and ecological processes along a meandering river.

Burnham, K.P. 1987. Design and analysis methods for fish survival experiments based on release-recapture. American Fisheries Society, Bethesda, MD. (USA).

California Hatchery Scientific Review Group (CHSRG). 2012. California Hatchery Review Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission.

Chapman, D.W., and Knudsen, E. 1980. Channelization and Livestock Impacts on Salmonid Habitat and Biomass in Western Washington. Transactions of the American Fisheries Society **109**(4): 357-363.

Cohen, A.N., and Carlton, J.T. 1998. Accelerating Invasion Rate in a Highly Invaded Estuary. Science **279**(5350): 555-558.

Connor, W.P., Burge, H.L., Yearsley, J.R., and Bjornn, T.C. 2003. Influence of Flow and Temperature on Survival of Wild Subyearling Fall Chinook Salmon in the Snake River. North American Journal of Fisheries Management **23**(2): 362-375.

Cormack, R.M. 1964. Estimates of Survival from the Sighting of Marked Animals. Biometrika **51**(3/4): 429-438.

Ferrari, M.C.O., Ranaker, L., Weinersmith, K.L., Young, M.J., Sih, A., and Conrad, J.L. 2014. Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. Environmental Biology of Fishes **97**(1): 79-90.

Fisher, F.W. 1994. Past and Present Status of Central Valley Chinook Salmon. Conservation Biology **8**(3): 870-873.

Garland, R.D., Tiffan, K.F., Rondorf, D.W., and Clark, L.O. 2002. Comparison of Subyearling Fall Chinook Salmon's Use of Riprap Revetments and Unaltered Habitats in Lake Wallula of the Columbia River. North American Journal of Fisheries Management **22**(4): 1283-1289.

Giorgi, A.E., Hillman, T., Stevenson, J.S., Hays, S.G., and Peven, C.M. 1997. Factors that influence the downstream migration rates of juvenile salmon and steelhead through the hydroelectric system in the mid-Columbia River basin. North American Journal of Fisheries Management **17**(2): 268-282.

Gregory, R.S., and Levings, C.D. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society **127**(2): 275-285.

Harnish, R.A., Johnson, G.E., McMichael, G.A., Hughes, M.S., and Ebberts, B.D. 2012. Effect of Migration Pathway on Travel Time and Survival of Acoustic-Tagged Juvenile Salmonids in the Columbia River Estuary. Transactions of the American Fisheries Society **141**(2): 507-519.

Healey, M.C. 1991. Pacific Salmon Life Histories *Edited by* C.G.a.L. Margolis. University of British Columbia Press, Vancouver. pp. 312-230.

Hogasen, H.R. 1998. Physiological changes associated with the diadromous migration of salmonids. Canadian Special Publication of Fisheries and Aquatic Sciences **127**: i-viii, 1-128.

Jolly, G.M. 1965. Explicit Estimates from Capture-Recapture Data with Both Death and Immigration-Stochastic Model. Biometrika **52**(1/2): 225-247.

Kjelson, M., Raquel, P.F., and Fisher, F.W. 1981. Influences of freshwater inflow on chinook salmon (*Oncorhynchus tshawystcha*) in the Sacramento-San Joaquin Estuary, U.S. Fish and Wildlife Service, pp. 88-108.

Laake, J., and Rexstad, E. 2008. RMark—an alternative approach to building linear models in MARK. *In* Program MARK: A Gentle Introduction. *Edited by* E. Cooch and G.C. White.

Larry, R.B., and Marissa, L.B. 2009. Effects of hydrologic infrastructure on flow regimes of California's Central Valley rivers: Implications for fish populations. River Research and Applications **26**(6): 751-765.

Lebreton, J.-D., Burnham, K.P., Clobert, J., and Anderson, D.R. 1992. Modeling Survival and Testing Biological Hypotheses Using Marked Animals: A Unified Approach with Case Studies. Ecological Monographs **62**(1): 67-118.

MacFarlane, R.B., and Norton, E.C. 2002. Physiological ecology of juvenile chinook salmon (*Oncorhynchus tshawytscha*) at the southern end of their distribution, the San Francisco Estuary and Gulf of the Farallones, California. Fishery Bulletin **100**(2): 244-257.

Magnusson, A., and Hilborn, R. 2003. Estuarine influence on survival rates of Coho (*Oncorhynchus kisutch*) and Chinook salmon (*Oncorhynchus tshawytscha*) released from hatcheries on the US Pacific Coast. Estuaries **26**(4B): 1094-1103.

McMichael, G.A., Eppard, M.B., Carlson, T.J., Carter, J.A., Ebberts, B.D., Brown, R.S., Weiland, M., Ploskey, G.R., Harnish, R.A., and Deng, Z.D. 2010. The Juvenile Salmon Acoustic Telemetry System: A New Tool. Fisheries **35**(1): 9-22.

Melnychuk, M.C., Korman, J., Hausch, S., Welch, D.W., McCubbing, D.J.F., and Walters, C.J. 2014. Marine survival difference between wild and hatchery-reared steelhead trout determined during early downstream migration. Canadian Journal of Fisheries and Aquatic Sciences **71**(6): 831-846.

Michel, C.J. 2010. River and estuarine survival and migration of yearling Sacramento River Chinook Salmon (*Oncorhynchus tshawytscha*) smolts and the influence of environment, Ecology and Evolutionary Biology, University of California - Santa Cruz, Santa Cruz, CA.

Michel, C.J., Ammann, A.J., Chapman, E.D., Sandstrom, P.T., Fish, H.E., Thomas, M.J., Singer, G.P., Lindley, S.T., Klimley, A.P., and MacFarlane, R.B. 2013. The effects of environmental factors on the migratory movement patterns of Sacramento River yearling late-fall run Chinook salmon (*Oncorhynchus tshawytscha*). Environmental Biology of Fishes **96**(2-3): 257-271.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press, Berkeley, California.

Moyle, P.B., Yoshiyama, R.M., Wikramanayake, E.D., and Williams, J.E. 1995. Fish Species of Special Concern. California Department of Fish and Game, Sacramento, CA.

Muir, W.D., Smith, S.G., Williams, J.G., Hockersmith, E.E., and Skalski, J.R. 2001. Survival Estimates for Migrant Yearling Chinook Salmon and Steelhead Tagged with Passive Integrated Transponders in the Lower Snake and Lower Columbia Rivers, 1993-1998. North American Journal of Fisheries Management **21**(2): 269-282.

Nehlsen, W., Williams, J.E., and Lichatowich, J.A. 1991. Pacific Salmon at the Crossroads: Stocks at Risk from California, Oregon, Idaho, and Washington. Fisheries **16**(2): 4-21.

Nichols, F.H., Cloern, J.E., Luoma, S.N., and Peterson, D.H. 1986. The Modification of an Estuary. Science **231**(4738): 567-573.

O'Farrell, M.R., Mohr, M.S., Palmer-Zwahlen, M.L., and Grover, A.M. 2013. The Sacramento Index (SI). NOAA Technical Memorandum. U.S. Department of Commerce.

Palmer-Zwahlen, M., and Kormos, B. 2013. Recovery of Coded-Wire Tags from Chinook Salmon in California's Central Valley Escapement and Ocean Harvest in 2011.

Perry, R.W., Skalski, J.R., Brandes, P.L., Sandstrom, P.T., Klimley, A.P., Ammann, A., and MacFarlane, B. 2010. Estimating Survival and Migration Route Probabilities of Juvenile Chinook Salmon in the Sacramento-San Joaquin River Delta. North American Journal of Fisheries Management **30**(1): 142-156.

Powell, L.A. 2007. Approximating variance of demographic parameters using the Delta Method: A reference for avian biologists. The Condor **109**(4): 949-954.

Rechisky, E.L., Welch, D.W., Porter, A.D., Furey, N.B., and Hinch, S.G. 2014. Telemetry-based estimates of early marine survival and residence time of juvenile Sockeye salmon in the Strait of Georgia and Discovery Passage, 2013. State of the Physical, Biological and Selected Fishery Resources of Pacific Canadian Marine Ecosystems in 2013, Canadian Technical Report of Fisheries and Aquatic Sciences, Fisheries & Oceans Canada: 123-127.

Rechisky, E.L., Welch, D.W., Porter, A.D., Jacobs-Scott, M.C., and Winchell, P.M. 2013. Influence of multiple dam passage on survival of juvenile Chinook salmon in the Columbia River estuary and coastal ocean. Proceedings of the National Academy of Sciences **110**(17): 6883-6888.

Rechisky, E.L., Welch, D.W., Porter, A.D., Jacobs, M.C., and Ladouceur, A. 2009. Experimental measurement of hydrosystem-induced delayed mortality in juvenile Snake River spring Chinook salmon (*Oncorhynchus tshawytscha*) using a large-scale acoustic array. Canadian Journal of Fisheries and Aquatic Sciences **66**(7): 1019-1024.

Sandstrom, P.T., Smith, D.L., and Mulvey, B. 2013. Two-dimensional (2-D) Acoustic Fish Tracking at River Mile 85, Sacramento River, California. U.S. Army Corps of Engineers, Engineer Research and Development Center.

Schmetterling, D.A., Clancy, C.G., and Brandt, T.M. 2001. Effects of Riprap Bank Reinforcement on Stream Salmonids in the Western United States. Fisheries **26**(7): 6-13.

Seber, G.A. 1982. The estimation of animal abundance and related parameters. Chapman, London and Macmillan.

Seber, G.A.F. 1965. A Note on the Multiple-Recapture Census. Biometrika **52**(1/2): 249-259.

Skalski, J.R., Smith, S.G., Iwamoto, R.N., Williams, J.G., and Hoffmann, A. 1998. Use of passive integrated transponder tags to estimate survival of migrant juvenile salmonids in the Snake and Columbia rivers. Canadian Journal of Fisheries and Aquatic Sciences **55**(6): 1484-1493.

Smith, S.G., Muir, W.D., Hockersmith, E.E., Zabel, R.W., Graves, R.J., Ross, C.V., Connor, W.P., and Arnsberg, B.D. 2003. Influence of river conditions on survival and travel time of Snake River subyearling fall chinook salmon. North American Journal of Fisheries Management **23**(3): 939-961.

Snider, B., and Titus, R.G. 1998. Evaluation of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, November 1995-July 1996. Stream Evaluation Program Technical Report. California Department of Fish and Game.

Snider, B., and Titus, R.G. 2000a. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1996-September 1997. Stream Evaluation Program Technical Report. California Department of Fish and Game.

Snider, B., and Titus, R.G. 2000b. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1997-September 1998. Stream Evaluation Program Technical Report. California Department of Fish and Game.

Snider, B., and Titus, R.G. 2000c. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, October 1998-September 1999. Stream Evaluation Program Technical Report. California Department of Fish and Game.

Vincik, R.F., Titus, R.G., and Snider, B. 2006. Timing, composition, and abundance of juvenile anadromous salmonid emigration in the Sacramento River near Knights Landing, September 1999-September 2000. Lower Sacramento River Juvenile Salmonid Emigration Program Technical Report. California Department of Fish and Game.

Welch, D.W., Melnychuk, M.C., Rechisky, E.R., Porter, A.D., Jacobs, M.C., Ladouceur, A., McKinley, R.S., and Jackson, G.D. 2009. Freshwater and marine migration and survival of endangered Cultus Lake sockeye salmon (*Oncorhynchus nerka*) smolts using POST, a large-scale acoustic telemetry array. Canadian Journal of Fisheries and Aquatic Sciences **66**(5): 736-750.

Welch, D.W., Rechisky, E.L., Melnychuk, M.C., Porter, A.D., Walters, C.J., Clements, S., Clemens, B.J., McKinley, R.S., and Schreck, C. 2008. Survival of Migrating Salmon Smolts in Large Rivers With and Without Dams. PLoS. Biol. **6**(10): 2101-2108.

White, G.C., and Burnham, K.P. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study **46**(1 supp 1): 120 - 139.

Williams, J.G. 2006. Central Valley Salmon: A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science **4**(3).

Yoshiyama, R.M., Gerstung, E.R., Fisher, F.W., and Moyle, P.B. 2001. Historical and present distribution of chinook salmon in the Central Valley drainage of California. *In* Contributions to the Biology of Central Valley Salmonids. *Edited by* R.L. Brown. California Department of Fish and Game, Sacramento, California. pp. 71-176.

Young, P.S., Cech, J.J., Jr., and Thompson, L.C. 2011. Hydropower-related pulsed-flow impacts on stream fishes: a brief review, conceptual model, knowledge gaps, and research needs. Reviews in Fish Biology and Fisheries **21**(4): 713-731.

Zeug, S.C., Sellheim, K., Watry, C., Wikert, J.D., and Merz, J. 2014. Response of juvenile Chinook salmon to managed flow: lessons learned from a population at the southern extent of their range in North America. Fisheries Management and Ecology **21**(2): 155-168.

Table 1. Means and standard deviations for weight and fork length of acoustically-tagged smolts by year and for all years combined

Year	Sample size	Fork length ± SD (mm)	Weight ± SD (g)
ALL	1350	158.8 ± 12.4	43.9 ± 11.2
2007	200	164.6 ± 10.7^{a}	46.6 ± 9.8^{a}
2008	304	168.7 ± 13.3^{b}	52.6 ± 13.8^{b}
2009	300	152.1 ± 8.5^{c}	38.9 ± 7.9^{c}
2010	306	152.5 ± 10.2^{c}	39.3 ± 8.8^{c}
2011	240	158.1 ± 7.8^{d}	42.9 ± 6.8^{d}

^{abcd} Size distributions with different superscripts are significantly different ($P < 0.05$)

Table 2. Locations of acoustic receivers and tagged smolt release locations. Positive river km values indicate distance upstream from the Golden Gate Bridge, negative values indicate distance seaward from the Golden Gate Bridge.

Location	River km	Description
Battle Creek	534	Release site 2007
Jelly's Ferry	518	Receiver location & release site 2008-2011
Bend Bridge	504	Receiver location
China Rapids	492	Receiver location
Above Thomes	456	Receiver location
Below GCID	421	Receiver location
Irvine Finch	412	Receiver location & release site 2008-2010
Above Ord	389	Receiver location
Butte City Bridge	363	Receiver location & release site 2008-2010
Above Colusa Bridge	325	Receiver location
Meridian Bridge	309	Receiver location
Above Feather River	226	Receiver location
City of Sacramento	189	Receiver location
Freeport	169	Receiver location
Chipps Island	70	Receiver location
Benicia Bridge	52	Receiver location
Carquinez Bridge	41	Receiver location
Richmond Bridge	15	Receiver location
Golden Gate East	2	Receiver location
Golden Gate West	1	Receiver location
Point Reyes	-58	Receiver location

Table 3. Survival models for different spatial and temporal factors, as well as individual covariates, ordered from lowest to highest QAICc, omitting 2011 data. The ΔQAICc statistic represents the QAICc distance from the most parsimonious model. The number of parameters includes the parameters for estimation of detection probabilities (reach and year-specific).

Survival (φ) treatment	**ΔQAICc**	**# Parameters**
(River survival * year) * reach	0.0	126
(Delta survival * year) * reach	25.3	93
BASE MODEL (Reach)	26.6	90
Reach + length	26.6	91
Reach * year	27.9	144
Reach * length	40.0	108
(Bays survival * year) * reach	49.0	105
Reach * weight	50.0	108
Reach * release	53.8	126
Reach * year * release	270.8	288
NULL MODEL (constant survival)	308.4	73

Table 4. Percent overall survival to Golden Gate East receiver line (rkm 2) per year, including standard error (SE), and mean successful migration movement rate (MSMMR) with standard error.

Release Group	% Survival	SE	MSMMR (km/day) ± SE
2007-ALL	**2.8**	**1.4**	**23.5 ± 3.6**
2007-River	15.5	3.6	
2007-Delta	63.0	14.5	
2007-Bays	28.3	12.4	
2008-ALL	**3.8**	**0.9**	**17.5 ± 1.5**
2008-River	24.5	3.0	
2008-Delta	59.1	4.4	
2008-Bays	26.1	4.9	
2009-ALL	**5.9**	**1.2**	**17.5 ± 1.1**
2009-River	31.9	3.2	
2009-Delta	43.1	4.3	
2009-Bays	43.0	6.5	
2010-ALL	**3.4**	**0.9**	**21.9 ± 2.1**
2010-River	22.7	2.5	
2010-Delta	53.6	5.6	
2010-Bays	28.1	6.4	
2011-ALL	**15.7**	**2.5**	**36.0 ± 3.0**
2011-River*	63.2*	8.5*	
2011-Delta	70.6	4.8	
2011-Bays	33.1	4.7	

*Estimated from post-hoc survival model

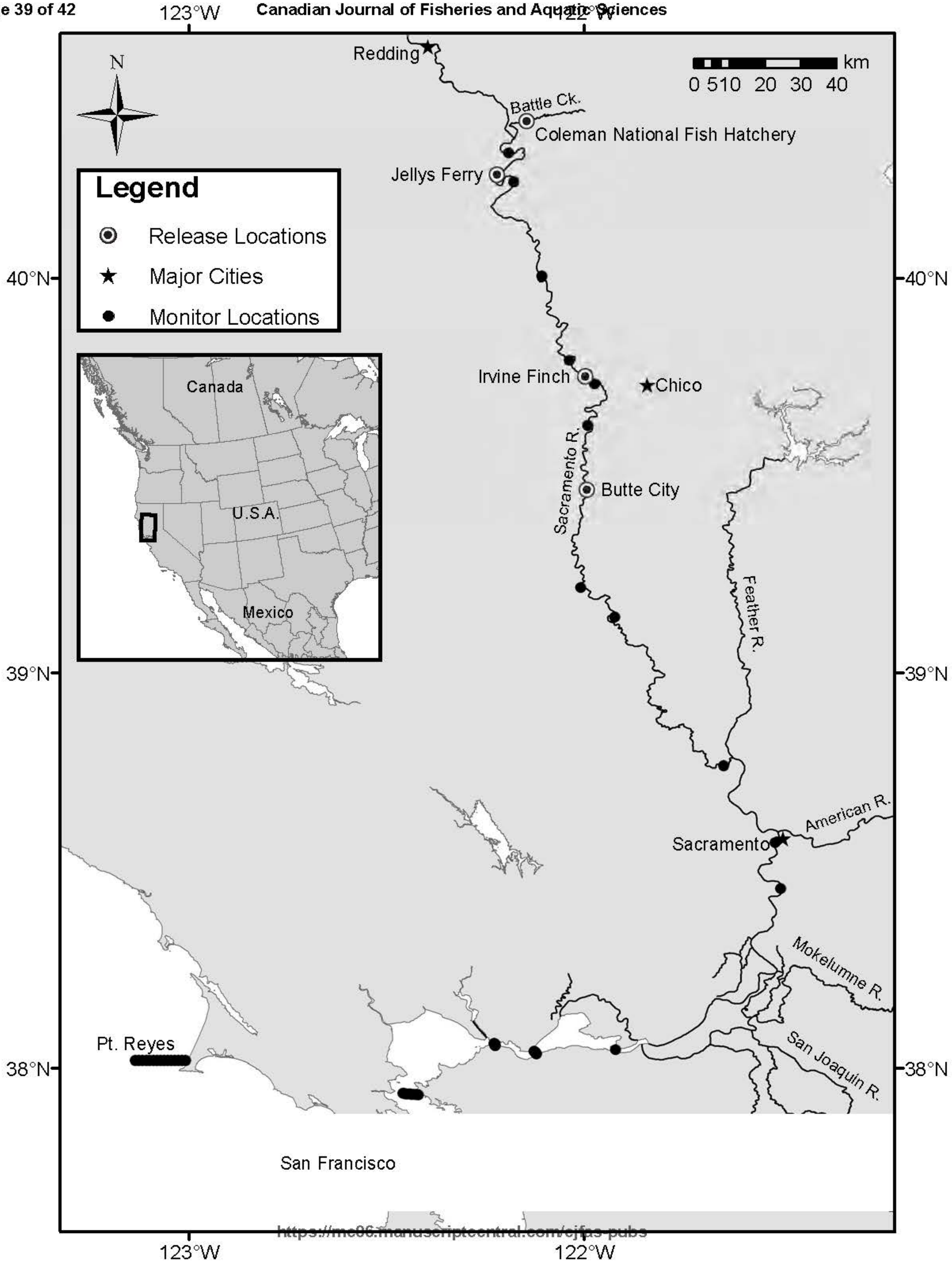
Figure Captions

Fig. 1. Study area map including the Sacramento River, Sacramento – San Joaquin River Delta, Suisun/San Pablo/San Francisco Bays and Pacific Ocean. Bull's-eye icons signify a release location, star symbolizes a major city, and black dot symbolizes a receiver location.

Fig. 2. Percent survival per 10 km per reach for the 2007-2010 study years combined. Figure and map are delimited based on the regions (from upstream to downstream): upper Sacramento River, lower Sacramento River, Sacramento – San Joaquin River Delta, and Suisun/San Pablo/San Francisco Bays. The Sacramento River was delimited into an upper and lower section to highlight the shift in survival rates. Error bars represent 95% confidence intervals. 2011 data was omitted due to poor detection probabilities.

Fig 3. Hydrograph at the Bend Bridge gauging station, 14 rkm downstream from furthest upstream release site (Jelly's Ferry), for each of the five years of the study. The median daily flow values over a 43 year period (including the study years) are represented with a dotted line. Black dots represent release date for tagged smolts in relation to the respective year's hydrograph. Hydrographs are only depicted as long as 90% of released smolts are still actively migrating in the river region; in some years December released fish have all died or outmigrated before January release, and therefore some yearly hydrographs are not continuous.

Fig. 4. Percent survival per major region for all five study years. Regions include river, delta, bays, and the percent survival for the entire watershed "All". Error bars represent 95% confidence intervals.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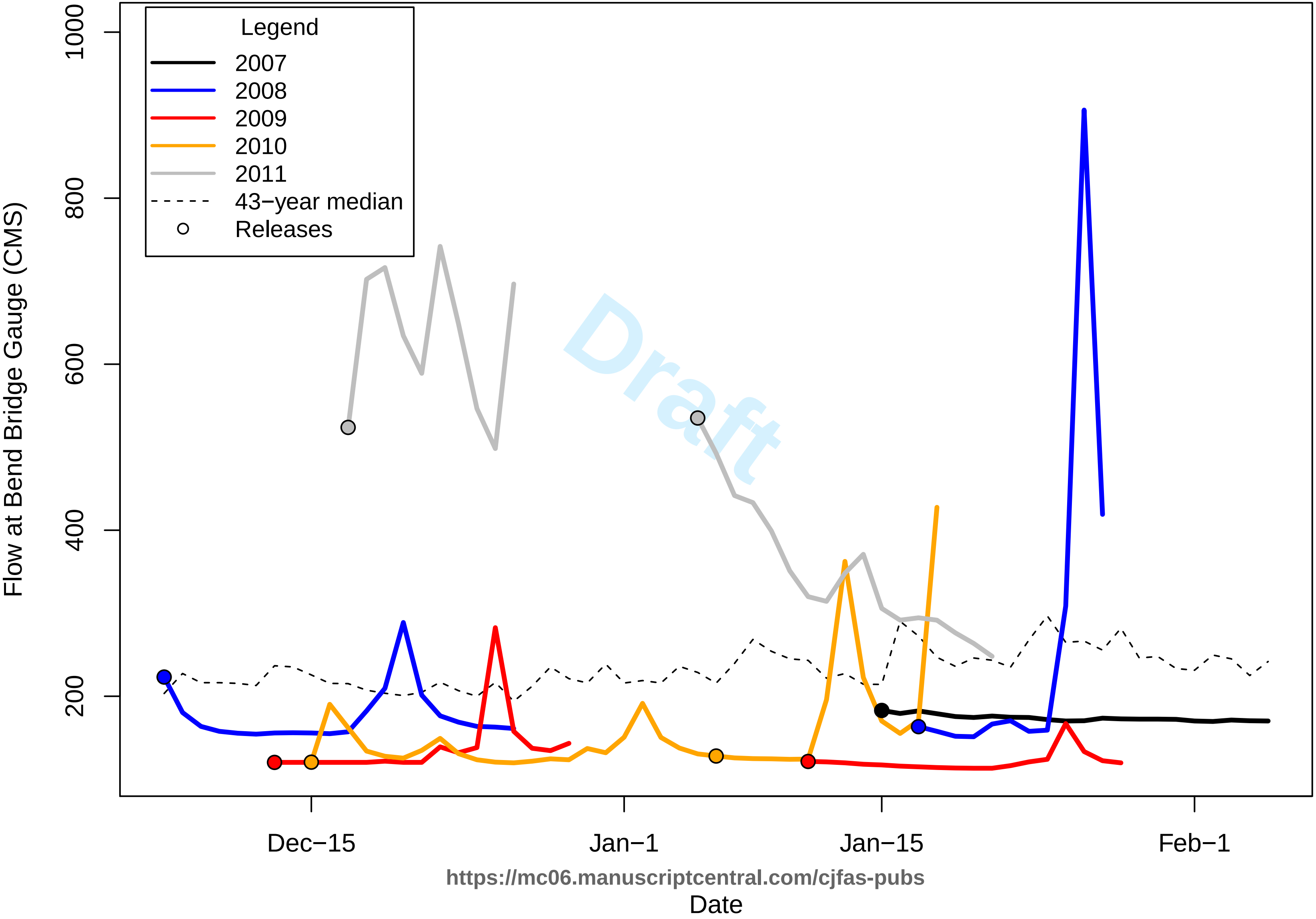
Chico
Sacramento R.
Butte City
Feather R.
39°N
American R.
Sacramento
Mokelumne R.
San Joaquin R.
Pt. Reyes
38°N
San Francisco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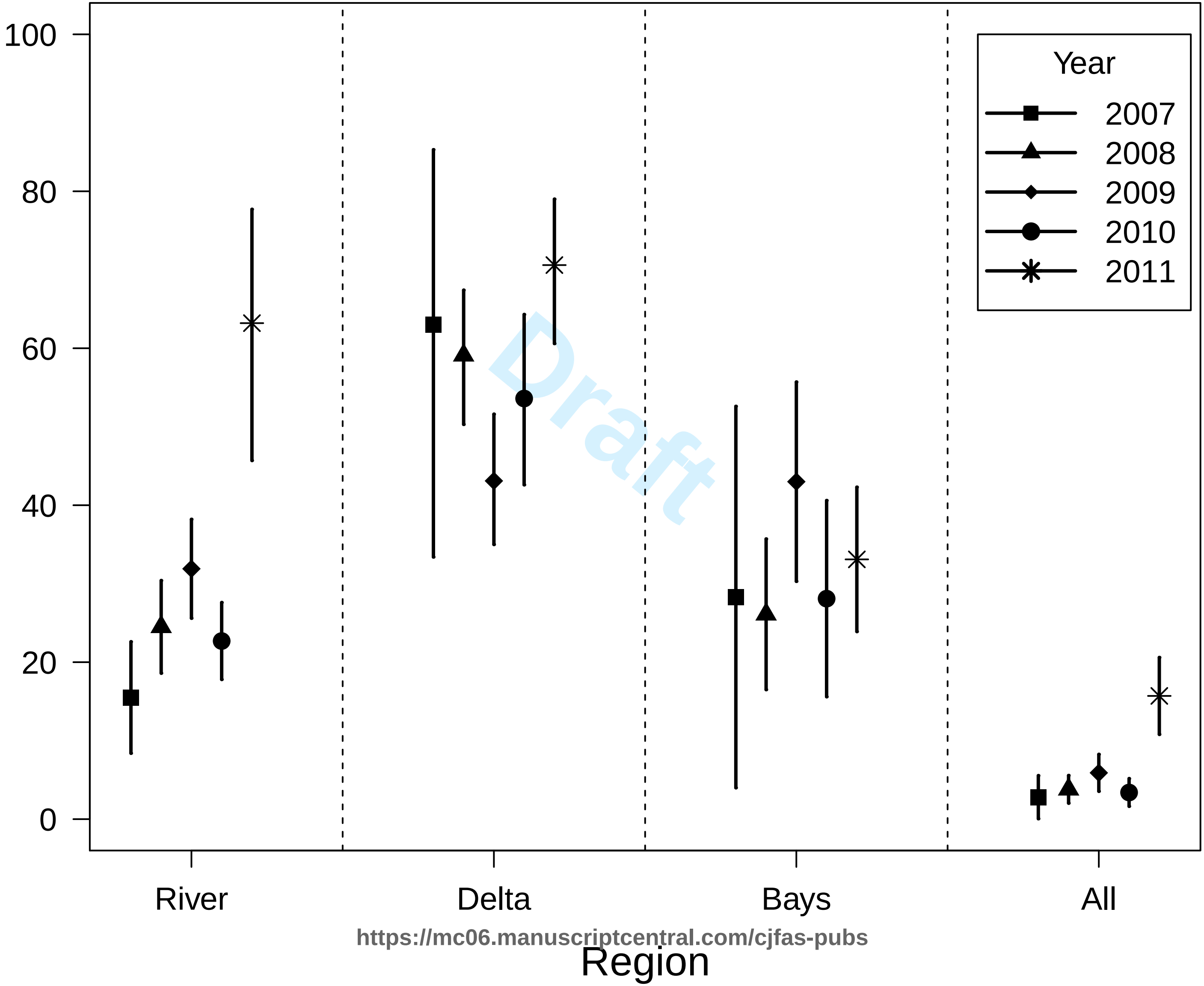
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Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: I. Model Description and Baseline Results

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ARTICLE

Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: I. Model Description and Baseline Results

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Abstract

Many factors have been implicated in the decline of Delta Smelt *Hypomesus transpacificus* in the upper San Francisco Estuary, and the importance of each factor is difficult to determine using field data alone. We describe a spatially explicit, individual-based population model of Delta Smelt configured for the upper estuary. The model followed the reproduction, growth, mortality, and movement of individuals over their entire life cycle on the same spatial grid of cells as the Delta Simulation Model (DSM2) hydrodynamics model. Daily values of water temperature, salinity, and densities of six zooplankton prey types were represented on the spatial grid. Reproduction was evaluated daily, and new individuals were introduced into the model as yolk sac larvae. Growth of feeding individuals was based on bioenergetics and zooplankton densities. Mortality sources included natural mortality, starvation, and entrainment in water diversion facilities. Movement of larvae was determined using a particle tracking model, while movement of juveniles and adults was based on salinity. Simulations were performed for 1995–2005. The baseline simulation was generally consistent with the available data. Predicted daily fractions of larvae entrained and annual fractions of adults entrained were similar in magnitude to data-based estimates but showed less interannual variation. Interannual differences in mean length at age 1 had large effects on maturity and subsequent egg production. Predicted and observed spatial distributions in the fall showed moderately good agreement for extremely low- and high-outflow years. As indicated by the population growth rate, 1998 was the best year and 2001 was the worst year. Water year 1998 (i.e., October 1997–September 1998) was characterized by fast growth in fall 1997, low entrainment, and high stage-specific survival rates, whereas water year 2001 had opposite conditions. Our analysis further shows how multiple factors can operate simultaneously to result in the decline in abundance of Delta Smelt.

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Understanding the critical drivers and environmental changes that influence the population dynamics of fish is vital for effective resource management and restoration. Most fish species live multiple years and show ontogenetic shifts in the habitats they utilize, which exposes them to multiple environmental and biological factors spread over several points in their life cycle (Rose 2000). Identification of the relative importance of these factors and how they may interact with each other is an important step toward understanding and managing fish populations. A major debate is underway about the status of many harvested marine and coastal fish populations (Myers and Worm 2003; Hilborn 2007; Worm et al. 2009), as human development of coastal areas (McGranahan et al. 2007) and demand for high-quality freshwater (Vörösmarty et al. 2000) continue to accelerate. Identification of the major factors affecting population dynamics (especially declines in population) is critical because the high economic costs of protection and restoration demand efficient and effective responses.

The need to understand mechanisms of population decline for Delta Smelt *Hypomesus transpacificus* in the San Francisco Estuary is critical. This endemic species is listed as threatened under the U.S. Endangered Species Act and is listed as endangered under the California Endangered Species Act. Delta Smelt have generally been at low abundance since the 1980s and showed an even further sharp decrease starting in about 2002 (Bennett 2005; Sommer et al. 2007; Thomson et al. 2010). Delta Smelt have also become the focus of contentious debate because of perceived conflicts between the conservation of this species and the operation of facilities that divert water from the Delta Smelt's habitat for agricultural and urban uses (Brown et al. 2009; NRC 2010). These facilities alter seasonal patterns of flow, and they entrain and kill large numbers of Delta Smelt (Kimmerer 2008).

Many factors may be involved in the decline of Delta Smelt, and quantifying the importance of each factor has proven to be elusive despite the availability of extensive long-term field data (NRC 2012). Factors examined as possible contributors to the decline include entrainment of Delta Smelt by the two large water diversion facilities in the Sacramento–San Joaquin River Delta (hereafter, "the Delta"), shifts in the composition and densities of the zooplankton (prey) community, and changes in physical habitat related to salinity and turbidity (Baxter et al. 2010). A sharp decline in four fish species (juvenile Striped Bass *Morone saxatilis*; Longfin Smelt *Spirinchus thaleichthys*; Threadfin Shad *Dorosoma petenense*; and Delta Smelt) within the upper San Francisco Estuary beginning in approximately 2000 led to a substantial effort at synthesizing existing data to determine the cause (Sommer et al. 2007). The results to date have narrowed the possible factors to some extent (e.g., contaminant effects are likely small) and have facilitated the conclusion that the recent decline in Delta Smelt was due to multiple factors acting together (Baxter et al. 2010). Two statistical analyses (Mac Nally et al. 2010; Thomson et al. 2010) examined the dynamics of the four fish species by using monitoring data collected from the 1970s to 2007. Both analyses, which used similar data but different statistical methods, showed several covariates that were related to abundance of the fish, but they could not resolve the cause of the recent declines.

An alternative approach to the analysis of the effects of multiple factors on fish populations is simulation modeling of the growth, mortality, reproduction, and movement processes underlying the population dynamics. Population modeling allows the investigator to control everything and thus to perform simulation experiments for isolating the effects of individual factors and for exploring the effects of previously unobserved combinations of conditions (Rose et al. 2009). However, model results must be interpreted with caution because models are always simplifications of reality, and their predictions can be biased by decisions about which processes to include and at what temporal and spatial scales to represent those processes.

In this paper, we describe a spatially explicit, individual-based population model of Delta Smelt configured for the upper San Francisco Estuary. We chose this approach because many of the factors that are thought to contribute to the Delta Smelt's decline vary in space (Baxter et al. 2010), and simulating fish movement is more straightforward with an individual-based approach than with other modeling approaches (Tyler and Rose 1994). We first briefly describe the San Francisco Estuary and the life cycle of Delta Smelt. We then describe the spatial grid, environmental conditions, and reproduction, growth, mortality, and movement processes that are represented in the individual-based model. Hydrodynamic model output for the spatial grid and field data for temperature, salinity, and zooplankton densities were used as inputs to the population model for simulation of the period 1995–2005. The results of the baseline simulation are compared with the observed data, and we contrast the conditions between a "good year" and a "bad year" for Delta Smelt growth and survival within the baseline simulation. We conclude with a discussion of our results relative to other analyses and the strengths and weaknesses of our current model formulation. In our companion paper (Rose et al. 2013, this issue), we show that the results presented here are robust to alternative baseline assumptions, and we further explore the factors causing good and bad years by using a simulation experiment approach.

UPPER SAN FRANCISCO ESTUARY AND DELTA SMELT

The San Francisco Estuary is the largest estuary on the U.S. Pacific coast, with a watershed covering approximately 40% of California (Figure 1). The estuary connects the Sacramento and San Joaquin rivers through San Francisco Bay to the Pacific Ocean. Freshwater enters via the Sacramento River from the north and the San Joaquin River from the south; the confluence is roughly the landward limit of ocean salt penetration (Kimmerer 2004). We focus on the upper portion of the estuary (including the Delta and Suisun Bay), which encompasses the entire range of the Delta Smelt.

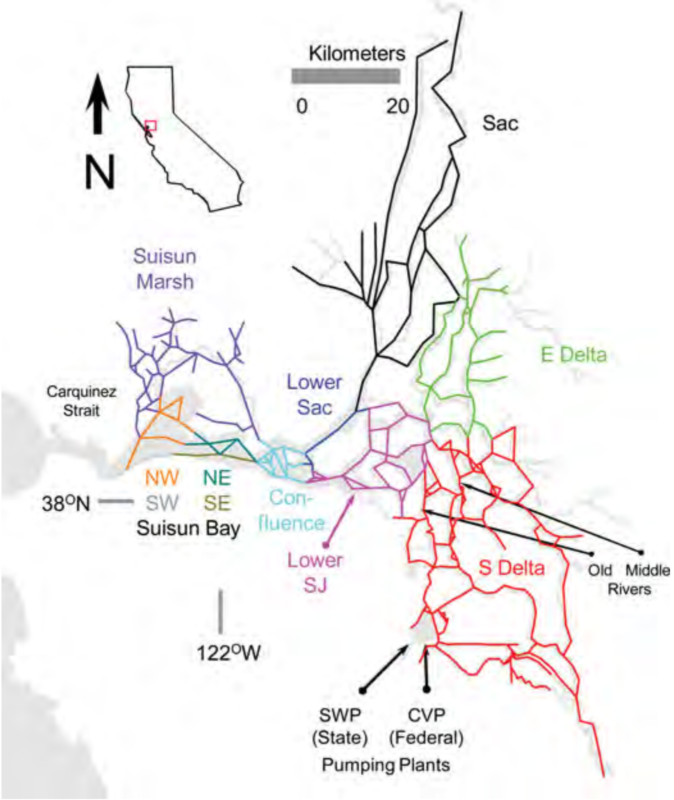

FIGURE 1. Location of the San Francisco Estuary, California, and the spatial grid and boxes used in the model. Gray represents the outline of the estuary. The 11 boxes are color coded and refer to (in numerical order): (1) Sacramento River region (Sac) of the Sacramento–San Joaquin Delta; (2) eastern Delta (E Delta); (3) southern Delta (S Delta); (4) lower Sacramento River region (Lower Sac); (5) lower San Joaquin River region (Lower SJ); (6) confluence (westernmost box in the Delta); (7) southeast Suisun Bay (SE); (8) northeast Suisun Bay (NE); (9) Suisun Marsh; (10) southwest Suisun Bay (SW); and (11) northwest Suisun Bay (NW). Additional labels show the Old River, Middle River, Carquinez Strait, and the State Water Project (SWP) and Central Valley Project (CVP) pumping plants.

The San Francisco Estuary has been described as one of the most highly altered estuarine ecosystems in the world (Nichols et al. 1986; Lund et al. 2010). Over the past 150 years, approximately 95% of the marshes surrounding the estuary have been isolated from tidal action, and numerous nonnative species have been introduced—some with substantial ecological effects (e.g., Nichols et al. 1990; Winder and Jassby 2011). The Delta, which formerly consisted of tidal marsh, is now a complex network of linked channels and sloughs surrounding islands that are protected by a constructed levee system. During the past 60 years, the upper estuary has increasingly been managed through large-scale manipulation of river flows in order to provide freshwater for agricultural, municipal, and industrial uses.

The two large water diversions in the south Delta have exported an average of 30% of the available flow into the Delta during 1960–2000, with the percentage generally increasing through time and exceeding 60% in some years and seasons (Kimmerer 2004). The State Water Project (SWP) facility provides drinking water for over 23 million Californians, and together the two diversion facilities (the SWP and the Central Valley Project [CVP]) fuel an estimated \$25 × 10^9 annual agricultural economy (Grimaldo et al. 2009). Elaborate fish recovery facilities attempt to screen fish from the diverted water but with mixed success (Kimmerer 2011). All of these changes have substantially altered both the physical and ecological aspects of the system (Nichols et al. 1986; Hollibaugh 1996; NRC 2012).

The life history of the Delta Smelt is summarized briefly here based on several sources (Moyle et al. 1992; Moyle 2002; Bennett 2005). The Delta Smelt has a relatively unusual life history strategy (Bennett 2005), as it exhibits the small size and short life span that are typical of an opportunistic life history strategy, but it has low reproductive rates that are more similar to those of an equilibrium strategist (Winemiller and Rose 1992). The Delta Smelt's life history also somewhat resembles those of salmonids (McCann and Shuter 1997) but without parental care. The geographic range of the Delta Smelt is confined to the upper San Francisco Estuary. It is primarily an annual species but with some small fraction of the population surviving a second year to spawn. Spawning takes place in freshwater during February–May at temperatures between 12°C and 20°C; spawning appears to be clustered in 2-week intervals, presumably related to the spring–neap tidal cycle. Eggs are demersal and attached; larval stages generally rear in freshwater before being transported to brackish waters, which are typically located between the confluence of the San Joaquin and Sacramento rivers and Carquinez Strait at the seaward margin of Suisun Bay (Figure 1). All life stages remain at a salinity of about 0.5–6.0 psu (the low-salinity zone) until the end of the year, when migration to freshwater begins. Delta Smelt eat primarily zooplankton throughout their lives, although adults also eat epibenthic crustaceans, such as amphipods. Delta Smelt are consumed by a variety of fish, principally visual predators.

MODEL DESCRIPTION

Overview

The model followed the reproduction, growth, mortality, and movement of individual Delta Smelt over their entire life cycle on a spatial grid of cells (Figure 1). The spatial grid was a one-dimensional network of 517 channels and 5 reservoirs used in the Delta Simulation Model (DSM2) hydrodynamic model (California Department of Water Resources [CDWR]). This one-dimensional model simulates non-steady-state hydrodynamics in a network of channels and has been widely used for analyses and water supply planning for the Delta (Kimmerer and Nobriga 2008). Simulations from DSM2 provided (1) hourly water velocities and water levels at the ends of channels and (2) hourly water flows into and out of the reservoirs. Daily water temperature, salinity, and densities of six zooplankton prey types as estimated from field data were also represented on the same spatial grid.

Each 365-d model year began on October 1, the start date for each water year. Individuals were aged on January 1 of each year. Whenever we refer to a year, it is the year that includes the summer period (e.g., model year 1996 extended from October 1, 1995, to September 30, 1996). Multiyear simulations were performed using reproduction to introduce the new individuals each year.

Reproduction was evaluated daily during the spring spawning season, and eggs developed as a daily cohort at a temperature-dependent rate. Upon hatching, new yolk sac larvae were pooled for each day and were introduced as model individuals. Individuals developed through life stages of yolk sac larva, larva, postlarva, juvenile, and adult. Growth was based on bioenergetics and zooplankton densities in the grid cells. Mortality included a stage-specific mortality rate, starvation, and mortality due to entrainment at the water diversion facilities. Movement of yolk sac larvae, larvae, and postlarvae was determined hourly by using a particle tracking model (PTM) that incorporates water velocities from the DSM2 hydrodynamic model. Movement of juveniles and adults was based entirely on a behavioral response to salinity, and the locations of individual fish on the grid were updated every 12 h.

All simulations used hydrodynamic conditions, temperature, salinity, and zooplankton densities for the period 1995–2005. This period was selected because (1) it encompasses the main period of Delta Smelt decline, (2) hydrodynamic simulations were available, and (3) field data on zooplankton and Delta Smelt were relatively complete.

Environment

A second grid of 11 coarser boxes was overlaid onto the channel grid (Figure 1) so that the more sparsely sampled field data could be used to specify daily water temperature, salinity, and zooplankton densities. The 11 boxes were determined based on previously identified regions of hydraulic similarity (e.g., Miller et al. 2012) and the availability of enough stations to ensure that at least several stations were present in each box.

Daily values of temperature, salinity, and zooplankton densities were estimated for each box and then were assigned to each channel within each box on each day (see details in Supplement A in the online version of this article). Final daily temperature and salinity values for each box are shown in Figure 2 for a year with high freshwater outflow (1998) and a year with low freshwater outflow (2001). All channels within a given box were assigned the box values. Temperature did not vary much among sampling stations within boxes, and the sampling density was too low to represent the within-box (channel-level) spatial gradients in salinity.

The food environment was represented by the biomasses of six zooplankton types: adults of *Limnoithona* spp. (calanoid copepods), calanoid copepodids, other calanoid adults, adult *Eurytemora* (calanoid copepods), adult *Acanthocyclops vernalis* (cyclopoid copepods), and adult *Pseudodiaptomus* (calanoid copepods). We included random variation when we used the boxwide mean to assign values to the channels within each box (see Supplement A). Daily zooplankton biomass densities in each box are presented for the same high-outflow (Figure 3) and low-outflow (Figure 4) years as were shown for temperature and salinity.

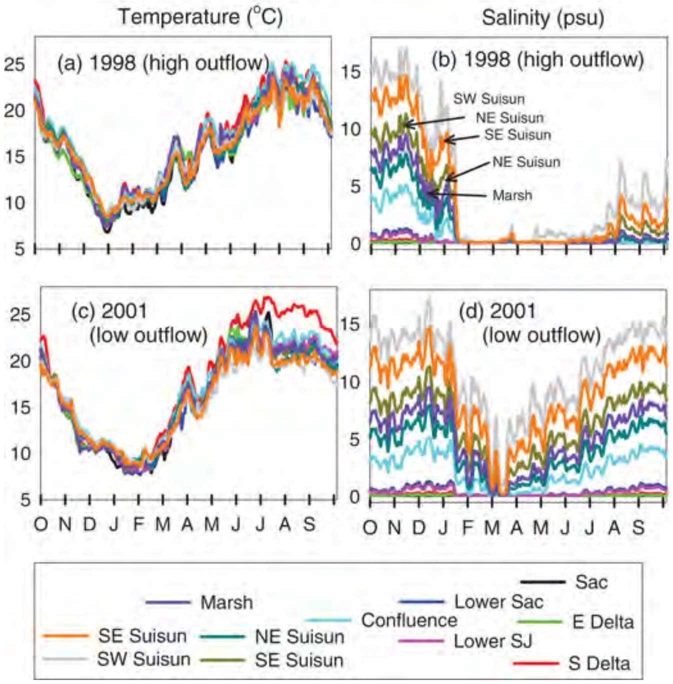

FIGURE 2. Daily temperature and salinity values in each box for **(a)**, **(b)** 1998 (a year of high outflow) and **(c)**, **(d)** 2001 (a year of low outflow). See Figure 1 for definition of box abbreviations. [Figure available online in color.]

Spawning

Each female individual that was longer than 60 mm TL at the start of the spawning season was allowed to spawn up to two times within the spawning season. We used a simple threshold of 60 mm because it was well supported by data (Bennett 2005) and because the manner in which maturity varies around the 60-mm length was uncertain. We explore a smoother maturity function in our companion paper (Rose et al. 2013).

The earliest day of spawning was first determined each year on October 1 by looking ahead at temperatures and finding the first day on which temperature exceeded 12°C in any box. On the earliest possible day of spawning in each year, a temperature of first actual spawning was assigned to each mature individual from a uniform distribution between 12°C and 20°C. To mimic the clustering of spawning on spring–neap tidal cycles, an individual spawned at the end of the 14-d tidal cycle that followed the day when water temperature in that individual's channel exceeded its assigned spawning temperature. By the time of spawning, the migratory movement algorithm based on salinity had put adults near or into freshwater boxes.

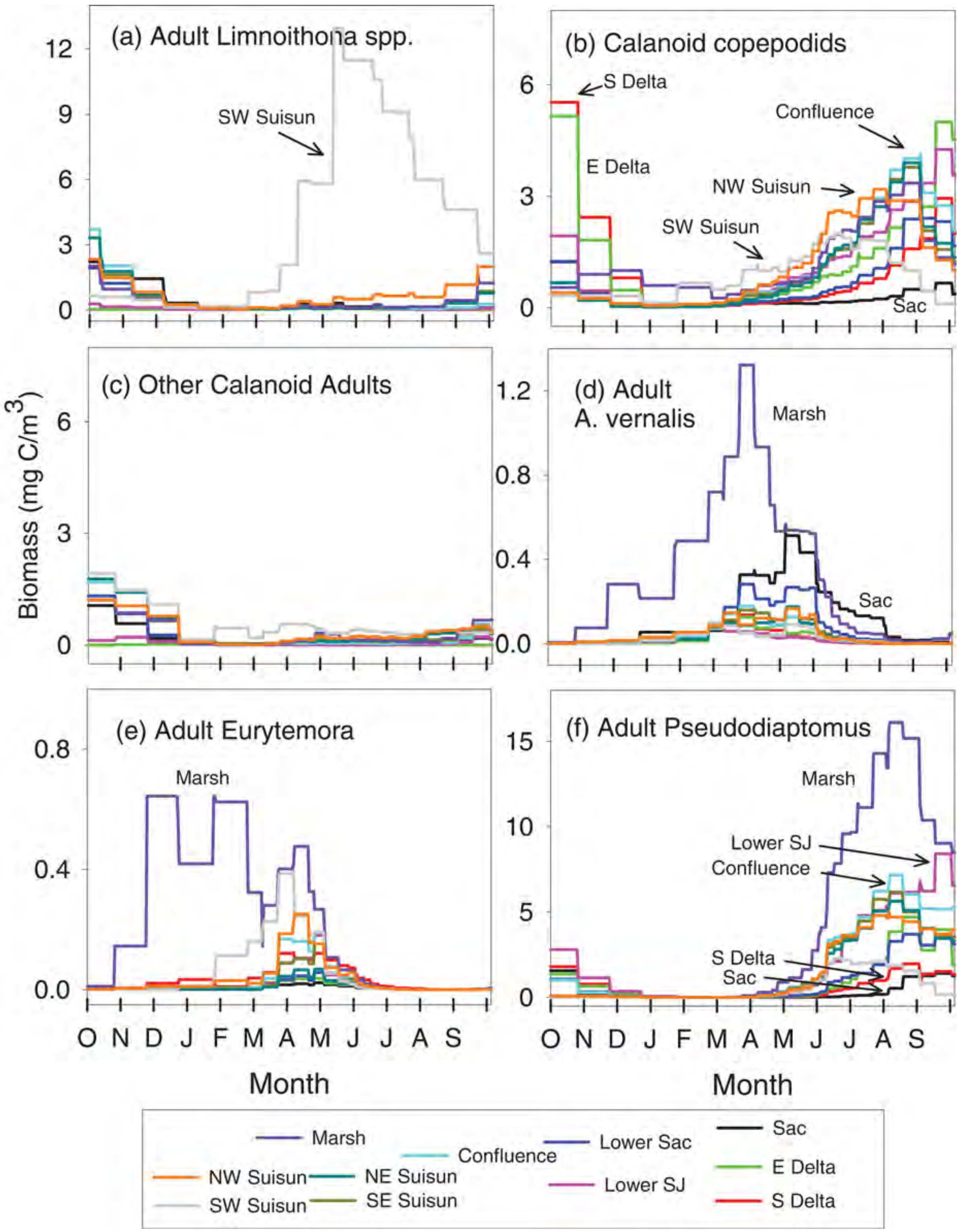

FIGURE 3. Daily biomass density values (mg C per m^3 of water) for each of the six zooplankton groups in each spatial box during a year of high outflow (1998): **(a)** adults of *Limnoithona* spp., **(b)** calanoid copepodids, **(c)** other calanoid adults, **(d)** adult *Acanthocyclops vernalis*, **(e)** adult *Eurytemora*, and **(f)** adult *Pseudodiaptomus*. See Figure 1 for definition of box abbreviations. [Figure available online in color.]

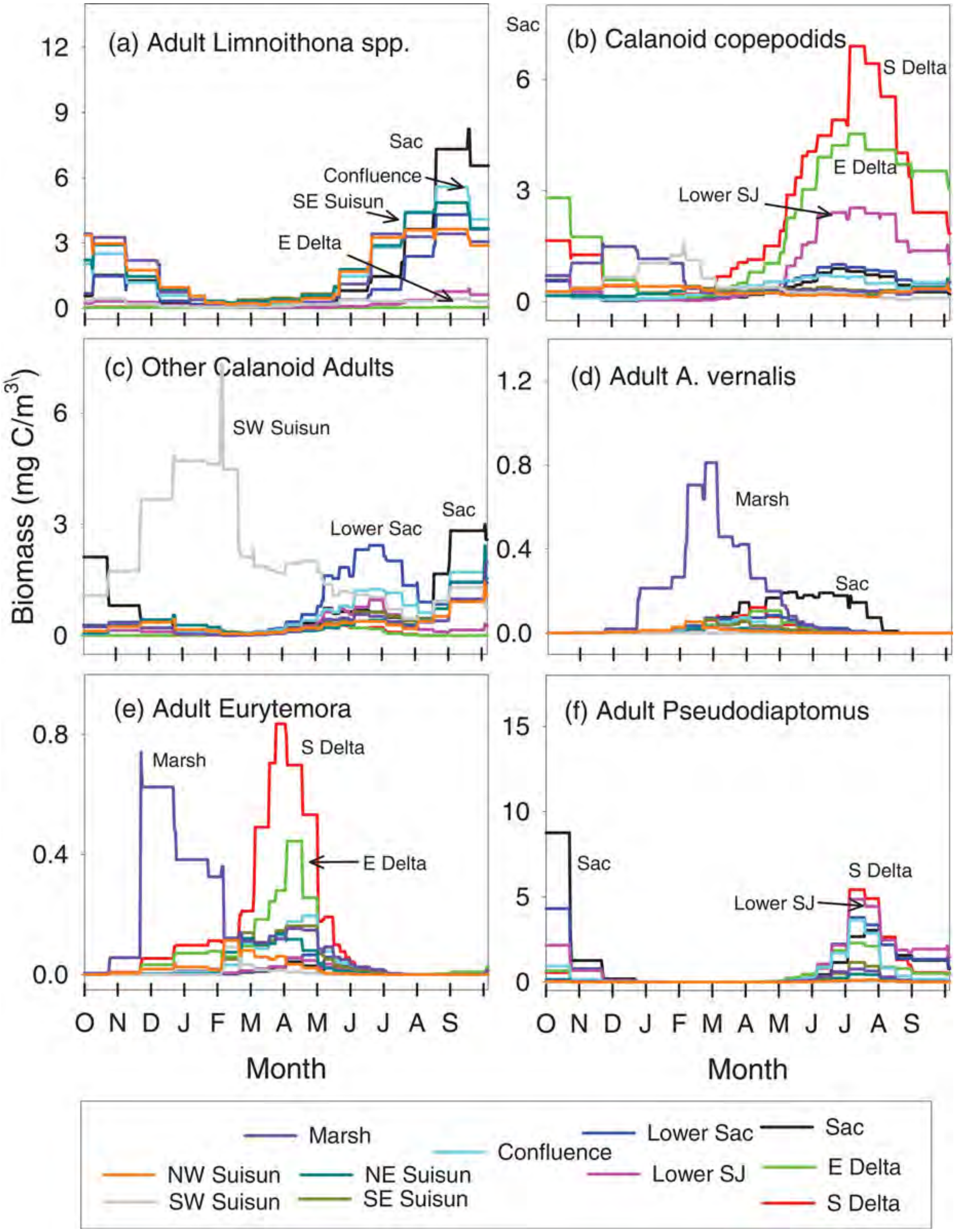

FIGURE 4. Daily biomass density values (mg C per m^3 of water) for each of the six zooplankton groups in each spatial box during a year of low outflow (2001): **(a)** adults of *Limnoithona* spp., **(b)** calanoid copepodids, **(c)** other calanoid adults, **(d)** adult *Acanthocyclops vernalis*, **(e)** adult *Eurytemora*, and **(f)** adult *Pseudodiaptomus*. See Figure 1 for definition of box abbreviations. [Figure available online in color.]

Fecundity (D; eggs/female) depended on the individual's weight on the day of spawning (Bennett 2005),

$$D = 175.4e^{\frac{L_{equiv}}{28.3}}, \tag{1}$$

where L_{equiv} (mm) is the length based on the actual weight of the fish. Upon spawning, the body weight of the individual Delta Smelt was reduced by 15%. We treated males the same as females (i.e., spawning temperatures and weight loss), but without any contribution of eggs, to produce similar weights at age.

After their first spawning event, females were evaluated daily to determine whether they would spawn a second time. Second spawning occurred if (1) the individual had regained enough weight (>95% of the weight expected from its length), (2) 14 or more days had passed since the first spawning, and (3) it was not too late (too warm) in the season for that individual to spawn in its box. The last possible day of spawning in each box was calculated as the first day after temperature exceeded 20°C plus 14 d to allow for the final tidal cycle to complete. The fecundity relationship used for the second spawning was the same as that for the first spawning, and weight was again reduced by 15%.

Eggs

Each female's first and second (if it occurred) spawns of eggs were followed separately as cohorts until hatching, when they became yolk sac larvae. Day of hatching was determined for each cohort by accumulating the daily fractional egg development (DV_e) until the degree of development exceeded 1.0. The daily fractional development towards hatching was based on temperature (Bennett 2005),

$$DV_e = \frac{1}{28.1 - 1.1 \cdot T}, \tag{2}$$

where T is the daily temperature (°C) in the box where spawning occurred. Spawning box temperature (which varied daily) was used because the eggs are attached. All eggs in each cohort that was spawned in a given box on a given day hatched on the same day. Daily egg mortality rates (M; d^{-1}) were calculated by converting hatch rates observed at constant temperature in the hatchery to daily mortality (Bennett 2005),

$$M = \frac{-\log(s)}{DV_e} \tag{3}$$

and

$$s = -2.35 + 0.45 \cdot T - 0.016 \cdot T^2, \tag{4}$$

where s is the survival fraction through the egg stage.

Yolk Sac Larvae

Beginning with yolk sac larvae, new model individuals were created and followed for the rest of their lives. New individuals were created from all those that hatched in each box on each day, and they were distinguished by whether they came from a first or second spawning event. Length (L; mm) at hatch depended on the temperature on the day of hatching (Bennett 2005),

$$L = 5.92 - 0.05 \cdot T. \tag{5}$$

Weight (g wet weight) at hatch was determined from a field-based length–weight relationship (Kimmerer et al. 2005):

$$W = 0.005 \cdot L^3. \tag{6}$$

Similar to the method used for eggs, the duration of the yolk sac larval stage was determined by accumulating the daily fractional development (DV_y) of each model individual based on the temperature in its box (Bennett 2005) until the cumulative development exceeded 1.0:

$$DV_y = \frac{1}{7.53 - 0.08 \cdot T}. \tag{7}$$

Daily mortality rate of yolk sac larvae was assumed constant (0.035 d^{-1}) and was a key parameter adjusted as part of model calibration.

Feeding Life Stages: Development and Bioenergetics

Larvae became postlarvae at 15 mm, and postlarvae became juveniles at 25 mm; juveniles then became age-1 adults and age-1 adults from the previous year advanced to age 2 on January 1 (Bennett 2005). Age-2 adults were removed from the model just before attaining age 3. Larval to postlarval development coincided with the development of a swim bladder, and the juvenile stage marked the appearance of fin folds and an association with the low-salinity zone.

The daily growth of each feeding individual was represented by a difference form of the Wisconsin bioenergetics model (Ney 1993; Hanson et al. 1997),

$$\begin{aligned} W_t = W_{t-1} &+ (C - R - F - U - SDA) \\ &\cdot W_{t-1} \cdot \frac{e_p}{e_s} - Sp \cdot W_{t-1}, \end{aligned} \tag{8}$$

where W is the weight of each individual, C is the realized consumption rate, R is the total metabolic rate, F is egestion, U is excretion, SDA is specific dynamic action, and Sp is loss due to spawning. All rates except Sp were in units of grams of prey per gram of Delta Smelt per day (g prey·g smelt^{-1}·d^{-1} in wet weight); Sp was the fraction of weight lost (0.15) and occurred only on the day of spawning. The e_p and e_s terms (J/g) were used to convert grams of prey per gram of Delta Smelt to grams of smelt per gram of smelt, which was then multiplied by weight (W) to yield the weight change in grams of Delta Smelt per individual per day. The value of e_s was fixed at 4,814 J/g, while e_p was computed each day based on the fraction of *Limnoithona* in the diet. All zooplankton groups had an energy density of 2,590 J/g; the exception was *Limnoithona*, for which energy density was assumed to be 30% lower (1,823 J/g) because Delta Smelt grow more slowly when fed *Limnoithona* (Lindsay Sullivan, San Francisco State University, personal communication).

Total length (L; mm) was obtained from weight by using equation (6). Length was partially uncoupled from weight because length was allowed only to increase, whereas fish could lose weight. On days of weight gain, length was increased only after the individual's weight equaled that expected from its length. Thus, fish were allowed to become skinny but not fat.

Maximum consumption (C_{max}) depended on an individual's weight (W) and the water temperature (T):

$$C_{max} = a_c W^{b_c} f(T). \tag{9}$$

The temperature adjustment to maximum consumption ($f[T]$) increased from a value of CK_1 at temperature CQ to 0.98 at temperature T_O and then stayed at 0.98 until temperature reached T_M, after which the adjustment declined to CK_4 as temperature approached T_L (Table 1).

Realized consumption by the ith fish (C_i) was a functional response that depended on C_{max} and the densities of each zooplankton group j (prey density, PD_j) in the same channel as the fish:

$$C_{ij} = \frac{C_{max} W_i \left(\frac{PD_j \cdot V_{ij}}{K_{ij}}\right)}{1 + \sum_{k=1}^{6} \left(\frac{PD_k \cdot V_k}{K_{ik}}\right)} \tag{10}$$

and

$$C_i = \sum_{j=1}^{6} C_{ij}, \tag{11}$$

where C_{ij} is the daily rate of consumption of the jth prey type (six zooplankton groups) by individual fish i; V_{ij} is the vulnerability of prey type j to fish i; and K_{ik} is the half-saturation constant for fish i feeding on each prey type k. Equations (10) and (11) allowed an individual fish to consume multiple prey types without exceeding its maximum consumption. Vulnerabilities (V_{ij}) were set to 1.0 for all life stages eating all zooplankton types; the exception was Delta Smelt larvae, for which V_{ij} values of zero were used for all adult prey groups other than *Limnoithona* spp. The K-values were calibrated outside of the model to obtain diet and consumption rates that appeared realistic (Supplement B in the online version of this article).

The total metabolic rate (R) was an allometric function of weight and used an exponential relationship ($g[T]$) to adjust metabolism for temperature:

$$R = a_r W^{b_r} \cdot g(T), \tag{12}$$

where

$$g(T) = e^{(R_Q \cdot T)}. \tag{13}$$

Egestion (F) was a constant fraction of consumption, while *SDA* and excretion (U) were fractions of net assimilated energy

TABLE 1. Parameter values for each Delta Smelt life stage in the bioenergetics model.

Parameter	Description	Larvae	Postlarvae	Juveniles and adults
	Maximum consumption (C_{max})			
a_c	Weight multiplier	0.18	0.18	0.1
b_c	Weight exponent	−0.275	−0.275	−0.54
CQ (°C)	Temperature at CK_1 of maximum	7	10	10
T_O (°C)	Temperature at 0.98 of maximum	17	20	20
T_M (°C)	Temperature at 0.98 of maximum	20	23	23
T_L (°C)	Temperature at CK_4 of maximum	28	27	27
CK_1	Effect at temperature CQ	0.4	0.4	0.4
CK_4	Effect at temperature T_L	0.01	0.01	0.01
	Metabolism (R)			
a_r	Weight multiplier	0.0027	0.0027	0.0027
b_r	Weight exponent	−0.216	−0.216	−0.216
R_Q	Exponent for temperature effect	0.036	0.036	0.036
S_d	Fraction of assimilated food lost to *SDA*	0.175	0.175	0.175
	Egestion (F) and excretion (U)			
F_a	Fraction of consumed food lost to egestion	0.16	0.16	0.16
U_a	Fraction of assimilated food lost to excretion	0.1	0.1	0.1

($C - F$; Table 1):

$$F = F_a \cdot C, \tag{14}$$

$$SDA = S_d \cdot (C - F), \tag{15}$$

and

$$U = U_a \cdot (C - F). \tag{16}$$

During calibration, we adjusted the bioenergetics parameter values developed for Rainbow Smelt *Osmerus mordax* (Lantry and Stewart 1993) until we obtained growth that was realistic for Delta Smelt. We adjusted the allometric and temperature-related parameter values of maximum consumption (a_c, b_c, CQ, T_O, T_M, and T_L in Table 1) and the temperature parameter that affected respiration (R_Q in Table 1). We determined parameter values that satisfied two conditions: (1) realistic daily growth rates and optimal temperatures for growth for mid-stage-sized larvae, juveniles, and adults; and (2) realistic weights and lengths for an individual that had grown from first feeding through age 2 under daily average temperatures and a consumption rate (C) that was equal to 0.8 of the maximum (i.e., proportion of maximum consumption [p-value] = 0.8; $C = p\text{-value} \times C_{max}$). The final bioenergetics rates for the mid-stage-sized larvae, postlarvae, juveniles, and adults are shown in Supplement B.

Mortality

Mortality occurred from stage-specific mortality rates (M), starvation, entrainment losses at the two water export pumping facilities, and old age. Stage-specific mortality rates represented predation and other causes of mortality not explicitly calculated from starvation or entrainment. Daily instantaneous mortality was temperature dependent for eggs (equations 3 and 4); M was set at 0.035 for yolk sac larvae (calibrated), 0.05 for larvae, 0.03 for postlarvae, 0.015 for juveniles, and 0.006 for adults. Starvation occurred if the weight of an individual fell below 50% of the weight expected from its length. Upon reaching age 3 (i.e., the individual's third January 1), the individual died from old age and was removed from the population.

Entrainment mortality for all life stages except eggs occurred when an individual entered Clifton Court Forebay (reservoir number 4; SWP) or arrived at node 181 (CVP; Figure 1). Yolk sac larvae, larvae, and postlarvae were transported there by the PTM, whereas juveniles and adults were unaffected by hydrodynamic conditions except through salinity. Use of only those individual juveniles and adults that arrived at the SWP and CVP by behavioral movements based on salinity resulted in underestimation of the numbers entrained by the pumping facilities. Delta Smelt are recovered at the south Delta fish facilities at higher rates when daily net flow in the southern Delta (Middle and Old rivers) is southwards toward the SWP and CVP (Grimaldo et al. 2009; Kimmerer 2011). Therefore, juveniles and adults that were located in the south Delta box (box 3) of the model were exposed to additional entrainment mortality of 0.02 d^{-1} whenever the daily averaged flow in Middle River (downstream end of channel 90; Figure 1) was southward. The value of the added mortality (0.02 d^{-1}) was determined as part of model calibration.

Movement

Yolk sac larvae, larvae, and postlarvae were transported by water velocities on the spatial grid hourly by using a particle tracking approach, whereas juveniles and adults were moved every 12 h by using a kinesis approach to behavioral movement.

The PTM was a recoded version of the CDWR's PTM and used the same formulations (Wilbur 2000; Miller 2002). The CDWR's PTM has been used to examine entrainment impacts (e.g., Kimmerer and Nobriga 2008) and has been compared with other PTMs (Gross et al. 2010). Our recoded version used as input the hourly values of velocity at each end of each channel and the water level at each node that was generated by the DSM2 hydrodynamic model. The PTM kept track of the hourly positions of particles (the three larval stages) in three dimensions: along-channel (x = distance [m] from the upstream end of a channel), lateral (y = distance [m] from the center line of the channel), and vertical (z = distance [m] from the bottom of the channel). The y and z positions within a channel were altered by random perturbations and were used to adjust the x-direction velocity (Supplement C in the online version of this article).

Day-to-day movements and seasonal migrations of juveniles and adults were based on a kinesis approach (Humston et al. 2000, 2004), with salinity used as the cue. Salinity was used to simulate reasonable distributions of individuals within the system, but salinity did not directly affect growth or mortality. Rather, salinity was used to distribute individuals realistically, and individuals then experienced the local conditions (temperature and prey densities) in the channels.

Only the along-channel (x) position was tracked for juveniles and adults. At each 12-h time step, each individual's x position was updated, and its channel or reservoir location was determined. Kinesis represents the distance moved by each individual as the sum of an inertial component (IC) and a random component (RC), with the inertial component dominating when conditions (salinity) are good and the random component dominating when conditions are poor. The position in the x dimension (m from the upstream end of the channel) was updated every 12 h as

$$x_{t+1} = x_t + \Delta x_t \tag{17}$$

and

$$\Delta x_t = IC + RC, \tag{18}$$

where IC is the inertial component that depends on the movement velocity at the last time step (Δx_{t-1}), and RC is the random component based on fish swimming speed.

To compute *IC* and *RC*, we first computed the functions (f and g) that defined the degree to which salinity (S) in the box deviated from optimal salinity,

$$f(S) = H_1 \cdot e^{-0.5 \cdot \left(\frac{S - S_O}{\sigma_S}\right)^2} \quad (19)$$

and

$$g(S) = 1 - H_2 \cdot e^{-0.5 \cdot \left(\frac{S - S_O}{\sigma_S}\right)^2}, \quad (20)$$

where S_O is the optimal value of salinity (2.0 psu); σ_S ($= 3.0$) determines how quickly the function decreases as salinity deviates from its optimal value; and the H-values are constants (0.75 and 0.90) that define the maximum values of the functions. Inertial velocity (*IC*) was then computed using the distance moved in the last time step (Δx_{t-1}) and $f(S)$:

$$IC = \Delta x_{t-1} \cdot f(S), \quad (21)$$

Equation (21) results in the individual moving at the same total velocity (inertial and random combined) as in the last time step to the degree that conditions (salinity) are favorable; $f(S)$ is larger when salinity is near the optimal value (equation 19).

The random component of distance moved (*RC*) was computed based on $g(S)$ and a random component (r):

$$RC = r \cdot g(S). \quad (22)$$

The random component r was calculated as

$$r = N(0,1) \cdot \frac{d}{2} + d \quad (23)$$

with

$$d = \sqrt{\frac{(0.001 \cdot L \cdot \Delta t \cdot 60 \cdot 60)^2}{2}}, \quad (24)$$

where r is a normal deviate with a mean of d and an SD of $d/2$. The numerator in equation (24) represents the distance (m) moved during one 12-h time step, assuming a swimming speed of 1.0 body length/s. The parameter d computed by equation (24) is typically about 70% of the distance to account for fish not swimming in a straight line. The probability of up-estuary movement (P_{up}) was specified as 0.50; for each individual and each time step, a random uniform number was compared with P_{up} to determine the x direction of movement (seaward or up-estuary) in a channel. The distance moved in that direction was determined by the computed velocity of the individual (Δx_t; equation 18).

If individuals moved past the end of a channel, they then entered a node where they either continued into a new channel or entered a reservoir. The new channel or reservoir was randomly selected from all those connected to the node, regardless of flow (Supplement C). Individuals were simply started at the beginning of a new channel. Supplement D (in the online version of this article) shows the results of testing the behavioral movement with simplified salinity patterns on the model grid.

Up-estuary migrations of adults and seaward migrations of juveniles were simulated using the above kinesis approach by changing S_O (equations 19 and 20) and P_{up}. On December 15 of each year, the spawning migration to freshwater began by changing S_O from 2 to 0 psu and by setting P_{up} to 0.85 (rather than 0.50) so that more moves were in the up-estuary direction. On May 1, the migration of adults and juveniles back to low-salinity water was simulated by setting S_O back to 2 psu and setting P_{up} to 0.15. Once individuals reached their new optimal salinity, P_{up} was switched back to 0.50.

Numerics

We used a super-individual approach (Scheffer et al. 1995) in order to accurately simulate the addition of new yolk sac larvae each year while ensuring that we did not exceed computer limitations (Supplement E in the online version of this article). Each super-individual represented some number of identical individuals in the population, which we term its "worth." Each year during spawning, the same number of super-individuals was added, but with their initial worth adjusted to reflect the yolk sac larvae produced. Mortality acted to decrement the worth of an individual, with the worth then being used to determine population-level numbers of eggs spawned and Delta Smelt densities and abundances. We used a complicated algorithm for determining how to allocate the fixed number of super-individuals each year among hatch dates and boxes (Supplement E). In all simulations, we used 150,000 super-individuals per age-class (450,000 super-individuals total) because this was sufficient for convergence (i.e., almost identical results were obtained when we followed more super-individuals). The model was coded in FORTRAN90.

Computation of Population Growth Rate

We used the individual-based model output to estimate a simple Leslie age-based matrix model for each year, which allowed us to summarize the multidimensional individual-based model results with a single variable of annual finite population growth rate (λ). The value of λ was based on the detailed dynamics of the individual-based model but allowed for easier comparison among years. A 2×2 matrix model was estimated for each year by computing the average maturity, fecundity, and age-specific survival rates (Supplement F in the online version of this article); eigenvalue analysis was then used to determine λ. The value of λ for a specific year is a measure of the conditions for Delta Smelt during that year. The λ value is also a reflection of conditions from the previous year by indicating how growth in the fall prior to spawning affected the elements related to maturity and fecundity in the matrix.

TABLE 2. Calculation of the major model output variables examined in Delta Smelt model simulations and the calculations for the data when model–data comparisons were performed. The corresponding figures for the results are noted; "text" means the results are described in the text.

Variable	Model calculations	Data calculations
(a) January adult abundance (Figure 5)	Summed worth of all individuals on January 1; includes young of the year that just became age 1 and age-1 fish that just became age 2 but does not include age-2 fish that were just removed as they became age 3.	Catch per trawl from the spring Kodiak trawl survey for 2002–2006 was averaged for January and February (first two trawls) and expanded to population size using volume sampled, 100% efficiency, and volume of Sacramento–San Joaquin Delta and Suisun Bay less than 4 m deep. November and December midwater trawl (MWT) abundance was computed the same way but by using volume of Delta and Suisun Bay less than 4 m deep. Log(Kodiak trawl abundance) was then regressed against log(MWT abundance), and the MWT values were used to estimate Kodiak trawl values for 1995–2001.
(b) Mean length of young-of-the-year, age-1, and age-2 fish (Figure 6)	Computed the weighted mean lengths on January 1 (just before their birthdays) using worth as the weighting factor in the averaging.	Mean length of fish in the December MWT samples, excluding fish greater than 100 mm, which were assumed to be age 1 or older.
(c) Annual number of adults entrained in diversion facilities (Figure 7)	Summed worth of individuals that were killed by arrival at reservoir 4 (State Water Project) or node 181 (Central Valley Project), plus the worth associated with the added mortality of all individuals in box 3 (South Delta) when Middle River flow is negative. The amount of worth (w) attributable to Middle River-related mortality (R) versus natural mortality (M) is $w(\frac{R}{M+R})(1-e^{-M+R})$.	Methods are described by Kimmerer (2008), and results used here are shown in Figure 12a of that paper.
(d) Fraction of adults on January 1 subsequently entrained during that year	Ratio of numbers entrained (see variable c) divided by the January adult abundance (see variable a)	Methods are described by Kimmerer (2008), and results used here are shown in Figure 12c of that paper.
(e) Fraction of age-1 individuals that were mature and the number of eggs per entering age-1 individual (Figure 8)	Fraction mature was computed as the summed worth of age-1 individuals greater than 60 mm at the time of projected spawning divided by the summed worth of all age-1 individuals on the same day. The ratio of eggs to entering age-1 fish was computed as the cumulative number of eggs produced by age-1 individuals divided by the summed worth of age-1 fish on January 1 prior to spawning.	No data.
(f) Salinity weighted by densities of larvae, juveniles, and adults (Figure 9)	First, the worth of larvae (including postlarvae) was summed for each box on each day and then divided by the volume of the box to obtain number per m^3 by box on each day. Salinity in each box on each day was used to compute average salinity across boxes, weighted by the larval densities in each box. This process was repeated for juveniles and for adults. This was done for calendar years to better match following a year-class from the early spring spawning.	Number per trawl in each sample of the 20-mm, summer townet, fall MWT, and spring Kodiak trawl surveys was used to weight the salinity value measured with the trawls. Data values include a mix of larvae, juveniles, and adults that varied throughout the year depending on the survey.
(g) Proportion of individuals in and seaward of the confluence box for adults on December 14 and April 30, for postlarvae on June 24, and for juveniles and adults on September 1 (Figure 10)	For each stage and day, we summed the worth of individuals in each box and then divided the sum of worth in the confluence box and seaward boxes by the total summed worth over all boxes.	All of the fall MWT data from all stations during September–December were aggregated for each year, assigned to up-estuary of the confluence box (47 stations) or in or seaward of the confluence box (39 stations). The proportion in Figure 10f was computed from these two totals.

TABLE 2. Continued.

Variable	Model calculations	Data calculations
(h) Daily fraction of larvae plus postlarvae entrained in diversion facilities (Figure 11)	Summed worth of larval and postlarval individuals reaching reservoir 4 and node 181 divided by the summed worth of larvae and postlarvae at the end of the day plus the numbers lost to pumping plant entrainment during that day.	Methods are described by Kimmerer (2008), who used the 20-mm survey data, and the results are shown in Figure 14 of that paper. Note: Kimmerer's (2008) estimates included some juveniles as well as larvae and postlarvae. Also see recent papers about the estimation by Kimmerer (2011) and Miller (2011).
(i) Diets (text)	Computed averaged diets for each life stage using the biomass of zooplankton types eaten by every 500th individual on every 30th day. We first computed the proportions for each individual and then averaged the proportions over individuals. This resulted in individuals covering all life stages for the time periods during which the stages were present.	Diets reported by Lott (1998), Nobriga (2002), and Baxter et al. (2010), who summarized unpublished data from Steven Slater (California Department of Fish and Game); data were only sufficient for qualitative and general comparison.
(j) Annual finite population growth rate (λ; Figure 12)	The λ value was computed from a 2×2 Leslie matrix model with parameter values determined from the individual-based model output each year (see Supplement F).	No data.
(k) Stage-specific survival rates (Figure 13)	Summed worth of individuals entering each life stage during the year divided by the summed worth of individuals entering the next life stage.	No data.
(l) Averaged temperature and proportion of maximum consumption (*p*-values; text)	Computed average temperature and average *p*-value for all individuals (weighted by their worth) each day and then computed seasonal averages weighting the daily values for total daily worth of age-1 individuals during February 27–June 7 (spawning) and total daily worth of juveniles during April 18–October 1 (growing season) and October 1–December 30 (fall).	

MODEL SIMULATIONS

Calibration

The model was calibrated in three steps. We first tested the movement of juveniles and adults on test grids with fixed salinity patterns to understand movement in contrived situations where we knew the correct movement patterns (Supplement D). Once the entire model had been calibrated, we again evaluated the movement patterns among years to confirm that simulated movement was realistic under dynamic salinity conditions. The results using the full model are presented below as part of the 1995–2005 historical simulation.

The second step was to determine the *K*-values (equation 10) for each Delta Smelt life stage and each zooplankton prey group (Supplement B). We averaged daily temperature and the biomass of each zooplankton group in each box over the periods when each life stage would be in the system. We assumed that larvae, juveniles, and adults remained in each of the 11 boxes, and we then iteratively adjusted the *K*-values so that the average consumption rate (i.e., with p-value $= 0.8$) and diets were reasonably close to the available observations.

The third and final step was to put the above two calibrated components (movement and growth) into the full model and then to simulate the period 1995–2005 by adjusting only the yolk sac larval mortality rate and the entrainment mortality multiplier based on Middle River flow. The mortality rate of yolk sac larvae was adjusted because this mortality was relatively simple (i.e., only temperature dependent and of short duration). The entrainment mortality multiplier was adjusted because the role of Middle River flow in affecting entrainment is well documented (Grimaldo et al. 2009), although the magnitude is uncertain, and we had data on adult entrainment mortality (Kimmerer 2011). We adjusted the yolk sac larval mortality rate until the predicted average January abundance for 1995–2005 was close to the data average of 2.7×10^6; we then adjusted the entrainment mortality multiplier until the average annual fraction of adults removed by diversions was close to the data average of 10%. We did not try to fit to individual years or to the pattern in the time series of annual abundances. Thus, any interannual differences in model output were generated by differences in temperature, salinity, entrainment, and zooplankton densities.

Historical Simulation

We report the results from the last step of the calibration: the 1995–2005 historical simulation. The calculations that were performed to obtain all reported model outputs and to summarize the field data used for model–data comparisons are shown in Table 2. The field data for Delta Smelt originate mostly from four surveys that are conducted annually by the California Department of Fish and Game (www.dfg.ca.gov/delta/): (1) the fall midwater trawl (MWT) survey began in 1967 and samples juveniles and adults monthly during September–December at 116 stations; (2) the spring Kodiak trawl survey began in 2002 and samples adults every 2–4 weeks during winter and spring at 39 stations; (3) the 20-mm survey (larval net) began in 1995 and samples larvae at 48 stations between March and July; and (4) the summer townet survey began in 1959 and samples mostly juveniles at up to 32 stations during June–August. These field data have been described and used extensively in previous analyses (e.g., Bennett 2005; Kimmerer et al. 2009; Sommer et al. 2011; Miller et al. 2012).

The model outputs and the model–data comparisons in Table 2 confirmed various aspects of the calibration or served to assess the realism of model behavior. None of the model–data comparisons can be considered as true model validation because no data were kept aside for independent comparison. Comparisons a–d in Table 2 were related to the three steps in model calibration as described above. Maturity of age-1 individuals and the number of eggs per entering age-1 individual (Table 2, comparison e) integrated the effects of growth differences (due to temperature and prey biomass) from the previous year on reproduction. Movement patterns were confirmed by using averaged salinities weighted by Delta Smelt density (comparison f) and the proportions of individuals in and seaward of the Sacramento River–San Joaquin River confluence box (comparison g). We used monthly Delta outflows (m^3/s) from DAYFLOW (www.water.ca.gov/dayflow/) to help interpret the spatial distributions in comparison g. Comparison h, the daily fraction of larvae lost to entrainment, confirmed the realism of the pumping-related mortality determined by the PTM. Overall average diets (comparison i) were examined to confirm reasonable shifts in diet from larvae to juveniles to adults. The λ values (comparison j) and stage survival rates (comparison k) provided condensed summaries of the differences among years. Finally, comparison l identified the between-year differences in temperature and food as actually experienced by the simulated fish.

MODEL RESULTS

Dynamics within the Historical Simulation

For the simulated period 1995–2005, calibration resulted in an average January adult abundance of 2.7×10^6 (compared to the data target of 2.3×10^6) and an average fraction of adults lost to the pumps of 11% (the target was 10%). The final calibrated mortality rates were 0.035 d^{-1} for yolk sac larvae and 0.02 d^{-1} for Middle River-related pumping mortality. Annual January abundances varied from year to year in a pattern similar to that of data-based estimates, with a peak in 2000, a decline in 2001, and then low abundances in 2002–2005 (Figure 5). One exception was that the January adult abundance in 1996 had the highest data-based estimate but a relatively low simulated value.

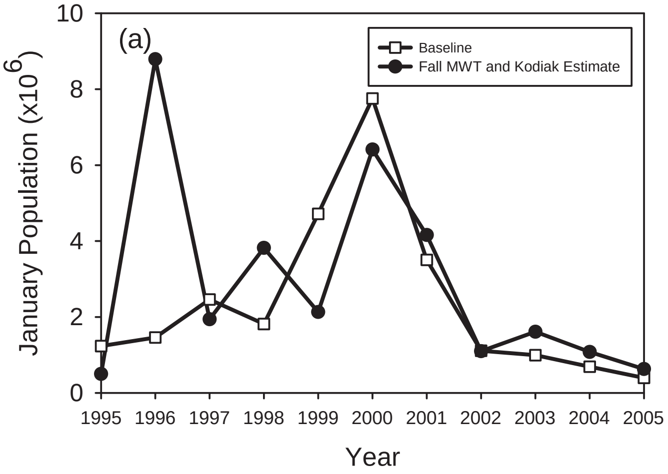

FIGURE 5. Annual abundance of adult Delta Smelt in January for 1995–2005 from the baseline simulation and as estimated from the fall midwater trawl (MWT) and spring Kodiak trawl sampling.

Simulated lengths at age on January 1 were similar to data values for young of the year about to become age 1, with both model and data values varying between 55 and 65 mm (Figure 6). Faster growth was predicted for the summer and fall of 1995 (shown as the January 1996 value), 1997 (the January 1998 value), and 2001–2004. Simulated growth was slow in 1996, 1999, and 2000, resulting in shorter fish recorded during the

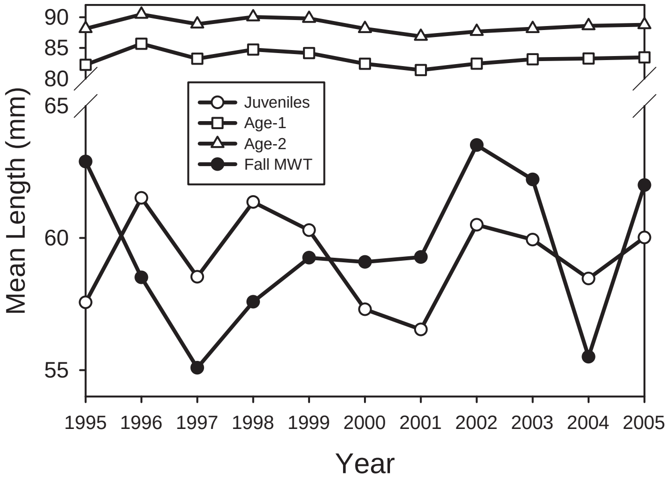

FIGURE 6. Mean total length of juvenile, age-1, and age-2 Delta Smelt on January 1 in each year (just prior to birthdays) of the 1995–2005 baseline simulation. Also included are the mean lengths of young-of-the-year fish from fall midwater trawl (MWT) sampling.

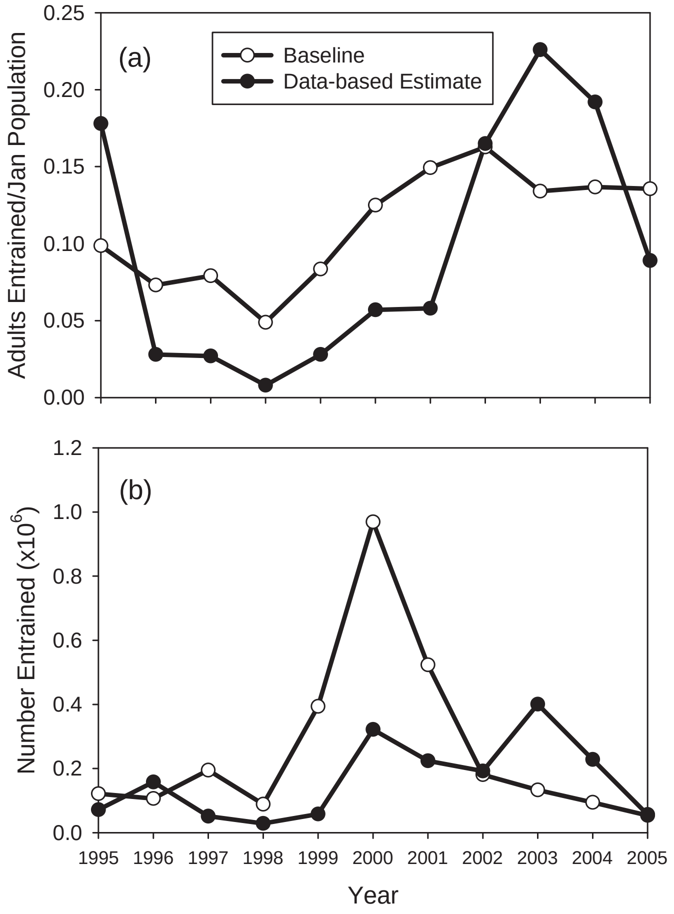

FIGURE 7. Predicted and observed annual values in 1995–2005 for **(a)** the fraction of adult Delta Smelt present in January that were entrained in pumping plants during the next few months (i.e., winter) and **(b)** the number of adults that were entrained during the same time period.

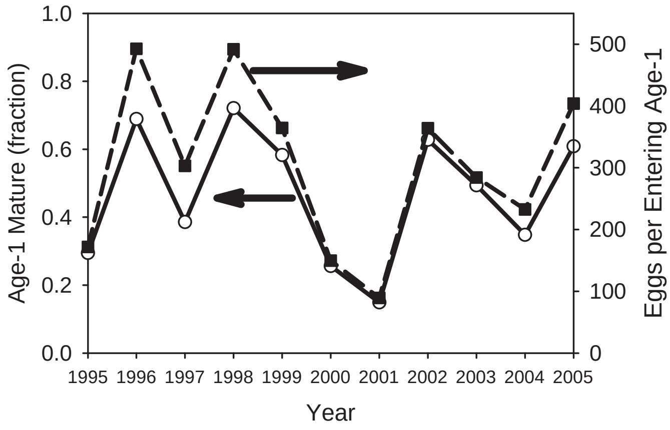

FIGURE 8. Annual fraction of age-1 individual Delta Smelt that were mature (solid line, open circles) and the number of eggs produced per entering age-1 individual (dashed line, black shaded squares) for the 1995–2005 baseline simulation.

next January. Mean lengths of about 82 mm for age-1 fish (about to become age 2) and 90 mm for age-2 fish (about to become age 3) were consistent with the results of Bennett (2005).

The predicted annual fraction of adults entrained showed less interannual variation than the data-based values (Figure 7a), and the predicted numbers entrained were as much as two times the data values for 1999–2001 (Figure 7b). Predicted and estimated annual fractions entrained were low ($<10\%$) for 1996–1999 and then increased to 15–20% for 2002–2004. Predicted fractions showed less variation and were higher than estimated values during the earlier, low-entrainment-loss years and were lower than estimated values during the latter, high-entrainment-loss years (i.e., in Figure 7a, the line connected by open circles is flatter than the line connected by black shaded circles). Substantially more model adults were entrained during 1999–2001 than were shown by the data (Figure 7b) because the fraction entrained was higher, and in two of those years the population estimate (Figure 5a) was higher than that in the data. Overestimation of the fraction entrained in early years and underestimation of the fraction entrained in later years suggested inaccuracies in the simulated adult spatial distributions or in the use of a single value for the pumping mortality at any southward Middle River flow.

Even though the variation in mean length of age-1 adults was small (± 5 mm; Figure 6), interannual differences had large effects on maturity (Figure 8, solid line) and subsequent egg production (Figure 8, dashed line) by age-1 individuals. Age-1 individuals at the beginning of the spawning season (about 3 months into age 1) varied above and below 60 mm from year to year. This hovering around 60 mm caused the fraction of age-1 fish that were mature to range from 0.15 (in 2001) to 0.60–0.70 (in 1996, 1998, and 2002; Figure 8), tracking the slow and fast age-0 growth from the previous year (Figure 6). A greater fraction of individuals becoming mature and a higher weight of these individuals (equation 1) resulted in a fivefold difference among years in the number of eggs produced per entering age-1 individual (Figure 8). Egg production per entering age-1 fish was highest in 1998 (491.8) due to the fast growth of juveniles in 1997 and the high proportion (72%) of age-1 fish being mature at spawning; egg production per entering age-1 individual was lowest in 2001 (89.3; 15% maturity) due to slow juvenile growth in 2000. Such large variation in the fraction mature and eggs produced per entering age-1 fish seems extreme and may partially reflect the all-or-none maturity rule (100% mature if longer than 60 mm) we used. We further investigate the maturity rule in our companion paper (Rose et al. 2013).

Simulated Delta Smelt density-weighted salinities showed the up-estuary spawning migration of adults and the subsequent larval and juvenile movement seaward (Figure 9). Note that the years in Figure 9 are calendar years (i.e., they start on January 1) in order to follow a year-class. Salinity slowly rose for larvae and postlarvae during June–September as they were transported seaward (Figure 9a). Salinity also rose for juveniles during June–October (Figure 9b) after the S_O for juveniles was changed from 0 to 2 psu on May 1. Salinity for adults went from near zero in January–May to approaching 2–6 psu beginning in June

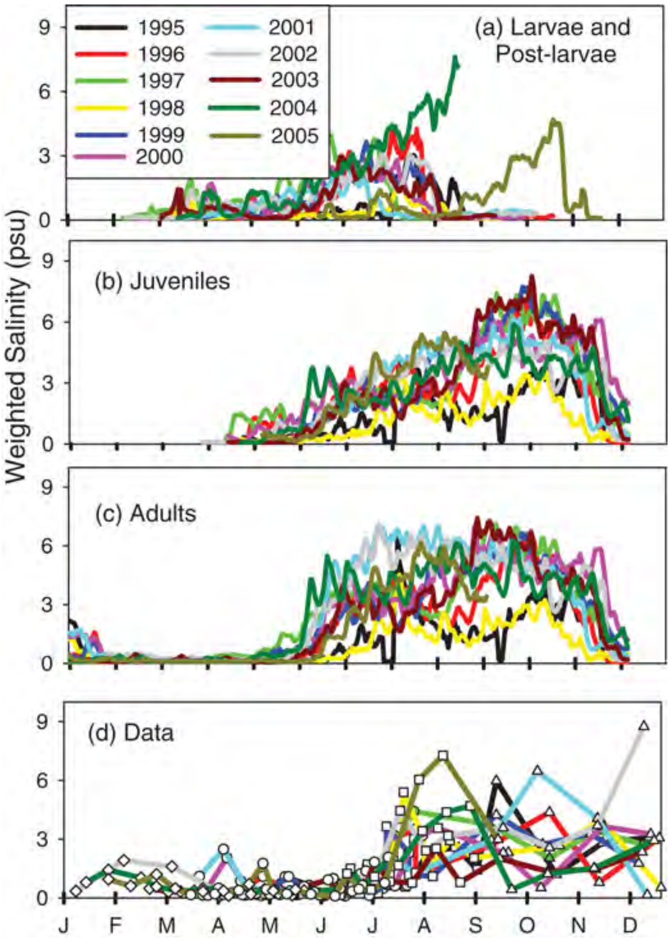

FIGURE 9. Average salinity (psu) weighted by Delta Smelt density computed daily during calendar years 1995–2005 for **(a)** larvae and postlarvae combined, **(b)** juveniles, and **(c)** adults in the baseline simulation. Panel **(d)** shows the weighted salinity values obtained by merging catch per unit effort data from the 20-mm, summer townet, fall midwater trawl (MWT), and spring Kodiak trawl surveys for 1995–2005. Years are calendar years rather than water years (e.g., 1997 refers to January–December). [Figure available online in color.]

(Figure 9c), triggered by a change in the adults' S_O back to 2 psu on May 1. During most years, the density-weighted salinity values for juveniles and adults caused their seaward migration to occur earlier than was shown in the data (June in Figure 9c versus 9d), and they occupied water during the late summer and fall with salinities of 2–6 psu, whereas the data suggested somewhat lower-salinity waters of 1–4 psu during the late summer and fall (August–October in Figure 9c versus 9d).

The interannual influence of Delta outflow on the proportion of individuals in each spatial box is shown in Supplement G (in the online version of this article) and is summarized here by using a single metric: the proportion of fish that were within or seaward of the confluence box (Figure 10). In December, prior to their up-estuary spawning migration, adults were distributed based on salinity, which was roughly correlated with average October outflow (Figure 10a). During the high-outflow years of 1996 and 1999, more than 80% of adults were in or seaward of the confluence box, whereas during the remaining years fewer than 60% were in or seaward of the confluence box.

Spawning migration (including young-of-the-year fish that became age 1 on January 1) began in January and ended by April 30, with almost all individuals located up-estuary of the confluence box (Figure 10b). Once hatched, larvae were transported by the PTM; by June 24, when postlarvae were about to become juveniles, proportions again roughly reflected outflow conditions (Figure 10c). During 1995 and 1998, which were years of high May outflow, over 80% of postlarvae were in or seaward of the confluence box, whereas during relatively low-outflow years (2001, 2002, and 2004) only 20–30% of postlarvae were located in or seaward of the confluence box. Data for 1997 appear anomalous relative to May outflow because that year had a low May outflow but the highest June outflow over the simulation time period (2,033 m^3/s versus less than 1,327 m^3/s). Juvenile and adult distributions on September 1 (Figure 10d, e) resembled each other because both reflected behavioral movement towards 2-psu water. Juveniles and adults were farthest seaward during the high outflow of August 1998 and were situated up-estuary during the low-outflow years of 2001, 2002, and 2004.

Finally, the predicted and observed proportions of adults that were in or seaward of the confluence during the fall showed moderately good agreement for extremely low- and high-outflow years but not for years of intermediate flow (Figure 10f). Predicted and observed proportions showed relatively more fish in and seaward of the confluence during 1996 and 1999 and more fish being relatively up-estuary during 1995, 2004, and 2005. October outflow was highest in 1996 and 1999 and was low in 1995 and 2004 (Figure 10a); October outflow for 2005 was not low, but the summed October–December outflow in 2005 was relatively low. However, predicted proportions were flatter than observed proportions (proportions under low outflow were above the 1-to-1 line, and proportions under high outflow were below the 1-to-1 line in Figure 10f), indicating that simulated adults were generally too far seaward under low outflow and too far up-estuary under high outflow.

The simulated daily proportion of larvae and postlarvae entrained, which results from transport by the PTM, generally agreed with the data-based estimates (Figure 11). Model predictions showed less interannual variation than the data-based values. A few extreme model values of 0.2–0.3 were predicted, whereas data values never exceeded 0.1. In both the simulation and in the data, entrainment was relatively low during 1995, 1996, and 1998 and was high during 2002 and 2003. Model-predicted entrainment was also high during 2000, 2001, and 2005, which were intermediate entrainment years in the data.

Simulated diets were reasonable and consistent among years, even between the most extreme years (not shown). Larvae consumed *Limnoithona* spp. (20% of consumed biomass) and calanoid copepodids (80%) because other prey had vulnerabilities of zero. As Delta Smelt increased in size, they consumed

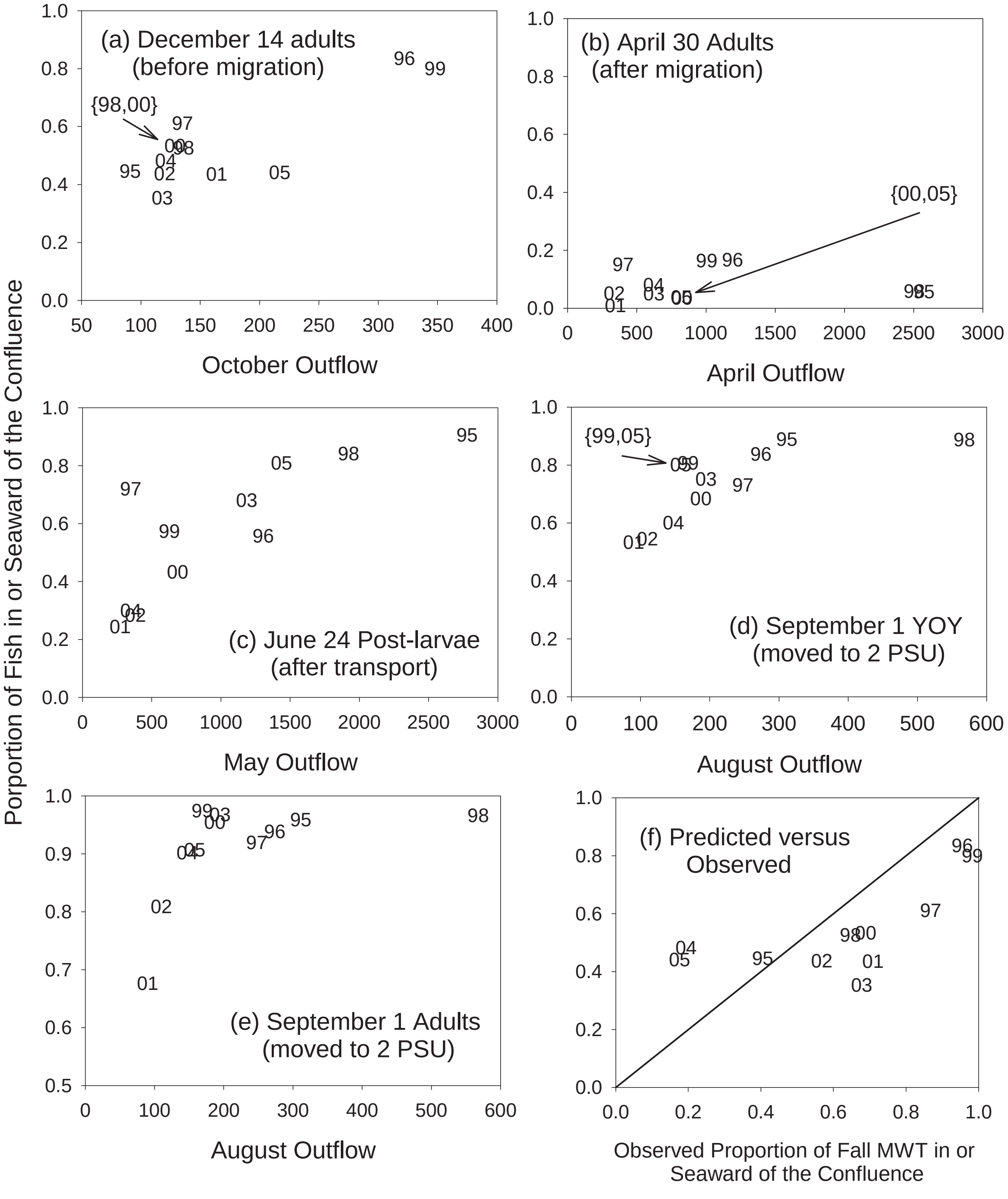

FIGURE 10. Predicted proportion of Delta Smelt individuals in the confluence and seaward boxes (see Figure 1) versus monthly Sacramento–San Joaquin Delta outflow (m^3/s) in the immediately preceding months for 1995–2005 of the baseline simulation: **(a)** adults on December 14 (before the spawning migration), **(b)** adults on April 30 (after the spawning migration), **(c)** postlarvae on June 24 (after particle tracking model transport), **(d)** juveniles (young of the year) on September 1, and **(e)** adults on September 1. Two-digit numbers indicate water years (e.g., 96 = 1996; 02 = 2002). Panel **(f)** is a comparison of the predicted proportion of Delta Smelt in and seaward of the confluence box from December 14 versus the proportion estimated from the fall midwater trawl (MWT) survey. Panel (a) uses outflow from October of the previous year (e.g., October 2001 outflow for the year 2002).

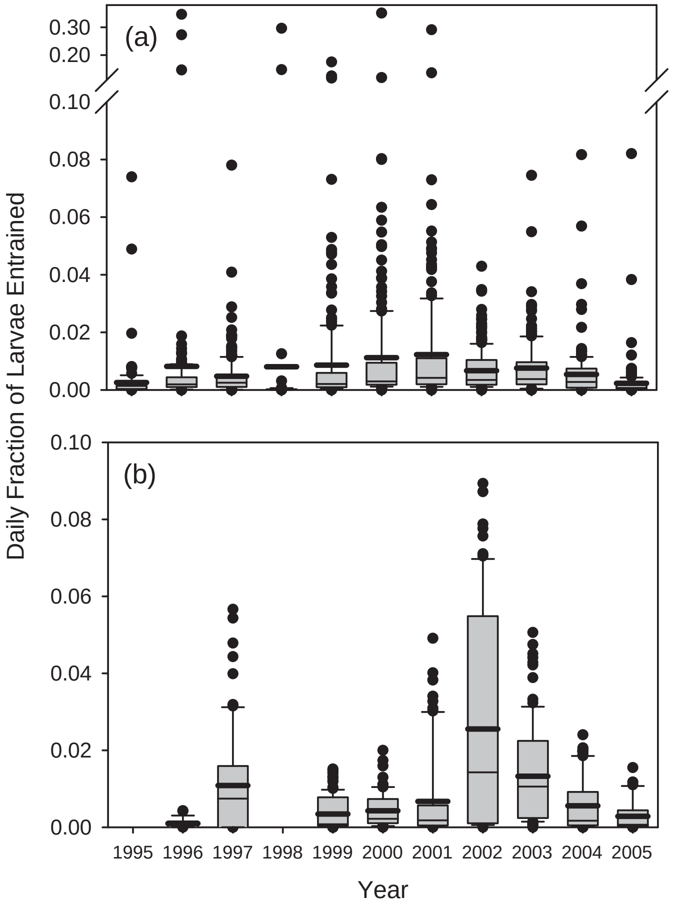

FIGURE 11. Daily entrained fraction of **(a)** Delta Smelt larvae and postlarvae combined as determined by the particle tracking model for 1995–2005 of the baseline simulation and **(b)** larvae (and some juveniles) as estimated by Kimmerer (2008). The thin line within each box is the median, the thick line is the mean, the ends of the box represent the 25th and 75th percentiles, the ends of the whiskers represent the 10th and 90th percentiles, and the black circles are points outside of the 10th and 90th percentiles.

less *Limnoithona* spp. and calanoid copepodids and more of the other four adult zooplankton types (50% [*Limnoithona* spp. and calanoid copepodids] and 50% [other types] for postlarvae; 79% and 21% for juveniles; 92% and 8% for adults). *Pseudodiaptomus* increased in the diet as fish transitioned from postlarvae to juveniles, but the *Pseudodiaptomus* contribution then decreased slightly between juvenile diets and adult diets as the biomass of this zooplankton type decreased in the fall. These results qualitatively agreed with several diet studies of Delta Smelt (Table 2), but more rigorous comparison was not attempted because of the difficulties in interpreting field diets involving rapidly digested zooplankton and without simultaneous measurement of zooplankton densities.

Best versus Worst Years in the Historical Simulation

Population growth rate (λ) from the Leslie matrix model showed that water year 1998 was the best year and water year 2001 was the worst year for the simulated Delta Smelt population (Figure 12). The λ in each year resulted from a combination of (1) growth in the prior year affecting subsequent reproduction and (2) higher stage-specific survival rates in the current year for most of the life stages. Thus, water year 1998 extended from October 1997 to September 1998 and included the fall of 1997, which led up to spawning in spring 1998. Fast growth in fall 1997 resulted in large new adults at the beginning of 1998 (Figure 6) and therefore a high fraction of mature age-1 fish and a high number of eggs per entering age-1 individual (Figure 8). The year 1998 also had moderately high growth during summer (Figure 6), the lowest entrainment losses (Figure 7a, 11), and the highest stage-specific survival rates for all life stages (Figure 13). The bad year, 2001, had the second slowest growth in the prior year (2000; Figure 6) and consequently had the lowest number of eggs per entering age-1 fish (Figure 8). In addition, 2001 had moderately high entrainment losses (Figure 7) and low survival of eggs (Figure 13a), juveniles (Figure 13e), and adults (Figure 13g, h).

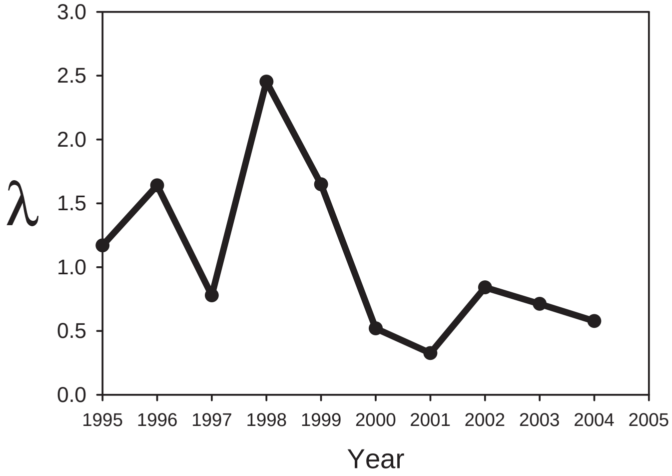

FIGURE 12. Population growth rate (λ; fraction per year) of Delta Smelt as determined by the age-based Leslie matrix model applied to individual-based model output for each year of the 1995–2005 baseline simulation. No value for 2005 was possible because the simulations ended on September 30, 2005; information through December 31, 2005, would be needed to estimate the matrix model for 2005.

Compared with 2001, water year 1998 had a relatively cool and delayed warming in spring that benefited Delta Smelt larvae, but both years had similar growth conditions for juveniles during summer. Mean temperature experienced by age-1 individuals during February 27–June 7 (spawning) was 14.8°C in 1998 versus 16.4°C in 2001. Average day of spawning was April 28 in 1998 versus April 6 in 2001, and average duration of the larval stage (inversely related to growth rate) was 25.2 d (1998) versus 28.6 d (2001). Although juveniles also experienced cooler temperatures during the early summer (16.7°C versus 22.2°C for April 18–June 7), differences became smaller when viewed over the entire growing season. Average temperature experienced by juveniles during April 18–October 1 was slightly cooler during 1998 than during 2001 (20.9°C versus

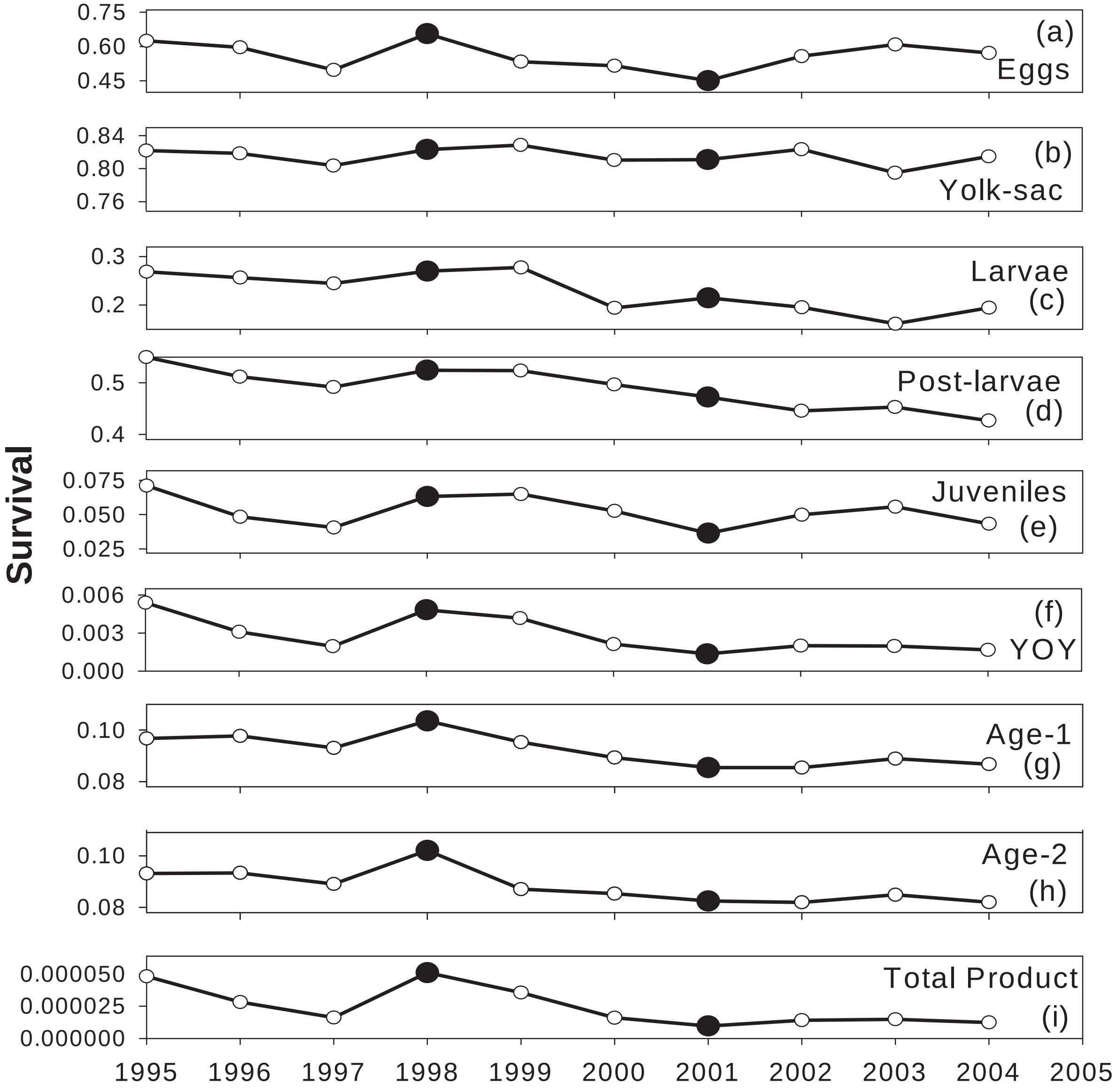

FIGURE 13. Delta Smelt stage-specific survival (fraction) from the 1995–2005 baseline simulation for **(a)** eggs, **(b)** yolk sac larvae, **(c)** larvae, **(d)** postlarvae, **(e)** juveniles, **(f)** total young of the year (product of a–e), **(g)** age 1, **(h)** age 2, and **(i)** total (product of f–h).

22.1°C), and the average *p*-value was higher in 1998 (0.89 versus 0.84). However, mean lengths of juveniles were similar between 1998 and 2001 (60.3 mm in 1999 versus 60.5 mm in 2002; Figure 6), so the difference in summer growth of juveniles between 1998 and 2001 was not a major factor.

The higher number of eggs per age-1 individual in 1998 compared with 2001 was due to faster growth during fall 1997 compared to fall 2000. Mean length of juveniles on January 1 (just before their birthday to age 1) was 61.4 mm for 1998 versus 56.5 mm for 2001. The mean *p*-value for October 1–December 30 was 0.76 in 1997 versus 0.68 in 2000; 1997 was also warmer than 2000 (15.9°C versus 15.0°C).

Delta outflow was generally higher in 1998 than in 2001 (Figure 10), so individuals were farther seaward, resulting in lower entrainment mortality during 1998. The PTM put 84% of postlarvae in or seaward of the confluence box on June 24 in 1998 compared with 24% on June 24 in 2001 (Figure 10c). Similarly, behavioral movement of juveniles resulted in about 88% of them occurring in or seaward of the confluence box on September 1, 1998, versus 53% on September 1, 2001 (Figure 10d). Almost no larvae were predicted to be entrained during 1998, whereas a daily average loss of 1.2% was predicted for 2001 (Figure 11a); the fraction of January adults entrained was 0.05 in 1998 versus 0.14 in 2001 (Figure 7a).

DISCUSSION

We used a detailed, individual-based approach to model the population dynamics of Delta Smelt during a time period that included a major population decline. The model was completely density independent; a density-dependent version is analyzed by Rose et al. (2013). The Delta Smelt has been declining since the 1980s and was one of four species to show a step decline around 2002 (Sommer et al. 2007). The choice of a detailed individual-based model may seem odd because of the extensive data demands of this general approach. Survey data-based modeling approaches are easier to justify in terms of calibration and in testing the degree of fit (e.g., Thomson et al. 2010; Miller et al. 2012); however, unlike our process-based approach, survey data-based approaches do not provide a means of assessing cause-and-effect relationships and so far have not helped to settle the controversy over the causes of the decline.

We opted for a spatially explicit, individual-based approach to explore the potential causes for the Delta Smelt's decline and the conditions that result in good versus bad years for Delta Smelt. The term "spatially explicit" refers to multiple, linked spatial boxes with different conditions among them. The individual-based approach allows for relatively easy simulation of movement and for local experiences to accumulate as each individual moves among the spatial boxes. A spatially explicit approach was required to enable a model that could (1) represent feeding, growth, reproduction, and movement in some detail; and (2) simulate how interannual variation in spatial distributions by life stage interacted with dynamic habitat. The chief disadvantage of such a complicated mechanistic model is that describing how it works can be difficult (Grimm et al. 2006), and many of the assumptions and parameter values must be based on judgment; thus, replication of the modeling by others is a challenge (Wilensky and Rand 2007). Indeed, the output of our model was sufficiently complicated that we chose to fit an age-structured matrix model to its output to provide a more straightforward summary of each year's condition. Our model is designed for exploring hypotheses about some of the factors affecting Delta Smelt population dynamics but is not designed for forecasting future Delta Smelt population abundances. Hypotheses about future conditions can be explored with our model but in a relative way, whereby simulated values are compared with some simulated baseline condition.

Maunder and Deriso (2011) also fitted a stage-based model of Delta Smelt by using the same extensive long-term monitoring data used here. By including covariates such as annual entrainment rate in their model, Maunder and Deriso (2011) were able to evaluate the relative importance of different factors. Their data-based modeling approach is relatively easy to describe (mathematically compact) and can be easily judged for its performance and skill (fit to data), but the approach also inherits problems with the monitoring data in terms of bias and process versus observation errors and is heavily correlation based. Clearly, the data-based approach of Maunder and Deriso (2011) and the detailed, process-based approach used here can complement each other, and detailed comparison between the two approaches would likely allow for more insights than either approach alone can provide.

Calibration of complicated individual-based models is always a challenge. Our approach was first to adjust the movement and feeding algorithms externally under simplified conditions and then calibrate by adjusting two mortality-related parameters for the 1995–2005 historical simulation to get the averaged population abundance and averaged fraction entrained to match the data. None of the calibration steps involved adjustments to fit the model to specific years.

Model results were generally consistent with the available data and information (Table 2) about Delta Smelt. The model reasonably matched a variety of measures related to growth, mortality, and movement. Predicted growth resulted in realistic lengths at age (Figure 6). The PTM produced reasonable larval entrainment rates (Figure 11), and a simple function of Middle River flow yielded annual adult entrainment fractions that mimicked the observed values (Figure 7). Movement was confirmed both based on salinity experienced by individuals (Figure 9) and geographically (Figure 10). The fraction of individuals in the confluence box and seaward boxes during the fall agreed with estimates from fall MWT sampling. Thus, the calibrated model is a good descriptor of the 1995–2005 conditions and is useful for comparing Delta Smelt dynamics among those years. We caution that our bioenergetics model was sufficient for relating prey and temperature to growth, but it must be re-evaluated for other purposes.

There were several major discrepancies between model results and observed values. First, the model underestimated the January abundance in 1996 (Figure 5), and the reason for this is unclear. Second, the model overestimated the degree of adult entrainment in early years and underestimated the degree of adult entrainment in later years (Figure 7). This lack of sufficient interannual variation in simulated adult entrainment may be attributable to the simulated movement of adults being too similar among years (Figure 10f); the center of distribution for simulated adults was less variable across years than the center of distribution for fish caught by the fall MWT. Another possible explanation is that adult entrainment mortality was switched on or off depending on the sign of Middle River flow, whereas analyses showed that the actual entrainment rate probably increases with the magnitude of southward flow toward the diversion facilities (Kimmerer 2011).

A third discrepancy between the model and the data was that movement in the model tended to put juveniles and adults in water that was too saline during late summer to winter (Figure 9). This could reflect a conceptual difference between the data-based and modeled density-weighted salinities. Because the model tracks each individual, an individual-weighted salinity is unbiased by any sampling error. In contrast, the sampling programs catch relatively few fish and do not sample all salinities equally. However, even with the sampling issues, the results suggest that the model is contributing to this discrepancy. Two possibilities are that (1) behavioral movement of juveniles in the model may be too slow to react to local salinity changes (Supplement D) and (2) the starting locations from the PTM were too far seaward. Some of the movement of late larval Delta Smelt in nature likely is a result of both transport (which we assumed) and behavior as the fish gain competence to direct their movements.

Finally, the model showed wide fluctuations in the fraction of age-1 individuals that were mature and the number of eggs per entering age-1 individual (Figure 8) from small changes in mean length (Figure 6). Although we lack data with which to compare these results, these differences among years seemed larger than what we would expect to see in the real population. We partially address this in Rose et al. (2013) by including length-dependent maturation as one of the alternative baselines.

We performed many comparisons of model results with the available data (Table 2), but we did not perform the classical model calibration and validation comparisons and we did not compare model predictions with commonly used abundance indices from the monitoring programs. We focused on using most of the data for calibration and often in a pattern-matching mode (Grimm et al. 2005) rather than a more traditional comparison of predicted values versus observed data (Stow et al. 2009); thus, some of the consistency between the model and the data was a result of calibration. While Delta Smelt abundance indices from the various monitoring programs have been used extensively as indicators of population abundance and survival (Bennett 2005; Maunder and Deriso 2011; Miller et al. 2012), we found the model–data comparisons using the indices to be uninformative due to the sensitivity of the indices to calculation details, such as the months included and the gear selectivity (e.g., Newman 2008).

Our analysis of model results and data for 1995–2005 clearly illustrated why it has been difficult to ascribe the Delta Smelt's decline to a single causative factor, either over the long term or as part of the recent 2002 decline. Interannual variation in λ (Figure 12) was due to a combination of the effects of temperature, salinity, larval growth, hydrodynamics, and growth of juveniles in the prior year affecting the movement, growth, mortality, and reproduction in various combinations of life stages. Small changes in mean length of young-of-the-year fish from the previous year (Figure 6) were amplified into large effects on egg production (Figure 8), and temperature affected the timing of spawning and the subsequent growth of larvae.

We did not include an explicit representation of turbidity in the final version of our model. Turbidity affects spatial distributions (Feyrer et al. 2007; Nobriga et al. 2008) and larval growth (Baskerville-Bridges et al. 2004) of Delta Smelt. We initially included turbidity (estimated from extensive Secchi depth measurements) in the same way that we included salinity and temperature (Supplement A). Turbidity showed the expected decrease during the modeled time period, which is part of a longer-term downward trend (Kimmerer 2004; Wright and Schoellhamer 2004; Nobriga et al. 2008). However, we had no basis upon which to determine relationships between turbidity and growth rate or mortality rate, and thus we could have simulated a decline in the Delta Smelt population based solely on the lower turbidity in the later years. Because we predicted the decrease in Delta Smelt without turbidity (i.e., based on hydrodynamics, temperature, salinity, and zooplankton), a turbidity effect was not included.

In the companion paper (Rose et al. 2013), we further explore Delta Smelt dynamics using the individual-based model. We configure alternative baseline simulations and perform a simulation experiment to further refine our understanding of bad versus good years for Delta Smelt. We vary salinity, temperature, zooplankton, hydrodynamics, and eggs per entering age-1 individual between the best year (1998) and the worst year (2001) to systematically quantify the effects of each factor and their combined effects on λ. We then show that these results are robust to alternative baseline configurations.

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REFERENCES

Baskerville-Bridges, B., J. C. Lindberg, and S. I. Doroshov. 2004. The effect of light intensity, alga concentration, and prey density on the feeding behavior of Delta Smelt larvae. Pages 219–227 *in* F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. 2010 pelagic organism decline work plan and synthesis of results. Interagency Ecological Program for the San Francisco Estuary, California Department of Water Resources, Sacramento.

Bennett, W. A. 2005. Critical assessment of the Delta Smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science [online serial] 3(2):article 1.

Brown, L. R., W. Kimmerer, and R. Brown. 2009. Managing water to protect fish: a review of California's environmental water account, 2001–2005. Environmental Management 43:357–368.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723–734.

Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, B. Herbold, and P. Smith. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? North American Journal of Fisheries Management 29:1253–1270.

Grimm, V., U. Berger, F. Bastiansen, S. Eliassen, V. Ginot, J. Giske, J. Goss-Custard, T. Grand, S. K. Heinz, G. Huse, A. Huth, J. U. Jepsen, C. Jørgensen, W. M. Mooij, B. Müller, G. Pe'er, C. Piou, S. F. Railsback, A. M. Robbins, M. M. Robbins, E. Rossmanith, N. Rüger, E. Strand, S. Souissi, R. A. Stillman, R. Vabø, U. Visser, and D. L. DeAngelis. 2006. A standard protocol for describing individual-based and agent-based models. Ecological Modelling 198:115–126.

Grimm, V., E. Revilla, U. Berger, F. Jeltsch, W. M. Mooij, S. F. Railsback, H. H. Thulke, J. Weiner, T. Wiegand, and D. L. DeAngelis. 2005. Pattern-oriented modeling of agent-based complex systems: lessons from ecology. Science 310:987–991.

Gross, E. S., M. L. MacWilliams, C. D. Holleman, and T. A. Hervier. 2010. Particle tracking model testing and applications report. Report to the Interagency Ecological Program for the San Francisco Estuary, California Department of Water Resources, Sacramento.

Hanson, P. C., T. B. Johnson, D. E. Schindler, and J. F. Kitchell. 1997. Fish bioenergetics 3.0 software for Windows®. University of Wisconsin, Sea Grant Institute, Technical Report WISCU-T-97-001, Madison.

Hilborn, R. 2007. Reinterpreting the state of fisheries and their management. Ecosystems 10:1362–1369.

Hollibaugh, J. T., editor. 1996. San Francisco Bay: the ecosystem. American Association for the Advancement of Science, San Francisco.

Humston, R., J. S. Ault, M. Lutcavage, and D. B. Olson. 2000. Schooling and migration of large pelagic fishes relative to environmental cues. Fisheries Oceanography 9:136–146.

Humston, R., D. B. Olson, and J. S. Ault. 2004. Behavioral assumptions in models of fish movement and their influence on population dynamics. Transactions of the American Fisheries Society 133:1304–1328.

Kimmerer, W. J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science [online serial] 2(1):article 1.

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to entrainment in water diversions in the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] 6(2):article 2.

Kimmerer, W. J. 2011. Modeling Delta Smelt losses at the south Delta export facilities. San Francisco Estuary and Watershed Science [online serial] 9(1):article 5.

Kimmerer, W. J., S. R. Avent, S. M. Bollens, F. Feyrer, L. F. Grimaldo, P. B. Moyle, M. Nobriga, and T. Visintainer. 2005. Variability in length–weight relationships used to estimate biomass of estuarine fish from survey data. Transactions of the American Fisheries Society 134:481–495.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32:375–389.

Kimmerer, W. J., and M. L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento–San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science [online serial] 6(1):article 4.

Lantry, B. F., and D. J. Stewart. 1993. Ecological energetics of Rainbow Smelt in the Laurentian Great Lakes: an interlake comparison. Transactions of the American Fisheries Society 122:951–976.

Lott, J. 1998. Feeding habits of juvenile and adult Delta Smelt from the Sacramento–San Joaquin River Estuary. Interagency Ecological Program Newsletter 11(1):14–19.

Lund, J. R., E. Hanak, W. E. Fleenor, W. A. Bennett, R. E. Howitt, J. F. Mount, and P. B. Moyle. 2010. Comparing futures for the Sacramento–San Joaquin Delta. University of California Press, Berkeley.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417–1430.

Maunder, M. N., and R. B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to Delta Smelt (*Hypomesus transpacificus*). Canadian Journal of Fisheries and Aquatic Sciences 68:1285–1306.

McCann, K., and B. Shuter. 1997. Bioenergetics of life history strategies and the comparative allometry of reproduction. Canadian Journal of Fisheries and Aquatic Sciences 54:1289–1298.

McGranahan, G., D. Balk, and B. Anderson. 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization 19:17–37.

Miller, A. 2002. Particle tracking model verification and calibration. Pages 2.1–2.25 *in* M. Mierzwa, editor. Methodology for flow and salinity estimates in the Sacramento–San Joaquin Delta and Suisun marsh. California Department of Water Resources, Office of State Water Project Planning, 23rd Annual Progress Report, Sacramento. Available: modeling.water.ca.gov/delta/reports/annrpt/2002/2002Ch2.pdf. (November 2012).

Miller, W. J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of Delta Smelt by state and federal water diversions from the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] 9(1):article 4.

Miller, W. J., B. F. J. Manly, D. D. Murphy, D. Fullerton, and R. R. Ramey. 2012. An investigation of factors affecting the decline of Delta Smelt (*Hypomesus transpacificus*) in the Sacramento–San Joaquin Estuary. Reviews in Fisheries Science 20:1–19.

Moyle, P. B. 2002. Inland fishes of California, revised and expanded. University of California Press, Berkeley.

Moyle, P. B., B. Herbold, D. E. Stevens, and L. W. Miller. 1992. Life history and status of Delta Smelt in the Sacramento–San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67–77.

Myers, R. A., and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280–283.

Newman, K. B. 2008. Sample design-based methodology for estimating Delta Smelt abundance. San Francisco Estuary and Watershed Science [online serial] 6(3):article 3.

Ney, J. J. 1993. Bioenergetics modeling today: growing pains on the cutting edge. Transactions of the American Fisheries Society 122:736–748.

Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. The modification of an estuary. Science 231:567–573.

Nichols, F. H., J. K. Thompson, and L. E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis:* II. displacement of a former community. Marine Ecology Progress Series 66:95–101.

Nobriga, M. L. 2002. Larval Delta Smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149–164.

Nobriga, M. L., T. R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-term trends in summertime habitat suitability for Delta Smelt (*Hypomesus transpacificus*). San Francisco Estuary and Watershed Science [online serial] 6(1):article 1.

NRC (National Research Council). 2010. A scientific assessment of alternatives for reducing water management effects on threatened and endangered fishes in California's Bay–Delta. National Academies Press, Washington, D.C.

NRC (National Research Council). 2012. Sustainable water and environmental management in the California Bay–Delta. National Academies Press, Washington, D.C.

Rose, K. A. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10:367–385.

Rose, K. A., A. T. Adamack, C. A. Murphy, S. E. Sable, S. E. Kolesar, J. K. Craig, D. L. Breitburg, P. Thomas, M. H. Brouwer, C. F. Cerco, and S. Diamond. 2009. Does hypoxia have population-level effects on coastal fish? musings from the virtual world. Journal of Experimental Marine Biology and Ecology 381(Supplement):188–203.

Rose, K. A., W. J. Kimmerer, K. P. Edwards, and W. A. Bennett. 2013. Individual-based modeling of Delta Smelt population dynamics in the upper San Francisco Estuary: II. Alternative baselines and good versus bad years. Transactions of the American Fisheries Society 142:1260–1272.

Scheffer, M., J. M. Baveco, D. L. DeAngelis, K. A. Rose, and E. H. van Nes. 1995. Super-individuals: a simple solution for modelling large populations on an individual basis. Ecological Modelling 80:161–170.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32:270–277.

Sommer, T., F. Mejia, M. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The spawning migration of Delta Smelt in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science [online serial] 9(2):article 2.

Stow, C. A., J. Jolliff, D. J. McGillicuddy Jr., S. C. Doney, J. I. Allen, M. A. M. Friedrichs, K. A. Rose, and P. Wallhead. 2009. Skill assessment for coupled biological/physical models of marine systems. Journal of Marine Systems 76:4–15.

Thomson, J. R., W. J. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431–1448.

Tyler, J. A., and K. A. Rose. 1994. Individual variability and spatial heterogeneity in fish population models. Reviews in Fish Biology and Fisheries 4:91–123.

Vörösmarty, C. J., P. Green, J. Salisbury, and R. B. Lammers. 2000. Global water resources: vulnerability from climate change and population growth. Science 289:284–288.

Wilbur, R. J. 2000. Validation of dispersion using the particle tracking model in the Sacramento–San Joaquin Delta. Master's thesis. University of California, Davis. Available in condensed form: modeling.water.ca.gov/delta/reports/annrpt/2001/2001Ch4.pdf. (November 2012).

Wilensky, U., and W. Rand. 2007. Making models match: replicating an agent-based model. Journal of Artificial Societies and Social Simulation [online serial] 10(4):2. Available: jasss.soc.surrey.ac.uk/10/4/2.html. (November 2012).

Winder, M., and A. D. Jassby. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary. Estuaries and Coasts 34:675–690.

Winemiller, K. O., and K. A. Rose. 1992. Patterns of life-history diversification in North American fishes: implications for population regulation. Canadian Journal of Fisheries and Aquatic Sciences 49:2196–2218.

Worm, B., R. Hilborn, J. K. Baum, T. A. Branch, J. S. Collie, C. Costello, M. J. Fogarty, E. A. Fulton, J. A. Hutchings, S. Jennings, O. P. Jensen, H. K. Lotze, P. M. Mace, T. R. McClanahan, C. Minto, S. R. Palumbi, A. M. Parma, D. Ricard, A. A. Rosenberg, R. Watson, and D. Zeller. 2009. Rebuilding global fisheries. Science 325:578–585.

Wright, S. A., and D. H. Schoellhamer. 2004. Trends in the sediment yield of the Sacramento River, California, 1957–2001. San Francisco Estuary and Watershed Science [online serial] 2(2):article 2.

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Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: II. Alternative Baselines and Good versus Bad Years

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ARTICLE

Individual-Based Modeling of Delta Smelt Population Dynamics in the Upper San Francisco Estuary: II. Alternative Baselines and Good versus Bad Years

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Abstract

We used a previously described individual-based population model to further explore the population dynamics of Delta Smelt *Hypomesus transpacificus* in the upper San Francisco Estuary. We formulated four alternative baseline configurations of the model and used a factorial design to systematically isolate the effects of factors that determined a good versus bad year. The alternative baseline conditions were obtained by substituting different assumptions about growth, maturity, and mortality into the original baseline configuration. In the simulation experiment, we varied five factors by setting each value to its 1998 (best year) or 2001 (worst year) value: salinity, temperature, zooplankton densities, hydrodynamics, and eggs per age-1 individual at spawning. Although some of the alternative baselines resulted in lower January abundances, estimated finite population growth rates were very similar for all versions. The simulation experiment showed that juvenile growth in the winter prior to spawning (i.e., eggs per age-1 individual) was the most important single factor in making 2001 a bad year, although no single factor alone was sufficient to fully account for the poor conditions in 2001 relative to 1998. Temperature played an important secondary role, and hydrodynamics played a more minor role. The results of the simulation experiment were robust, as similar results were obtained under the four alternative baselines. We compare our results with previous modeling and statistical analyses of the long-term monitoring data; we also discuss some implications of our results for Delta Smelt management and suggest future directions for analyses.

The Delta Smelt *Hypomesus transpacificus* resides only in the San Francisco Estuary and is listed as threatened under the U.S. Endangered Species Act and as endangered under the California Endangered Species Act. Abundance of Delta Smelt started to decline in the 1980s, and a sharp decrease starting in 2001 led to a series of management actions that were intended to benefit the species but that also involved reducing the water available to be diverted for irrigation and water supply (NRC

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2012). The State Water Project and the Central Valley Project have exported an average of 30% of the freshwater flowing into the estuary during 1960–2000, with the percentage generally increasing through time and exceeding 60% in some years and seasons (Kimmerer 2004). The State Water Project facility provides drinking water for over 23 million Californians; combined, the two diversion facilities fuel an estimated $\$25 \times 10^9$ annual agricultural economy (Grimaldo et al. 2009).

A suite of factors has been identified as important in contributing to the decline of Delta Smelt. These factors include entrainment by water diversion facilities (Kimmerer 2008, 2011; Miller 2011), contaminant effects (Kuivila and Moon 2004; Connon et al. 2009; Brooks et al. 2012), shifts in the zooplankton (prey) community (Nobriga 2002; Feyrer et al. 2003; Winder and Jassby 2011), and changes in physical habitat (Feyrer et al. 2007; Nobriga et al. 2008; Kimmerer et al. 2009). The role of these factors in contributing to the Delta Smelt's decline has been examined by using statistical analysis of long-term field data (Mac Nally et al. 2010; Thomson et al. 2010; Miller et al. 2012) and population dynamics modeling (Maunder and Deriso 2011). These analyses have led to what many consider to be contradictory conclusions about the relative importance of various factors in affecting Delta Smelt population dynamics (NRC 2010; Kimmerer 2011; Miller 2011).

Determining the factors that affect Delta Smelt population dynamics is critical for formulating effective remediation actions. Remediation actions under the federal Endangered Species Act are termed "reasonable and prudent alternatives" (RPAs), and specific actions were proposed as part of the recent biological opinion for Delta Smelt (USFWS 2008) and were subsequently argued in court (NRC 2010). One RPA restricts water diversions during the winter to limit losses of Delta Smelt at the diversion facilities (Grimaldo et al. 2009; Kimmerer 2011). Another controversial RPA was designed to protect fall habitat by using reservoir releases to maintain the estuarine salinity field in certain spatial regions (NRC 2010). The high economic costs of these various management actions, coupled with uncertainty about how they may affect Delta Smelt population dynamics, have led to controversy (NRC 2012).

In a companion paper (Rose et al. 2013, this issue), we described an individual-based population model of Delta Smelt and used a historical baseline simulation for 1995–2005 to identify the factors leading to good and bad years for Delta Smelt. In the present paper, we extend the analysis of Rose et al. (2013) by formulating alternative baseline configurations of the model and by using a factorial design to systematically isolate the effects of factors that determined a good year versus a bad year. We formulated four alternative baseline conditions by substituting different assumptions about growth, maturity, and mortality into the baseline configuration. The four alternative baselines were (1) fixed larval growth instead of food-dependent larval growth, (2) size-dependent mortality instead of stage-dependent mortality, (3) density-dependent mortality instead of density-independent mortality, and (4) length-dependent maturity rather than a length threshold for maturity. Each of these assumptions was important to baseline dynamics, and each was uncertain. Our earlier identification of good and bad years was from the historical simulation, and the effects of some factors can be confounded by the autocorrelation that is inherent in a historical simulation. Here, we follow up with a designed simulation experiment in which we systematically varied the factors that are potentially important in determining good and bad years, and we further show the robustness of the simulation experiment results by repeating the experiment for each of the four alternative baseline conditions. We demonstrate that the results obtained under the original baseline conditions were similar under the four alternative baseline conditions (i.e., robust), and we further refine the role of various factors in determining good and bad years.

MODEL DESCRIPTION

Overview

The individual-based model followed the reproduction, growth, mortality, and movement of super-individuals over their entire life cycle (from eggs to age 3) on the same spatial grid as the Delta Simulation Model (DSM2) hydrodynamics model that was developed by and is widely used by the California Department of Water Resources (baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm). A model year was defined as a water year: October 1 of the previous year to September 30 (e.g., model year 2001 extends from October 1, 2000, to September 30, 2001). The model is described in detail by Rose et al. (2013) and is briefly summarized here.

The spatial grid was one-dimensional, with 517 channels and 5 reservoirs (Figure 1 in Rose et al. 2013). The DSM2 hydrodynamics model provided hourly values of water velocities and flows into and out of channels and reservoirs, which were used as inputs to a particle tracking model (PTM) that was embedded in the Delta Smelt individual-based model. A second grid of 11 coarser boxes was overlaid onto the channel grid, and values of daily temperature, salinity, and biomass densities of six zooplankton groups in each box were used to assign values to each channel.

For each super-individual, we tracked a suite of traits, including life stage, growth rate, weight, length, age, diet, location on the grid, maturity status, fecundity, and worth. Worth was the number of identical population individuals represented by the super-individual. Rather than following every individual and removing them upon death, we followed a fixed number of super-individuals and decreased their worth in each time step to account for mortality (Scheffer et al. 1995). All computations were scaled from the super-individuals to the population by multiplying by the worth of the super-individuals. Individuals were assigned to five life stages: egg, yolk sac larva, postlarva, juvenile, and adult. Advancement to the next life stage (development) was based on (1) temperature for egg to yolk sac larva

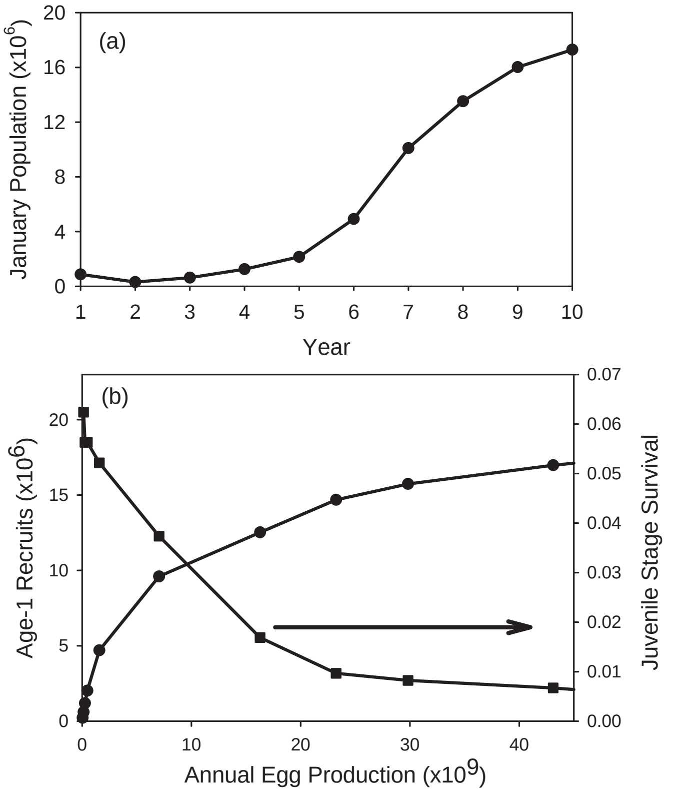

FIGURE 1. Simulated adult Delta Smelt abundance over time and juvenile survival from each year in a 15-year model run with artificially increasing egg production every year and density-dependent juvenile mortality: **(a)** adult abundance in January of each year and **(b)** age-1 recruits (circles, primary *y*-axis) and juvenile-stage survival (squares, secondary *y*-axis) versus annual egg production for each year.

to larva; (2) length for larva to postlarva to juvenile; and (3) date (January 1) for juvenile to age 1 and for age 1 to age 2.

Growth increments at each time step were determined from body weight, temperature, and the biomass densities of the six zooplankton groups (adult *Limnoithona* spp.; calanoid copepodids; other calanoid adults; adult *Eurytemora*; adult *Acanthocyclops vernalis*; and adult *Pseudodiaptomus*). Length was then increased if fish weight had increased sufficiently. Mortality was a stage-specific, fixed rate plus starvation (if the weight of an individual fell below 50% of the weight expected for its length) and entrainment by the two water diversion facilities. Movement on the spatial grid was by physical transport using a PTM for yolk sac larvae, larvae, and postlarvae; movement was behavioral (in response to salinity) for juveniles and adults. Development, reproduction, growth, and mortality were updated daily, whereas movement of eggs and all larval stages was updated hourly and movement of juveniles and adults was updated every 12 h.

Model Outputs

In our companion paper (Rose et al. 2013), we presented a detailed comparison between individual-based model outputs and data. We focus here on model predictions involving a small subset of those output variables. The major outputs presented for all simulations in this paper are the annual adult abundance in January and the annual finite population growth rate (λ). Annual adult abundance in January was computed as the summed worth of all individuals on January 1, including the young of the year that just became age 1 and the age-1 fish that just became age 2; it did not include age-2 fish that were just removed as they became age 3. We used the individual-based model output to estimate a Leslie age-based matrix model for each year to summarize the complicated individual-based model results with a single variable, λ. The value of λ was based on the detailed dynamics of the individual-based model but allowed for easier comparison among years. A 2×2 matrix model was estimated each year by computing the average maturity, fecundity, and age-specific survival rates and by using eigenvalue analysis to determine λ (see Supplement F in the online version of Rose et al. 2013).

Additional model outputs were used selectively to configure or confirm the alternative baselines and to provide some explanation for how the factors in the simulation experiment (described below) affected Delta Smelt. These outputs were defined and their calculations were described by Rose et al. (2013): stage-specific survival rates, recruitment (number of entering age-1 individuals on January 1), fraction of entering age-1 fish that were mature at the time of spawning, number of eggs per entering age-1 individual, percentage of individuals in and seaward of the Sacramento River–San Joaquin River confluence box at various times during the year (together with monthly average Sacramento–San Joaquin River Delta [hereafter, "Delta"] outflows), average daily fraction of larvae that were entrained in water diversions during a year, and annual fraction of adults that were entrained. Finally, we used a Lagrangian approach and reported the averaged values of *p* (proportion of maximum consumption) and temperature experienced by individuals for selected time periods in the simulations.

MODEL SIMULATIONS

Alternative Baselines

We configured four additional versions of the baseline model: fixed larval growth, size-dependent mortality, density-dependent mortality, and length-dependent maturity. We used the historical baseline simulation of 1995–2005 to help configure and calibrate the alternative baselines.

Fixed larval growth.—Model predictions of Delta Smelt abundance in the historical simulation were sensitive to larval growth rates, and we were uncertain about our formulation of larval feeding and bioenergetics. Use of a fixed duration for the larval stage eliminated variation in larval growth as a factor in year-to-year differences. Larval growth was fixed by specifying the larval duration in days rather than letting the transition from larva to juvenile be determined by length. We used the average larval duration over years from the baseline simulation (26 d) for all simulations with the fixed larval growth rate.

Size-dependent mortality.—Mortality in the original baseline version was constant within each stage but decreased with successive stages, so penalties in survival for slow growth occurred only through the delay in transition from larvae to postlarvae and from postlarvae to juveniles. Making mortality length dependent reflected the idea that vulnerability to predation mortality decreases with increasing size (Sogard 1997; Bailey and Duffy-Anderson 2010; Gislason et al. 2010), so that faster growth would increase cumulative survival regardless of how stage transitions were triggered. We assumed that mortality rate was a function of length (M_L; d^{-1}) for larvae through adults; we then fit the function to the constant stage-specific mortality rates from the baseline simulation, associating the rate with the midpoint length of each stage:

$$M_L = -0.034 + 0.165 \cdot L^{-0.322}. \tag{1}$$

We re-ran the 1995–2005 simulation and compared averaged annual stage-specific fractional survival rates between the baseline and the alternative with size-dependent mortality (Table 1) to confirm that this alternative produced mortality rates that were generally similar to those from the original baseline. Survival from yolk sac larva through age 2 was similar (4.4×10^{-5} in the baseline versus 3.5×10^{-5} under size-dependent mortality); juvenile survival increased (0.054 in the baseline; 0.073 under size-dependent mortality), and age-1 survival was approximately halved (0.092 in the baseline; 0.044 under size-dependent mortality).

Density-dependent mortality.—The original baseline version was set up as density independent because the recent Delta Smelt population is at such a low level that density-dependent effects seem unlikely. To allow for subsequent simulations at higher Delta Smelt densities, we included an alternative baseline with density-dependent mortality. The juvenile stage is the likely stage for density dependence based on general theory (Rothschild 1986; Cowan et al. 2000). Bennett (2005) and Maunder and Deriso (2011) found evidence for a density-dependent relationship between summer and fall Delta Smelt indices, and this relationship occurs in our simulation for the juvenile life stage. We assumed a multiplier of the juvenile daily mortality rate based on the normalized density of juveniles in each box on each day,

$$M' = M \cdot e^{3.0\left(\frac{D_t}{0.005}\right)}, \tag{2}$$

where D_t is the density of juveniles (number/m^3) and 0.005 is an average juvenile density (number/m^3).

We calibrated the value of 3.0 in equation (2) to obtain realistic maximum January adult abundances of about 20–25 million; the highest abundance estimate from the spring Kodiak trawl and fall midwater trawl (MWT) data during 1968–2006 was 24.3 million in 1981. We ran the model by repeating 1995 conditions from the historical simulation (high Delta Smelt survival) but with artificially increased egg production each year to generate a spawner–recruit curve under ever-increasing January adult abundances. We adjusted the multiplier in the exponent within equation (2) (final value = 3.0) until it generated a leveling off at high egg production that occurred roughly with about 20–25 million adults in January (Figure 1a). Juvenile-stage survival decreased with increasing population abundance from 0.06 to less than 0.01, resulting in a leveling off of age-1 recruits at about 20 million (Figure 1b). Abundance of age-1 recruits was similar to January adult abundance because most of the adults were age-1 individuals.

Length-dependent maturity.—The simple maturity rule (fish > 60 mm TL are mature) in the original baseline was substituted with a smoother, length-dependent maturity relationship (Figure 2). Model results were potentially sensitive to small

TABLE 1. Stage-specific durations (d) and survival (fraction) of Delta Smelt averaged over the 1995–2005 simulations for the original baseline and the alternative baseline that used size-dependent mortality.

	Duration (d)		Survival (fraction)	
Stage	Baseline	Size dependent	Baseline	Size dependent
Eggs	10.5	10.4	0.56	0.57
Yolk sac larvae	4.88	4.87	0.82	0.71
Larvae	26.3	26.0	0.23	0.25
Postlarvae	21.7	22.2	0.49	0.50
Juveniles	186	187	0.054	0.073
Age 1	365	365	0.092	0.044
Age 2	365	365	0.088	0.11

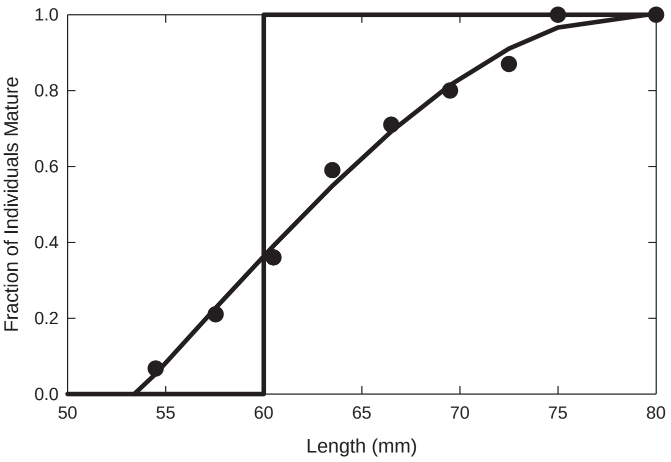

FIGURE 2. Fraction of Delta Smelt individuals that were mature as function of length for the baseline (60-mm cutoff) and the length-dependent maturity alternative. The points (circles) represent the fractions mature by length, estimated by assigning females (from the spring Kodiak trawl survey for 2002–2010) to 3-mm length bins and using ripe or spent individuals (condition codes 4–6) as mature.

changes in length of young of the year causing large changes in the mature fraction of individuals because typical lengths varied around 60 mm when maturity was determined. The relationship between fraction mature and fish length was fitted by allocating females that were sampled in the spring Kodiak trawl survey during 2002–2010 into 3-mm length bins and using ripe or spent individuals (codes 4–6) as mature. This resulted in an asymmetric relationship of fraction mature at around 60 mm (Figure 2). Use of other definitions for maturity resulted in relationships that were more symmetric at around 55–65 mm. We used the asymmetric relationship because it was justifiable based on the data and it provided a better test of model robustness.

Simulations under alternative baselines.—The 1995–2005 historical simulation with the original baseline (analyzed by Rose et al. 2013) was repeated with each of the four alternative baselines. We compared simulated January adult abundances and λ values among the original baseline and the four alternative versions. Results from a single simulation are presented. The individual-based model has stochastic aspects in assigning zooplankton biomass densities to channels and spawning temperatures to females, the *y* and *z* movements of the PTM, and the random component of behavioral movement. Because of the summing and averaging over many individuals and over time, population-level outputs (e.g., mean length at age, spatial distributions, and λ) varied by less than 5%—and often by less than 2%—among replicate simulations.

Good versus Bad Years

In this paper, we further explore the factors affecting the good year (1998) and bad year (2001) for Delta Smelt recruitment as identified in the analysis of the historical simulation (Rose et al. 2013). We performed a factorial simulation experiment to identify the conditions that caused the differences between water year 1998, which had the largest λ (2.45) within the baseline historical simulation, and water year 2001, which had the smallest λ (0.33) in the simulation. We varied five factors: salinity (*S*), temperature (*T*), zooplankton densities (*Z*), hydrodynamics (*H*), and eggs per entering age-1 individual (i.e., recruit) on January 1 (*E*). Each of these five factors was set to either its 1998 value or its 2001 value, resulting in a total of 32 (2^5) combinations.

Salinity.—Salinity affected the movement patterns of juveniles and adults and thus affected their spatial distribution and vulnerability to entrainment. The year 1998 was a high-outflow year, and salinities were very low for the modeled area from roughly March to August, after which salinity increased but remained below 5 psu (Figure 2b in Rose et al. 2013). Salinity in boxes down-estuary from the confluence was higher during the low-outflow year, 2001, than during 1998; this higher salinity occurred throughout 2001 except for a short period in March (Figure 2d in Rose et al. 2013). In the original baseline historical simulation, adults were located farther seaward with the salinity distribution in 1998. Average August outflow was 568 m^3/s in 1998 versus 90 m^3/s in 2001, and the percentage of adults that were in or seaward of the confluence box on September 1 was 97% during 1998 versus 67% during 2001 of the original baseline simulation (Figure 10e in Rose et al. 2013). The fraction of January adults that were entrained was 0.05 in 1998 versus 0.14 in 2001.

Temperature.—Temperature affected the initial date and duration of the spawning period; the egg and yolk sac development and mortality rates; and the bioenergetics (growth) of larvae, postlarvae, juveniles, and adults. When viewed systemwide, differences in temperature between 1998 and 2001 were not obvious (Figure 2a, c in Rose et al. 2013). More detailed analysis of the historical simulation using the average temperature experienced by model individuals showed two major differences between 1998 and 2001: (1) warmer fall and winter at the beginning of the water year and (2) cooler and delayed warming in the spring. Fall 1997 and winter 1998 were warmer than fall 2000 and winter 2001. During October 1–December 30, juveniles experienced an average temperature of 15.9°C in 1997 versus 15.0°C in 2000. Mean temperature experienced by these individuals (which became adults after January 1) during February 27–June 7 (the spawning period) was 14.8°C in 1998 versus 16.4°C in 2001. The warming in the spring also occurred later in 1998, and the average day of spawning was April 28 in 1998 versus April 6 in 2001.

Zooplankton.—The effect of switching 1998 and 2001 zooplankton densities would seem to be the simplest to interpret because this factor only affected feeding rate and therefore growth rate; however, the use of multiple prey groups made interpretation difficult. Dominant prey groups in the annual diets of postlarval, juvenile, and adult Delta Smelt in the baseline simulation were other calanoid adults and adult *Pseudodiaptomus*. The differences between 1998 and 2001 in the biomass densities of these two key prey groups were complicated (see Figure 3c versus 4c and Figure 3f versus 4f in Rose et al. 2013). Although adult *Pseudodiaptomus* biomasses were generally higher during summer and fall in 1998 than in 2001, biomasses of other calanoid adults during summer and fall were higher in 2001 and biomass in the southwest Suisun Bay box during winter and spring was much higher in 2001. Biomass densities of the other zooplankton groups also showed complicated differences. For example, the biomass density of adult *A. vernalis* was higher (and occurred at high levels for a longer period) in the Suisun Marsh box during 1998, but adult *Eurytemora* biomass density was higher in the southern Delta and eastern Delta boxes during 2001 (see Figure 3d versus 4d and Figure 3e versus 4e in Rose et al. 2013).

We relied on the *p*-value from the bioenergetics model to infer prey availability. The *p*-value reflects prey availability scaled for maximum consumption rate, which also depends on temperature. The historical simulation using the original baseline version showed that average *p*-values experienced by juveniles during the faster fall–winter growth (October 1–December 30) was 0.76 in 1997–1998 versus 0.68 in 2000–2001. This difference, in combination with warmer temperatures, led to longer recruits

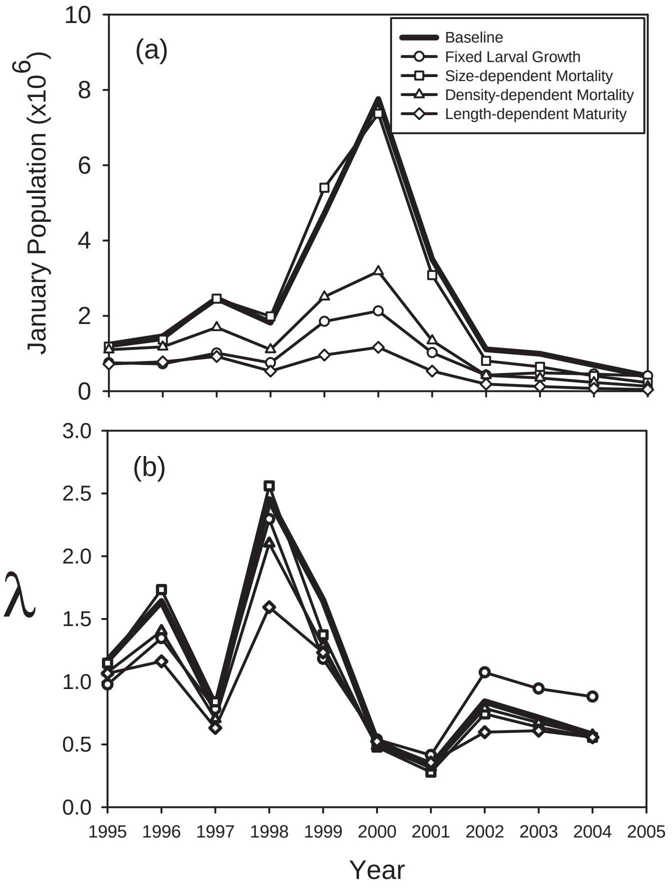

FIGURE 3. Simulated **(a)** annual adult Delta Smelt abundance in January and **(b)** finite population growth rate (λ; fraction per year), 1995–2005, for the original baseline simulation and the four alternative baseline simulations. The values of λ were determined by using an age-based Leslie matrix model applied to individual-based model output for each year. No value for 2005 is possible because the simulations ended on September 30, 2005; information through December 31, 2005, would be needed to estimate the matrix model for 2005.

on January 1 in 1998 than in 2001 (mean TL = 61.4 mm versus 56.5 mm). Averaged *p*-values in 1998 were also somewhat higher during the summer growth period (April 18–October 1) for young of the year (0.89 in 1998 versus 0.84 in 2001), although by October the mean lengths of young of the year were only slightly greater in 1998 than in 2001 (54 mm versus 52 mm).

Hydrodynamics.—Hydrodynamics affected the entrainment of yolk sac larvae, larvae, and postlarvae via the PTM; the entrainment of juveniles and adults; and the starting locations of new juveniles by determining the transport of larval life stages. Average May outflow was 1,922 m^3/s in 1998 versus 273 m^3/s in 2001, and the percentage of postlarvae that were in or seaward of the confluence box after transport (June 24) was 84% in 1998 versus 24% in 2001. Almost no larvae were predicted to be entrained during 1998, whereas the daily average entrainment loss was 1.2% in 2001.

Eggs per age-1 individual.—Unlike the other factors, which had readily available values for 1998 and 2001, the number of eggs per age-1 individual required additional calculations in the model to achieve 1998 or 2001 values in the factorial simulation experiment. The number of eggs per age-1 fish reflected growth that occurred in the fall and winter leading up to spawning. In the original historical simulation, the mean length of young of the year on October 1 was somewhat greater in 1997 (starting value for 1998) than in 2000 (54.0 mm versus 52.0 mm) due to the more favorable summer conditions in 1997 than in 2000. This small difference was amplified by warmer temperature and higher prey densities in the fall and winter of 1997, resulting in a mean length of 61.4 mm on January 1, 1998, versus 56.5 mm on January 1, 2001. These lengths straddled the 60-mm maturity cutoff, and whereas 72% of entering age-1 individuals were mature in 1998, only 15% of entering age-1 fish were mature in 2001 of the historical baseline simulation. Thus, although there were fewer recruits on January 1, 1998, than on January 1, 2001 (0.159×10^7 versus 0.258×10^7), the number of mature age-1 female spawners was greater in 1998 (0.287×10^6 versus 0.1105×10^6) and egg production was about 1.5 times higher in 1998 (0.942×10^9 versus 0.641×10^9).

In the historical baseline simulation, the average number of eggs per age-1 individual was 491.8 for 1998 versus 89.3 for 2001. We did not explicitly simulate the previous year's conditions for the simulation experiment, in which either 1998 or 2001 conditions were repeated year after year. Rather, we adjusted the fecundity of entering age-1 individuals each year when we projected spawning so that the total projected number of eggs divided by the number of simulated entering age-1 individuals would be either 491.8 or 89.3.

Simulations in the good year versus bad year experiment.—Simulations were for 15 years, with 4 years of spin-up using 1999 conditions as in the baseline simulations, followed by 11 years of 1 of the 32 combinations of 1998 or 2001 conditions repeated every year. We used the two extreme years because they provided the best contrast for separating out the effects of multiple factors and thus for identifying which factors were most important in determining year-class strength. Eleven years of repeated conditions were simulated in order to ensure that we had the long-term (equilibrium) population responses to the specified conditions; shorter simulations could be affected by initial conditions and still reflect aspects of the transient solutions. We refer to the 32 combinations by using the letters of the factors that were set to 2001 values (i.e., *S* for salinity, *T* for temperature, *Z* for zooplankton, *H* for hydrodynamics, and *E* for eggs per entering age-1 individual). For example, in the simulation labeled "*EH*," eggs per age-1 fish and hydrodynamics were set at 2001 values, while salinity, temperature, and zooplankton were set at 1998 values. We report λ averaged over years 10–14 of each 15-year simulation. As with the baseline simulations, results from a single simulation are presented because replicate simulations differed by less than 5% in their population-level outputs. Values of λ that were 25% and 50% higher than the

2001 value are shown for reference to aid in judging how close the other λ values were to the 2001 value.

Robustness

To confirm the robustness of results based on the original baseline, we also repeated all of the 32 simulation combinations under each of the four alternative baseline conditions. We only report the averaged λ for years 10–14 for four combinations (*ET*, *EH*, *ETH*, and *ETHS*) that resulted in low λ values to illustrate that the full set of combinations was robust to the alternative baselines. We focused on these four combinations because they resulted in low λ values near the 2001 value and because their robustness is particularly important, as they form the basis for identifying which factors determine how a good year differs from a bad year.

RESULTS

Alternative Baselines

The use of size-dependent mortality resulted in January adult abundances similar to those in the original baseline, while the alternative baselines with fixed larval growth, density-dependent mortality, and length-dependent maturity resulted in January abundances that were lower than those in the original baseline (Figure 3a). Lower peak abundances were expected for the density-dependent mortality version because juvenile survival was specified to decrease under high abundances. Larval growth (and therefore larval-stage survival) had an important influence on both good and bad years. Lower abundances under length-dependent maturity occurred because the maturity relationship was not symmetric around 60 mm (Figure 2) and thus would, on average, result in a lower fraction of young of the year becoming mature than was observed with the simple 60-mm rule in the original baseline.

Despite these differences in January abundances, λ values were very similar for all versions of the baseline, with the length-dependent maturity alternative differing the most from the original baseline (Figure 3b). Relatively high January adult abundance occurred in 2001 (Figure 3a), despite the lowest λ being observed in that year, because January abundance was related to conditions in the previous summer and fall and was not reflective of the spring and summer conditions in 2001. The high λ values during years prior to 2001 led to high January adult abundance in 2001. The temporal pattern in λ values for length-dependent maturity was the same as that for the original baseline, but values in all years were lower than baseline values, with the largest difference occurring in 1998 ($\lambda = 1.59$ for length-dependent maturity versus 2.45 for the original baseline). The original baseline and the four alternatives all identified 1998 as the best model year and 2001 as the worst model year for Delta Smelt.

Systematic Comparison of Best versus Worst Years

The intersimulation variability in λ values decreased and more combinations approached the 2001 value as the number of factors set to 2001 values increased (Figure 4). The percentage of combinations that resulted in λ values within 50% of the 2001 λ value increased from 0% when one factor was set to the 2001 value to 10% for two factors at 2001 values, 50% for three factors at 2001 values, and 60% for four factors at 2001 values. All but one of the combinations that generated a λ value within 50% of the 2001 value involved either eggs per age-1 individual or temperature being set at the 2001 value.

Juvenile growth in the fall prior to spawning (i.e., as reflected by the number of eggs per age-1 fish) was the most important single factor in making 2001 a bad year, although no single factor alone was sufficient to fully account for the poor conditions in 2001 relative to 1998 (Figure 4). Temperature (*T*) played an important secondary role (Figure 4, shaded circles), and hydrodynamics (*H*) played a more minor role; salinity (*S*) and zooplankton (*Z*) as single factors were unimportant. When one factor at a time was switched from 1998 to 2001 values (Figure 4, leftmost section), only eggs per age-1 fish (*E*) resulted in a λ value less than 1.0. The single factors *T* and *H* (each at the 2001 value) generated the second- and third-lowest λ values (1.1 and 1.5). As a single factor, *Z* (which determined

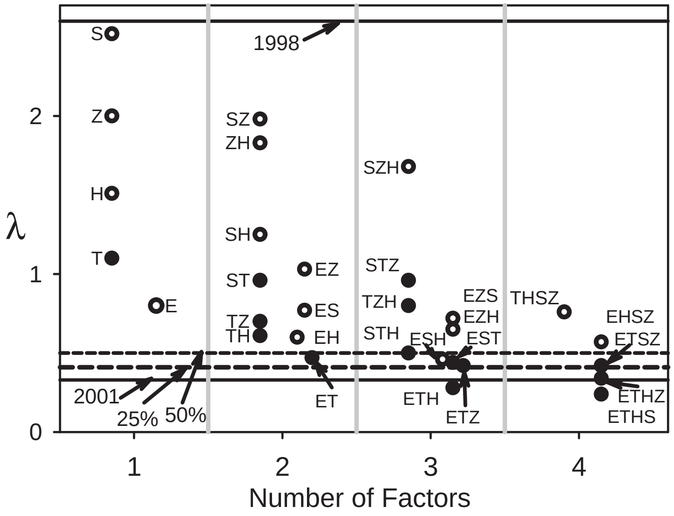

FIGURE 4. Contributions of five factors to differences between the best year (1998) and worst year (2001) for Delta Smelt. Each circle represents the mean finite population growth rate (λ) for years 10–14 of a 15-year simulation of repeated conditions for each factor (salinity [*S*], temperature [*T*], zooplankton [*Z*], hydrodynamics [*H*], and number of eggs per age-1 individual [*E*]) at either 1998 or 2001 values. Results are organized by the number of factors that were set to 2001 values (i.e., 1–4 factors; each combination code [e.g., "*STZ*"] lists the factors set at 2001 values); within each section, results with the number of eggs per age-1 individual at its 1998 value are shown on the left and results with that factor at its 2001 value are shown on the right. Shaded circles denote all combinations that included the 2001 temperature. The 1998 and 2001 values of λ are indicated by solid horizontal lines; the dotted horizontal lines represent λ values that are 25% and 50% higher than the 2001 value.

growth) generated a λ of 2.0, which was lower than the value for 1998 ($\lambda = 2.6$) but still much higher than the value for 2001 ($\lambda = 0.33$). When only *S* was set to the 2001 value, there was almost no effect on λ (2.52 versus 2.60).

All combinations of two factors set at 2001 values with eggs per age-1 individual at its higher 1998 value (left-side points in Figure 4, second section) generated λ values above 0.6; among these two-factor combinations, temperature and hydrodynamics at 2001 values together (*TH*) resulted in the lowest λ (0.61). The three lowest λ values all included 2001 temperature (Figure 4, shaded circles). The two-factor combinations that included the 2001 value for eggs per age-1 fish (right-side points in Figure 4, second section) resulted in λ values less than 1.0, and the *ET* and *EH* combinations produced λ values less than 0.6. Again, the lowest of these λ values was from the combination *ET* (Figure 4, shaded circle) and approached the λ value predicted for 2001 (0.47 versus 0.33).

Among the three-factor combinations set at 2001 values with eggs per age-1 individual set at the 1998 value (left-side points in Figure 4, third section), temperature and hydrodynamics were important. The highest λ (1.68) was predicted for the one combination that did not include 2001 temperature (*SZH*). The combinations with the three lowest λ values included the 2001 value for temperature (*STZ*, *TZH*, and *STH*; Figure 4, shaded circles); the two lowest of these λ values were from combinations that also included 2001 hydrodynamics ($\lambda = 0.8$ for *TZH* and 0.5 for *STH*).

When the number of eggs per age-1 fish was included as one of the three factors set at 2001 values (right-side points in Figure 4, third section), all λ values were less than 1.0. The combinations also including 2001 temperature (*ETH*, *ETZ*, and *EST*) generated the lowest λ values (0.28, 0.42, and 0.44, respectively), which were close to the λ value for 2001. The combinations that did not include 2001 temperature (Figure 4, open circles) generally had higher λ values (0.72 for *EZS* and 0.65 for *EZH*); the exception was *ESH*, which yielded a λ value (0.46) similar to those from the three combinations that included the 2001 temperature.

The number of eggs per age-1 individual and temperature continued to be very important in four-factor combinations. All four-factor combinations that included the 2001 value for eggs per age-1 fish (right-side points in Figure 4, fourth section) resulted in λ values less than 0.5, and those combinations that also included 2001 temperature (Figure 4, shaded circles) generated λ values that were close to the 2001 value. Of the four combinations that included the 2001 value for eggs per age-1 fish, the three combinations that also included 2001 temperature (*ETSZ*, *ETHZ*, and *ETHS*) all generated λ values less than 0.45, whereas the combination without temperature (*EHSZ*) generated the highest λ value (0.60). The remaining four-factor combination (*THSZ*; left-side point in Figure 4, fourth section), in which the number of eggs per age-1 individual was set at the 1998 value, generated the highest λ (0.85) observed for any four-factor combination.

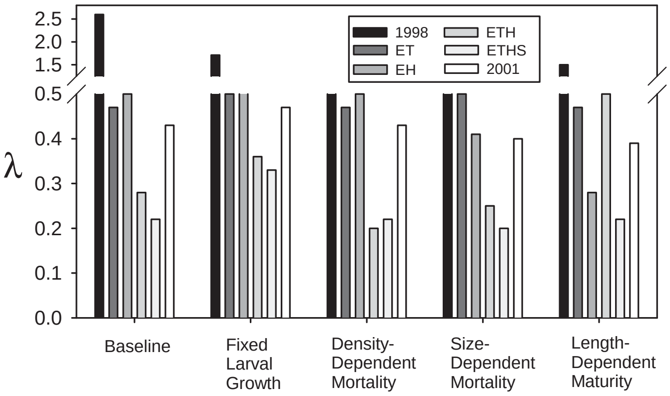

FIGURE 5. Averaged finite population growth rate (λ; years 10–14) of Delta Smelt under the four alternative baselines and the four factor combinations that resulted in low λ values near the value for 2001. Factors are salinity (*S*), temperature (*T*), zooplankton (*Z*), hydrodynamics (*H*), and number of eggs per age-1 individual (*E*); each combination code (e.g., "*ETH*") lists the factors that were set at 2001 values, and the remaining factors (i.e., with letters not shown) were set at 1998 values.

Robustness

The conditions leading to the good year (1998) were more sensitive to alternative baselines than the poor conditions leading to the bad year (2001; Figure 5). The four combinations (i.e., selected from Figure 4) that produced low λ values when set to their 2001 values under the original baseline generated similarly low λ values under the four alternative baselines. In contrast, the λ values varied more among the 1998 simulations. The alternative of density-dependent mortality produced the greatest reduction in λ for 1998 (λ decreased from 2.45 to 1.00). Larval growth and length-dependent maturity were also important in attaining the high λ predicted for 1998 in the original baseline. When larval growth was fixed at the overall average value (fixed duration), λ was reduced from 2.45 in the original baseline to 1.7; under length-based maturity, λ was reduced to 1.5. Size-dependent mortality was associated with the smallest reduction in the λ value for 1998 (λ decreased from 2.45 to 2.13).

DISCUSSION

Our analysis using a simulation experiment approach further clarified the relative influence of factors affecting Delta Smelt recruitment and population dynamics. In our companion paper (Rose et al. 2013), we compared conditions in 1998 with those in 2001 by using the 1995–2005 historical simulation. The five factors analyzed were inferred to be important in the historical simulation because their values differed, at least in some ways, between the best year and the worst year. In this paper, we systematically varied the five factors in a factorial simulation experiment to look for main and interaction effects. We moved away from the historical sequence of years and performed 15-year simulations with either 1998 or 2001 values repeated every year to allow the simulated population to reach a quasi-steady-state response. We also showed that our results, when viewed in a comparative mode, were generally robust to alternative versions of the baseline model.

Our results demonstrated that among the factors we examined, no single factor completely accounted for the difference between the high λ in the best year (1998) and the low λ in the worst year (2001). Growth of juveniles in the fall–winter, temperature, and hydrodynamics clearly had the strongest effects, but λ could not be brought down from its 1998 value to near its 2001 value without some combination of factors. Thus, our results support the growing consensus that no single factor explains the Delta Smelt decline that occurred during 1995–2005 (Bennett and Moyle 1996; Bennett 2005; Baxter et al. 2010; Thomson et al. 2010).

Although we have shown that growth conditions in fall–winter were an important factor, there are many ways to achieve the faster growth that was predicted for 1998 relative to 2001. The growth conditions in winter affected the lengths of entering age-1 fish on January 1, with a 1998 value of 60.2 mm versus a 2001 value of 58.8 mm, and consequently affected the fraction mature (0.55 versus 0.41) and the egg production per entering age-1 fish (502.6 versus 107.6). These values for 1998 and 2001 differ from those reported in Rose et al. (2013) because the present values are averaged from the repeated years in the simulation experiment, whereas in our other paper (Rose et al. 2013) we reported values for 1998 and 2001 within the historical simulation. The difference in predicted mean lengths between 1998 and 2001 was well within the range of observed interannual values (see Figure 6 in Rose et al. 2013). Our analysis did not, however, distinguish how juveniles attained greater lengths prior to becoming age 1 and spawning. We used 1998 and 2001 conditions, but other years can also generate similar differences in growth based on combinations of zooplankton conditions and temperature; essentially, any mechanism that allows new age-1 recruits to have a greater length prior to spawning would result in a high number of eggs per age-1 fish and would set the stage for a good year. This can be achieved via warmer winter temperature (as in 1998) or by higher zooplankton densities causing faster growth at any time from the previous summer through early spring. If zooplankton conditions are better at higher salinity (seaward), then hydrodynamics (via its effect on transport) or salinity could also produce faster growth by putting individuals in boxes with higher prey biomass densities. We did not systematically examine how temperature, zooplankton, hydrodynamics, and salinity during the growing season of the year before or during the winter–spring period could potentially combine to promote faster growth and larger spawners in the spring. Rather, we used the suite of conditions for 1998 and 2001 to contrast a good year with a bad year.

A second way to increase egg production without faster growth of spawners would be to increase young-of-the-year survival prior to spawning. Total egg production was calculated as the number of eggs per entering age-1 fish times the number of age-1 fish. Our results were robust to the size-dependent mortality and length-based maturity versions of the baseline, so the growth of adults affected the number of eggs per age-1 individual but not the abundance of age-1 fish. Higher Delta outflow at key times resulted in reduced entrainment, and hydrodynamics were consistently an important factor. Further analysis should explore spatial (box-scale) differences in mortality, which, if sufficient, could benefit the Delta Smelt via management manipulation of hydrodynamics and salinity, generating differences in starting age-1 abundances for spawning. We assumed that except for entrainment losses, mortality was stage dependent but not spatially variable.

Our results for the importance of food (zooplankton) are similar to those of Maunder and Deriso (2011), but we disagree about the roles of entrainment and density dependence. Maunder and Deriso (2011) used a stage-based life cycle model, and by introducing covariates into life stage survival (spawner–recruit) relationships, they determined that food abundance, temperature, predator abundance, and density dependence were the most important factors controlling the population dynamics of Delta Smelt. They further stated that there was some support for negative effects of water clarity and adult entrainment.

Our simulation experiment contrasting the best year versus the worst year agrees with the important role of temperature and zooplankton, but we did not examine the effects of predator abundance or water clarity. Maunder and Deriso (2011) used spring and summer zooplankton conditions: minimum *Eurytemora* and *Pseudodiaptomus* densities for April–June; average *Eurytemora* density for July; and average *Pseudodiaptomus* density for July–August. We found that fall, winter, and early spring growth was potentially important, at least for the comparison between 1998 and 2001. Maunder and Deriso (2011) examined a longer time period (1970–2006) that covered larger changes in the zooplankton community, and this could emphasize the importance of spring and summertime zooplankton relative to other factors, such as winter growth and its consequences for spring reproduction. We recommend that conditions in the winter and early spring and conditions from the year before be further evaluated for their potential to benefit Delta Smelt.

We disagree to some extent with Maunder and Deriso (2011) about the role of entrainment and density dependence. Examination of Figure 8 of Maunder and Deriso (2011) to assess the role of entrainment showed more agreement with our analysis than did their general statement of "some support for a negative relationship with . . . adult entrainment." They showed an approximately twofold increase in adults during 2002–2006 by eliminating entrainment. This agrees with our analysis, showing higher entrainment mortality during the same years as in our simulation; however, we would term their Figure 8 results as providing more than "some" support for a negative effect of adult entrainment. The Maunder and Deriso (2011) analysis covered a longer time period (1970–2006) than our analysis (1995–2005); thus, the role of covariates can differ and density dependence likely played a larger role at the earlier, higher abundance levels (see Bennett 2005). In addition, direct comparisons between the models are somewhat confounded because our analysis and the

Maunder and Deriso (2011) analysis shared some information, such as the entrainment estimates from Kimmerer (2008) and the spawner–recruit information from long-term monitoring.

Several statistical analyses of similar monitoring and covariate data as used by Maunder and Deriso (2011) also implicated various indicators of spring and summer zooplankton food availability as being important. Thomson et al. (2010) used Bayesian change point analysis to examine variation in the fall MWT index; Mac Nally et al. (2010) used multivariate autoregressive modeling to analyze the fall MWT index in a multispecies approach; and Miller et al. (2012) used Ricker spawner–recruit relationships to analyze the ratio of indices as survival indicators. These analyses all inferred that various combinations of water temperature, water clarity, zooplankton indicators, and entrainment were correlated to various degrees with the historical pattern in the Delta Smelt abundance indices.

Other assumptions that are inherent in our modeling merit further analyses as possible alternative versions of baseline conditions. The representation of predation on Delta Smelt was partially explored by using size-dependent mortality, but there are also temporal trends and spatial patterns to the key predators of Delta Smelt that could be important. Striped Bass *Morone saxatilis* and Largemouth Bass *Micropterus salmoides* show distinct spatial distributions within the San Francisco Estuary and have also exhibited recent temporal trends, with young Striped Bass declining and Largemouth Bass increasing (Nobriga and Feyrer 2007). Furthermore, exotic Mississippi Silversides *Menidia audens* are known to readily consume larval Delta Smelt and have increased substantially in recent years (Baerwald et al. 2012).

Another assumption worthy of investigation is that the Delta Smelt population in the individual-based model consisted of individuals that all exhibit the same migratory behavior. Limited field data indicate that there is partial or divergent migration (Secor 1999; Chapman et al. 2012) within the Delta Smelt population, with some individuals possibly remaining year-round in the Cache Slough region, which is located in the southwestern portion of our Sacramento River model box (Merz et al. 2011; Sommer et al. 2011). An alternative version of the baseline individual-based model could include some proportion of individuals that remain resident in some areas. Resident individuals, or individuals with reduced or altered migrations, could exhibit different growth because of spatial variation in temperature, zooplankton, and susceptibility to entrainment.

Our detailed individual-based approach is not commonly used to simulate the population dynamics of endangered fish species, although it can be adapted for use in the more traditional population viability analysis (PVA) and risk framework. The individual-based approach is increasingly being used to simulate fish population and community dynamics for purposes of answering ecological and fisheries management questions (DeAngelis and Mooij 2005). However, although the individual-based approach is usually mentioned in reviews of PVA approaches (e.g., Akçakaya and Sjögren-Gulve 2000; Morris et al. 2002; Petersen et al. 2008), the number of examples of its use specifically for PVA remains quite limited. Some commonly used general models apply an individual-based approach, but they employ a very simple representation of processes (e.g., Jarić et al. 2010). Examples in which a more mechanistic individual-based model approach was used include models of endangered birds (Letcher et al. 1998), turtles (Mazaris et al. 2005), and recruitment of Colorado Pikeminnow *Ptychocheilus lucius*. Using an individual-based approach very similar to our Delta Smelt modeling, Jager et al. (2001) analyzed the effects of habitat fragmentation by dams on the White Sturgeon *Acipenser transmontanus*, which is a species of concern and has been listed as endangered elsewhere. Population viability analysis usually involves many realizations of a modeled population trajectory to generate risk values. Our individual-based model cannot easily be used to perform thousands of simulations. A possible link to a PVA-type analysis of Delta Smelt would be to (1) use the individual-based model in a systematic way to create crude probability distributions for the elements of the Leslie matrix model (which can generate λ values with Monte Carlo simulation) or (2) use the coupled individual-based model and Leslie model to directly generate distributions of λ values. Once sets of λ values are obtained for a variety of environmental and biological conditions, they can be used in more traditional PVA projections of long-term persistence (see Morris et al. 2002).

Our analysis addresses several ongoing methodological issues in fish population dynamics: spatial dynamics in complex habitats, coupled biological–physical modeling, and recruitment and population dynamics at low abundances. The need for studies of long-term population dynamics to deal with spatial dynamics has recently been discussed (Giske et al. 1998; Struve et al. 2010), and approaches that deal with spatial variation explicitly are receiving greater attention (e.g., Kerr et al. 2010). Increasingly, fish-related management issues require an integrated approach that combines the physics of water with the biology of the fish and other biota (Shenton et al. 2012), and one method is the direct coupling of fine-scale hydrodynamics with long-term fish population dynamics (Buckley and Buckley 2010; Rose et al. 2010; Hinrichsen et al. 2011; Stock et al. 2011).

Our model expands on the classical particle tracking approach by simulating detailed biological processes, relatively complicated behavioral movement, and multiple generations. Our Delta Smelt model simulated growth, survival, reproduction, and movement of individual fish on the same spatial grid as the hydrodynamics, and the super-individual method allowed for 15-year simulations. Although PTMs are commonly embedded within hydrodynamics models (North et al. 2009; Hinrichsen et al. 2011), the PTMs typically do not include detailed descriptions of growth and reproduction. Rather, these studies usually invoke, at most, simple movement behavior as an addition to passive transport and are mostly used for short-term (<1 year) simulations (Miller 2007; Lett et al. 2009; Gallego 2011). However, a consequence of full life cycle modeling that includes juveniles and adults within a detailed spatial grid is that now we must simulate behavioral movement on relatively fine scales. Modeling behavioral movement is critical to ensure that individuals experience the appropriate conditions over time, but this remains a challenge (Watkins and Rose 2013). Delta Smelt movement patterns in our simulations were generally realistic but require further refinement.

Finally, much fish population modeling has focused on the effects of harvesting from high-number populations, whereas there is an increasing need to examine dynamics of fish populations at low abundances due to overharvest and in support of recovery plans for listed species (Keith and Hutchings 2012). The focus on harvesting leads to an emphasis on density-dependent mortality, often via the spawner–recruit relationship (Rose et al. 2001). Our approach differs from this by focusing on Delta Smelt population dynamics under density-independent conditions. We emphasized how individuals were transported through or navigated through their spatially complex and temporally varying habitat. Our analysis can be viewed as part of the broader idea of multiple factors within the match–mismatch theory of controls on young-of-the-year survival and therefore recruitment (Peck et al. 2012), coupled with the idea that adult bioenergetics are important for determining maturity and annual egg production (Neil et al. 1994; Rose et al. 2001). Because our model was density independent, all of the predicted variation in stage-specific survival rates was due to variation in how spatial distributions interacted with dynamic environmental conditions. Our results showed how the spatial and temporal positioning of all life stages each year (based on physical transport and salinity), combined with the pattern in daily water temperature and the amount of Delta outflow, affected the magnitude and location of egg production and the subsequent dynamic matching of larval and juveniles with their prey types, thus affecting recruitment success. However, even our modeling results were not simple to interpret, and therefore they also illustrate how spatially and temporally dynamic habitat can create complicated match–mismatch situations.

Delta Smelt have been at the center of escalating controversy in the San Francisco Estuary region for several decades (NRC 2010; Kimmerer 2011; Miller 2011). What initially arose as a conflict between water demands for export versus for the environment (including Delta Smelt) has metastasized as the number of ostensible factors behind the decline of Delta Smelt has grown (e.g., Mac Nally et al. 2010; Maunder and Deriso 2011; Miller et al. 2012). The conflict has now evolved into a complicated situation in which multiple factors operate in interactive ways and are continually being argued over in court (Delta Smelt Consolidated Cases 2010). Our results contribute to the growing number of examples showing that multiple factors affect aquatic ecosystems (Breitburg and Riedel 2005; Ormerod et al. 2010; Cloern and Jassby 2012) and that the search for a single factor controlling fish population dynamics is unlikely to be successful (e.g., Rose 2000; Krebs 2002; Hecky et al. 2010; Lindegren et al. 2011).

Our results to date suggest that management actions to benefit Delta Smelt must deal with multiple stressors that occur at different points in the life cycle. An increase in prey would induce relatively large responses in reproduction but may not be feasible. We showed that growth leading up to spawning was important for subsequent population growth; it remains to be seen whether it is possible to promote growth of Delta Smelt or higher young-of-the-year survival prior to spawning (fall–spring) via management actions. We also showed that no single factor can alone account for the differences between good and bad years and that promoting growth should be done in combination with other actions (if feasible) to (1) ensure good temperatures for summer growth and delayed spawning and (2) ensure sufficient outflow and avoidance of high entrainment (see results in Rose et al. 2013). Our results also demonstrate that expectations should be clearly stated, as most management actions are unlikely to generate large, immediate responses because the influence of stressors varies from year to year and because the reduction in a single stressor during any one year may be moderated by the conditions in other, non-manipulated stressors occurring in that year.

We envision two other areas for future analyses using the individual-based model. First, extending the model simulations for the periods before 1995 and after 2005 would allow for more comparisons and contrasts of good versus bad years to determine other combinations of factors that may be important; climate change scenarios should be included in these simulations to allow for future-looking comparisons. This would require use of the DSM2 hydrodynamic model or another hydrodynamic model and the development of synthetic temperature, salinity, and zooplankton data. Second, a more rigorous side-by-side comparison of the Maunder and Deriso (2011) model and our individual-based model would facilitate an understanding of the relative effects of key stressors on Delta Smelt population dynamics. The population dynamics and reasons for the decline of Delta Smelt are complex. However, complexity is not a reason to avoid rigorous quantitative analyses—indeed, it is perhaps the best reason to develop and compare alternative modeling approaches.

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REFERENCES

Akçakaya, H. R., and P. Sjögren-Gulve. 2000. Population viability analyses in conservation planning: an overview. Ecological Bulletins 48:9–21.

Baerwald, M. R., B. M. Schreier, G. Schumer, and B. May. 2012. Detection of threatened Delta Smelt in the gut contents of the invasive Mississippi Silverside in the San Francisco Estuary using TaqMan assays. Transactions of the American Fisheries Society 141:1600–1607.

Bailey, K. M., and J. T. Duffy-Anderson. 2010. Fish predation and mortality. Pages 322–329 *in* J. H. Steele, S. A. Thorpe, and K. K. Turekian, editors. Marine biology: a derivative of the encyclopedia of ocean sciences. Academic Press, San Diego, California.

Baxter, R., R. Breuer, L. Brown, L. Conroy, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer, and K. Souza. 2010. 2010 pelagic organism decline work plan and synthesis of results. Interagency Ecological Program for the San Francisco Estuary, California Department of Water Resources, Sacramento.

Bennett, W. A. 2005. Critical assessment of the Delta Smelt population in the San Francisco Estuary, California. San Francisco Estuary and Watershed Science [online serial] 3(2):article 1.

Bennett, W. A., and P. B. Moyle. 1996. Where have all the fishes gone? interactive factors producing fish declines in the Sacramento–San Joaquin Estuary. Pages 519–542 *in* J. T. Hollibaugh, editor. San Francisco Bay: the ecosystem. American Association for the Advancement of Science, San Francisco.

Breitburg, D. L., and G. F. Riedel. 2005. Multiple stressors in marine systems. Pages 167–182 *in* E. A. Norse and L. B. Crowder, editors. Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press, Washington, D.C.

Brooks, M. L., E. Fleishman, L. R. Brown, P. W. Lehman, I. Werner, N. Scholz, C. Mitchelmore, J. R. Lovvorn, M. L. Johnson, D. Schlenk, S. van Drunick, J. I. Drever, D. M. Stoms, A. E. Parker, and R. Dugdale. 2012. Life histories, salinity zones, and sublethal contributions of contaminants to pelagic fish declines illustrated with a case study of San Francisco Estuary, California, USA. Estuaries and Coasts 35:603–621.

Buckley, L. J., and L. B. Buckley. 2010. Toward linking ocean models to fish population dynamics. Progress in Oceanography 84:85–88.

Chapman, B. B., K. Hulthén, J. Brodersen, P. A. Nilsson, C. Skov, L. A. Hansson, and C. Brönmark. 2012. Partial migration in fishes: causes and consequences. Journal of Fish Biology 81:456–478.

Cloern, J. E., and A. D. Jassby. 2012. Drivers of change in estuarine-coastal ecosystems: discoveries from four decades of study in San Francisco Bay. Reviews of Geophysics 50:RG4001. DOI: 10.1029/2012RG000397.

Connon, R. E., J. Geist, J. Pfeiff, A. V. Loguinov, L. S. D'Abronzo, H. Wintz, C. D. Vulpe, and I. Werner. 2009. Linking mechanistic and behavioral responses to sublethal esfenvalerate exposure in the endangered Delta Smelt *Hypomesus transpacificus* (fam. Osmeridae). BMC Genomics [online serial] 10:608.DOI: 10.1186/1471-2164-10-608.

Cowan, J. H. Jr., K. A. Rose, and D. R. DeVries. 2000. Is density-dependent growth in young-of-the-year fishes a question of critical weight? Reviews in Fish Biology and Fisheries 10:61–89.

DeAngelis, D. L., and W. M. Mooij. 2005. Individual-based modeling of ecological and evolutionary processes. Annual Review of Ecology, Evolution, and Systematics 36:147–168.

Delta Smelt Consolidated Cases. 2010. F. Supp. 2d-2010 WL 2195960 at pp. 24, 26, 44. Eastern District of California.

Feyrer, F., B. Herbold, S. A. Matern, and P. B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277–288.

Feyrer, F., M. L. Nobriga, and T. R. Sommer. 2007. Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723–734.

Gallego, A. 2011. Biophysical models: an evolving tool in marine ecological research. Pages 279–290 *in* F. Jopp, H. Reuter, and B. Breckling, editors. Modelling complex ecological dynamics. Springer-Verlag, Berlin.

Giske, J., G. Huse, and Ø. Fiksen. 1998. Modelling spatial dynamics of fish. Reviews in Fish Biology and Fisheries 8:57–91.

Gislason, H., N. Daan, J. C. Rice, and J. G. Pope. 2010. Size, growth, temperature and the natural mortality of marine fish. Fish and Fisheries 11:149–158.

Grimaldo, L. F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. B. Moyle, B. Herbold, and P. Smith. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: can fish losses be managed? North American Journal of Fisheries Management 29:1253–1270.

Hecky, R. E., R. Mugidde, P. S. Ramlal, M. R. Talbot, and G. W. Kling. 2010. Multiple stressors cause rapid ecosystem change in Lake Victoria. Freshwater Biology 55(Supplement 1):19–42.

Hinrichsen, H. H., M. Dickey-Collas, M. Huret, M. A. Peck, and F. B. Vikebø. 2011. Evaluating the suitability of coupled biophysical models for fishery management. ICES Journal of Marine Science 68:1478–1487.

Jager, H. I., J. A. Chandler, K. B. Lepla, and W. Van Winkle. 2001. A theoretical study of river fragmentation by dams and its effects on White Sturgeon populations. Environmental Biology of Fishes 60:347–361.

Jarić, I., T. Ebenhard, and M. Lenhardt. 2010. Population viability analysis of the Danube sturgeon populations in a Vortex simulation model. Reviews in Fish Biology and Fisheries 20:219–237.

Keith, D. M., and J. A. Hutchings. 2012. Population dynamics of marine fishes at low abundance. Canadian Journal of Fisheries and Aquatic Sciences 69:1150–1163.

Kerr, L. A., S. X. Cadrin, and D. H. Secor. 2010. The role of spatial dynamics in the stability, resilience, and productivity of an estuarine fish population. Ecological Applications 20:497–507.

Kimmerer, W. J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science [online serial] 2(1):article 1.

Kimmerer, W. J. 2008. Losses of Sacramento River Chinook Salmon and Delta Smelt to entrainment in water diversions in the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] 6(2): article 2.

Kimmerer, W. J. 2011. Modeling Delta Smelt losses at the south Delta export facilities. San Francisco Estuary and Watershed Science [online serial] 9(1):article 5.

Kimmerer, W. J., E. S. Gross, and M. L. MacWilliams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32:375–389.

Kimmerer, W. J., and M. L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento–San Joaquin Delta using a particle tracking model. San Francisco Estuary and Watershed Science [online serial] 6(1):article 4.

Krebs, C. J. 2002. Two complementary paradigms for analysing population dynamics. Philosophical Transactions of the Royal Society of London B 357: 1211–1219.

Kuivila, K. M., and G. E. Moon. 2004. Potential exposure of larval and juvenile Delta Smelt to dissolved pesticides in the Sacramento–San Joaquin Delta, California. Pages 229–241 *in* F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi, editors. Early life history of fishes in the San Francisco Estuary and watershed. American Fisheries Society, Symposium 39, Bethesda, Maryland.

Letcher, B. H., J. A. Priddy, J. R. Walters, and L. B. Crowder. 1998. An individual-based, spatially explicit simulation model of the population dynamics of the endangered red-cockaded woodpecker, *Picoides borealis*. Biological Conservation 86:1–14.

Lett, C., K. A. Rose, and B. A. Megrey. 2009. Biophysical models. Pages 88–111 *in* D. Checkley, J. Alheit, Y. Oozeki, and C. Roy, editors. Climate change and small pelagic fish. Cambridge University Press, Cambridge, UK.

Lindegren, M., Ö. Östman, and A. Gårdmark. 2011. Interacting trophic forcing and the population dynamics of herring. Ecology 92:1407–1413.

Mac Nally, R., J. R. Thomson, W. J. Kimmerer, F. Feyrer, K. B. Newman, A. Sih, W. A. Bennett, L. Brown, E. Fleishman, S. D. Culberson, and G. Castillo. 2010. Analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417–1430.

Maunder, M. N., and R. B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to Delta Smelt (*Hypomesus transpacificus*). Canadian Journal of Fisheries and Aquatic Sciences 68:1285–1306.

Mazaris, A. D., Ø. Fiksen, and Y. G. Matsinos. 2005. Using an individual-based model for assessment of sea turtle population viability. Population Ecology 47:179–191.

Merz, J. E., S. Hamilton, P. S. Bergman, and B. Cavallo. 2011. Spatial perspective for Delta Smelt: a summary of contemporary survey data. California Fish and Game 97:164–189.

Miller, T. J. 2007. Contribution of individual-based coupled physical–biological models to understanding recruitment in marine fish populations. Marine Ecology Progress Series 347:127–138.

Miller, W. J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of Delta Smelt by state and federal water diversions from the Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] 9(1):article 4.

Miller, W. J., B. F. J. Manly, D. D. Murphy, D. Fullerton, and R. R. Ramey. 2012. An investigation of factors affecting the decline of Delta Smelt (*Hypomesus transpacificus*) in the Sacramento–San Joaquin Estuary. Reviews in Fisheries Science 20:1–19.

Morris, W. F., P. L. Bloch, B. R. Hudgens, L. C. Moyle, and J. R. Stinchcombe. 2002. Population viability analysis in endangered species recovery plans: past use and future improvements. Ecological Applications 12:708–712.

Neill, W. H., J. M. Miller, H. W. Van Der Veer, and K. O. Winemiller. 1994. Ecophysiology of marine fish recruitment: a conceptual framework for understanding interannual variability. Netherlands Journal of Sea Research 32:135–152.

Nobriga, M. L. 2002. Larval Delta Smelt diet composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149–164.

Nobriga, M. L., and F. Feyrer. 2007. Shallow-water piscivore–prey dynamics in California's Sacramento–San Joaquin Delta. San Francisco Estuary and Watershed Science [online serial] 5(2):article 4.

Nobriga, M. L., T. R. Sommer, F. Feyrer, and K. Fleming. 2008. Long-term trends in summertime habitat suitability for Delta Smelt (*Hypomesus transpacificus*). San Francisco Estuary and Watershed Science [online serial] 6(1):article 1.

North, E. W., A. Gallego, and P. Petitgas, editors. 2009. Manual of recommended practices for modelling physical–biological interactions during fish early life. ICES Cooperative Research Report 295.

NRC (National Research Council). 2010. A scientific assessment of alternatives for reducing water management effects on threatened and endangered fishes in California's Bay–Delta. National Academies Press, Washington, D.C.

NRC (National Research Council). 2012. Sustainable water and environmental management in the California Bay–Delta. National Academies Press, Washington, D.C.

Ormerod, S. J., M. Dobson, A. G. Hildrew, and C. R. Townsend. 2010. Multiple stressors in freshwater ecosystems. Freshwater Biology 55(Supplement 1): 1–4.

Peck, M. A., K. B. Huebert, and J. K. Llopiz. 2012. Intrinsic and extrinsic factors driving match–mismatch dynamics during the early life history of marine fishes. Advances in Ecological Research 47:177–302.

Petersen, J. H., D. L. DeAngelis, and C. P. Paukert. 2008. An overview of methods for developing bioenergetic and life history models for rare and endangered species. Transactions of the American Fisheries Society 137:244–253.

Rose, K. A. 2000. Why are quantitative relationships between environmental quality and fish populations so elusive? Ecological Applications 10:367–385.

Rose, K. A., J. I. Allen, Y. Artioli, M. Barange, J. Blackford, F. Carlotti, R. Cropp, U. Daewel, K. Edwards, K. Flynn, S. L. Hill, R. HilleRisLambers, G. Huse, S. Mackinson, B. Megrey, A. Moll, R. Rivkin, B. Salihoglu, C. Schrum, L. Shannon, Y.-J. Shin, S. L. Smith, C. Smith, C. Solidoro, M. St. John, and M. Zhou. 2010. End-to-end models for the analysis of marine ecosystems: challenges, issues, and next steps. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science [online serial] 2:115–130.

Rose, K. A., J. H. Cowan Jr., K. O. Winemiller, R. A. Myers, and R. Hilborn. 2001. Compensatory density dependence in fish populations: importance, controversy, understanding and prognosis. Fish and Fisheries 2:293–327.

Rose, K. A., W. J. Kimmerer, K. P. Edwards, and W. A. Bennett. 2013. Individual-based modeling of Delta Smelt population dynamics in the upper San Francisco Estuary: I. Model description and baseline results. Transactions of the American Fisheries Society 142:1238–1259.

Rothschild, B. J. 1986. Dynamics of marine fish populations. Harvard University Press, Cambridge, Massachusetts.

Scheffer, M., J. M. Baveco, D. L. DeAngelis, K. A. Rose, and E. H. van Nes. 1995. Super-individuals: a simple solution for modelling large populations on an individual basis. Ecological Modelling 80:161–170.

Secor, D. H. 1999. Specifying divergent migrations in the concept of stock: the contingent hypothesis. Fisheries Research 43:13–34.

Shenton, W., N. R. Bond, J. D. L. Yen, and R. Mac Nally. 2012. Putting the "ecology" into environmental flows: ecological dynamics and demographic modelling. Environmental Management 50:1–10.

Sogard, S. M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: a review. Bulletin of Marine Science 60:1129–1157.

Sommer, T., F. Mejia, M. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The spawning migration of Delta Smelt in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science [online serial] 9(2): article 2.

Stock, C. A., M. A. Alexander, N. A. Bond, K. Brander, W. W. L. Cheung, E. N. Curchitser, T. L. Delworth, J. P. Dunne, S. M. Griffies, M. A. Haltuch, J. A. Hare, A. B. Hollowed, P. Lehodey, S. A. Levin, J. S. Link, K. A. Rose, R. Rykaczewski, J. L. Sarmiento, R. J. Stouffer, F. B. Schwing, G. A. Vecchi, and F. E. Werner. 2011. On the use of IPCC-class models to assess the impact of climate on living marine resources. Progress in Oceanography 88:1–27.

Struve, J., K. Lorenzen, J. Blanchard, L. Börger, N. Bunnefeld, C. Edwards, C. Joaquín Hortal, A. MacCall, J. Matthiopoulos, B. Van Moorter, A. Ozgul, F. Royer, N. Singh, C. Yesson, and R. Bernard. 2010. Lost in space? Searching for directions in the spatial modelling of individuals, populations and species ranges. Biology Letters 6:575–578.

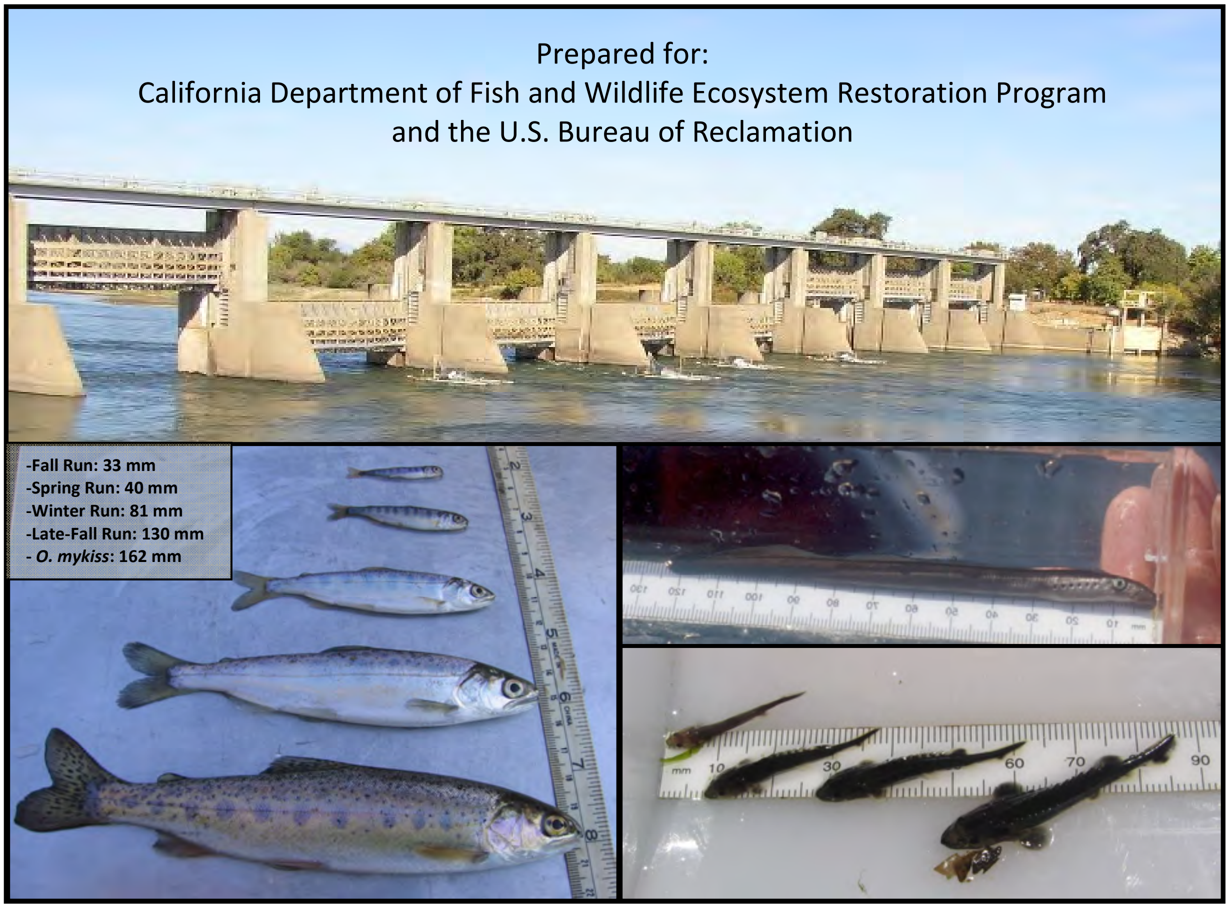
Thomson, J. R., W. J. Kimmerer, L. R. Brown, K. B. Newman, R. Mac Nally, W. A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431–1448.

USFWS (U.S. Fish and Wildlife Service). 2008. Biological opinion (BO) on the long-term operational criteria and plan (OCAP) for coordination of the Central Valley project and state water project. USFWS, California and Nevada Region, Sacramento, California.

Watkins, K. S., and K. A. Rose. 2013. Evaluating the performance of individual-based animal movement models in novel environments. Ecological Modelling 250:214–234.

Winder, M., and A. D. Jassby. 2011. Shifts in zooplankton community structure: implications for food web processes in the upper San Francisco Estuary. Estuaries and Coasts 34:675–690.

COMPENDIUM REPORT OF RED BLUFF DIVERSION DAM ROTARY TRAP JUVENILE ANADROMOUS FISH PRODUCTION INDICES FOR YEARS 2002-2012



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Compendium Report of Red Bluff Diversion Dam Rotary Trap Juvenile Anadromous Fish Production Indices for Years 2002-2012

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Abstract.— Fall, late-fall, spring, and winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and Steelhead/Rainbow trout (*Oncorhynchus mykiss*) spawn in the Sacramento River and tributaries in California's Central Valley upstream of Red Bluff Diversion Dam (RBDD) throughout the year. Sampling of juvenile anadromous fish at RBDD allows for year-round quantitative production and passage estimates of all runs of Chinook and *O. mykiss*. Incidental capture of Green Sturgeon (*Acipenser medirostris*) and various Lamprey species (*Lampetra spp. and Entosphenus tridentatus)* has occurred throughout juvenile Chinook monitoring activities since 1995. This compendium report addresses, in detail, juvenile anadromous fish monitoring activities at RBDD for the period April 4, 2002 through September 30, 2013.

Sampling was conducted along a transect using four 8-foot diameter rotary-screw traps attached via aircraft cables directly to RBDD. Trap efficiency (i.e., the proportion of the juvenile salmonid population passing RBDD captured by traps) was modeled with percent of river discharge sampled (%*Q*) to develop a simple least-squares regression equation. Chinook and *O. mykiss* passage were estimated by employing the trap efficiency model. The ratio of fry to pre-smolt/smolts passing RBDD was variable among years. Therefore, juvenile passage was standardized to determine juvenile production by estimating a fry-equivalent Juvenile Production Index (JPI) for among-year comparisons. Catch per unit volume (CPUV) was used as an index of relative abundance for Green Sturgeon and Lamprey species. Abiotic data collected or calculated throughout sample efforts included: water temperature, flow, turbidity, and moon illuminosity (fraction of moon illuminated). The abiotic variables were analyzed to determine if relationships existed throughout the migration periods of the anadromous species.

A trap efficiency model developed in 2000 to estimate fish passage demonstrated improved correlation between 2002 and 2013 with the addition of 85 mark-recapture trials. The model's *r*-squared value improved greatly with the addition of numerous mark-recapture trials that used wild fry size-class salmon over a variety of river discharge levels. Total passage estimates including annual effort values with 90% confidence intervals (CI) are presented, by brood year, for each run of Chinook. Fry and pre-smolt/smolt Chinook passage estimates with 90% CI's are summarized annually by run in Appendix 1. Comparisons of relative variation within and between runs of Chinook were performed by calculating Coefficients of Variation (CV). Fall Chinook annual total passage estimates ranged between 6,627,261 and 27,736,868 juveniles for brood years 2002-2012 ($\bar{y}$ = 14,774,923, CV = 46.2%). On average, fall Chinook passage was composed of 74% fry and 26% pre-smolt/smolt size-class fish (SD = 10.3). Late-fall

Chinook annual total passage estimates ranged between 91,995 and 2,559,519 juveniles for brood years 2002-2012 (ȳ = 447,711, CV = 159.9%). On average, late-fall Chinook passage was composed of 38% fry and 62% pre-smolt/smolt size-class fish (SD = 22.5). Winter Chinook annual total passage estimates ranged between 848,976 and 8,363,106 juveniles for brood years 2002-2012 (ȳ = 3,763,362, CV = 73.2%). On average, winter Chinook passage was composed of 80% fry and 20% pre-smolt/smolt size-class fish (SD = 11.2). Spring Chinook annual total passage estimates for spring Chinook ranged between 158,966 and 626,925 juveniles for brood years 2002-2012 (ȳ = 364,508, CV = 45.0%). On average, spring Chinook passage was composed of 54% fry and 46% pre-smolt/smolt size-class fish (SD = 20.0). Annual total passage estimates for *O. mykiss* ranged between 56,798 and 151,694 juveniles for calendar years 2002-2012 (ȳ = 116,272, CV = 25.7).

A significant relationship between the estimated number of adult females and fry-equivalent fall Chinook production estimates was detected ($r^2 = 0.53$, df = 10, $P = 0.01$). Recruits per female were calculated and ranged from 89 to 1,515 (ȳ = 749). Egg-to-fry survival estimates averaged 13.9% for fall Chinook. A significant relationship between estimated number of females and fry-equivalent late-fall Chinook production estimates was detected ($r^2 = 0.67$, df = 10, $P = 0.002$). Recruits per female were calculated and ranged from 47 to 243 (ȳ = 131). Egg-to-fry survival estimates averaged 2.8% for late-fall Chinook. A significant relationship between estimated number of females and fry-equivalent winter Chinook production estimates was detected ($r^2 = 0.90$, df = 10, $P < 0.001$). Recruits per female were calculated and ranged from 846 to 2,351 (ȳ = 1,349). Egg-to-fry survival estimates averaged 26.4% for winter Chinook. No significant relationship between estimated number of females and fry-equivalent spring Chinook production estimates was detected ($r^2 = 0.00$, df = 10, $P = 0.971$). Recruits per female were calculated and ranged from 1,112 to 8,592 (ȳ = 3,122). Egg-to-fry survival estimates averaged 61.5% for spring Chinook. Spring Chinook juvenile to adult correlation values appear unreasonable and well outside those found for other runs and from other studies.

Catch of Green Sturgeon was highly variable, not normally distributed and ranged between 0 and 3,701 per year (median = 193). Catch was primarily composed of recently emerged, post-exogenous feeding larvae. The 10-year median capture total length averaged 27.3 mm (SD = 0.8). Green Sturgeon annual CPUV was typically very low and ranged from 0.0 to 20.1 fish/ac-ft (ȳ = 2.5 fish/ac-ft, SD = 5.9). Data were positively skewed and median annual CPUV was 0.8 fish/ac-ft.

Lamprey species sampled included adult and juvenile Pacific Lamprey (*Entosphenus tridentatus*) and to a much lesser extent River Lamprey (*Lampetra ayresi*) and Pacific Brook Lamprey (*Lampetra pacifica*). Unidentified lamprey ammocoetes and Pacific Lamprey composed 99.8% of all captures, 24% and 75%, respectively. River Lamprey and Pacific Brook Lamprey composed the remaining 0.2%, combined. Lamprey captures occurred throughout the year between October and September. Lamprey ammocoete annual relative abundance ranged from 3.6 to 11.7 fish/ac-ft (ȳ = 6.8 fish/ac-ft, SD = 2.6). Overall, these data were normally distributed as median annual CPUV was 6.5 fish/ac-ft, similar to the mean value. Pacific Lamprey macropthalmia annual relative abundance was generally higher than ammocoete relative abundance and ranged from 2.1 to 112.8 fish/ac-ft ($\bar{y}$ = 41.0 fish/ac-ft, SD = 34.7). Overall, Pacific Lamprey data was slightly positively skewed and median CPUV was 34.1 fish/ac-ft.

Tabular summaries of the abiotic conditions encountered during each annual capture period were summarized for each run of salmon, *O. mykiss*, Green Sturgeon and Lamprey species. The range of temperatures experienced by Chinook fry and pre-smolt/smolts in the last 11 years of passage at RBDD have been within the optimal range of temperature tolerances for juvenile Chinook survival. Green Sturgeon have likely benefitted from temperature management efforts aimed at winter Chinook spawning and production, albeit less comprehensively. Lamprey species have also likely benefitted from temperature management as temperatures for early life stages of Lamprey in the mainstem Sacramento River appear to have been, on average, optimal in the last 11 years.

The relationship between river discharge, turbidity, and fish passage are complex in the Upper Sacramento River where ocean and stream-type Chinook of various size-classes (i.e., runs, life stages and ages) migrate daily throughout the year. Fish passage increases often coincided with an increase in turbidity which were sampled more effectively than increases in river discharge. A positive bias of fish passage estimates may result if the peak turbidity event was sampled following an un-sampled peak flow event. The importance of the first storm event of the fall or winter period cannot be overstated. Smolt passage and juvenile Lamprey passage increase exponentially and fry passage can be significant during fall storm events.

Rotary trap passage data indicated fry size-class winter Chinook exhibit decreased nocturnal passage levels during and around the full moon phase in the fall. Pre-smolt/smolt winter Chinook appeared less influenced by nighttime light levels and much more influenced by changes in discharge levels. Spring, fall and late-fall Chinook fry exhibited varying degrees of decreased passage during full moon periods, albeit storms and related hydrologic influx dominated peak migration periods.

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Introduction

The United States Fish and Wildlife Service (USFWS) has conducted direct monitoring of juvenile Chinook salmon (*Oncorhynchus tshawytscha)* passage at Red Bluff Diversion Dam (RBDD; RM 243) on the Sacramento River, CA since 1994 (Johnson and Martin 1997). Martin et al. (2001) developed quantitative methodologies for indexing juvenile Chinook passage using rotary-screw traps to assess the impacts of the RBDD Research Pumping Plant. Absolute abundance (production and passage) estimates were needed to determine the level of impact from the entrainment of salmonids and other fish community populations through experimental 'fish friendly' Archimedes and internal helical pumps (Borthwick and Corwin 2001). The original project objectives were met by 2000 and funding of the project was discontinued.

In 2001, funding was secured through a CALFED Bay-Delta Program grant for three years of annual monitoring operations to determine the effects of restoration activities in the Upper Sacramento River aimed primarily at winter Chinook[1] salmon. Through various amendments, extensions, and grant approvals by the CALFED Ecosystem Restoration Program, the State of California based funding source lasted until 2008. At this point, the State of California defaulted on their funding agreement and internal USFWS funding sources through the Central Valley Project Improvement Act (CVPIA) bridged the gap for a period of time until State funding was restored. The US Bureau of Reclamation, the primary proponent of the Central Valley Project (CVP) of which this project provides monitoring and abundance trend information, has funded this project since 2010 due to regulatory requirements contained within the Biological Opinion for the Operations and Criteria Plan for the CVP (NMFS 2009).

Protection, restoration, and enhancement of anadromous fish populations in the Sacramento River and its tributaries is an important element of the CVPIA Section 3402. The CVPIA has a specific goal to double populations of anadromous fishes in the Central Valley of California. Juvenile salmonid production monitoring is an important component authorized under Section 3406 (b)(16) of CVPIA and has funded many anadromous fish restoration actions which were outlined in the CVPIA Anadromous Fisheries Restoration Program (AFRP) Working Paper (USFWS 1995), and Draft Restoration Plan (USFWS 1997; finalized in 2001).

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[1] The National Marine Fisheries Service first listed Winter-run Chinook salmon as threatened under the emergency listing procedures for the ESA (16 U.S.C.R. 1531-1543) on August 4, 1989 (54 FR 32085). A proposed rule to add winter Chinook salmon to the list of threatened species beyond expiration of the emergency rule was published by the NMFS on March 20, 1990 (55 FR 10260). Winter Chinook salmon were formally added to the list of federally threatened species by final rule on November 5, 1990 (55 FR 46515), and they were listed as a federally endangered species on January 4, 1994 (59 FR 440). Critical habitat for winter Chinook salmon has been designated from Keswick Dam (RM 302) to the Golden Gate Bridge (58 FR 33212; June 16, 1993). Winter Chinook salmon have been listed as endangered under the CESA since September 22, 1989 (California Code of Regulations, Title XIV, Section 670.5). Their federal endangered status was reaffirmed in June 2005 (70 FR 37160).

Since 2002, the USFWS rotary trap winter Chinook juvenile production indices (JPI's) have primarily been used in support of production estimates generated from carcass survey derived adult escapement data using the National Oceanic and Atmospheric Administration's (NOAA) Juvenile Production Estimate Model. Martin et al. (2001) stated that RBDD was an ideal location to monitor juvenile winter Chinook production because (1) the spawning grounds occur almost exclusively above RBDD (Vogel and Marine 1991; Snider et al. 1997, USFWS 2011), (2) multiple traps could be attached to the dam and sample simultaneously across a transect, and (3) operation of the dam could control channel morphology and hydrological characteristics of the sampling area providing for consistent sampling conditions for purposes of measuring juvenile fish passage.

Fall, late-fall, spring, and winter-run Chinook salmon and Steelhead/Rainbow Trout (*Oncorhynchus mykiss*) spawn in the Sacramento River and tributaries upstream of RBDD throughout the year resulting in year-round juvenile salmonid passage (Moyle 2002). Sampling of juvenile anadromous fish at RBDD allows for year-round quantitative production and passage estimates of all runs of Chinook and Steelhead/Rainbow trout. Timing and abundance data have been provided in real-time for fishery and water operations management purposes of the CVP since 2004[2]. Since 2009, confidence intervals, indicating uncertainty in weekly passage estimates, have been included in real-time bi-weekly reports to allow better management of available water resources and to reduce impact of CVP operations on both federal Endangered Species Act (ESA) listed and non-listed salmonid stocks. Currently, Sacramento River winter Chinook are ESA listed as endangered. Central Valley spring Chinook and Central Valley Steelhead (hereafter *O. mykiss)* are listed as threatened within the Central Valley Endangered Species Unit.

Incidental capture of Green Sturgeon (*Acipenser medirostris*) and various Lamprey species (*Lampetra spp. and Entosphenus sp.)* has occurred throughout juvenile Chinook monitoring activities at RBDD since 1995 (Gaines and Martin 2002). Although rotary traps were designed to capture outmigrating salmonid smolts, data from the incidental capture of sturgeon and lamprey species has become increasingly relied upon for basic life-history information and as a measure of relative abundance and species trend data. The Southern distinct population segment of the North American Green Sturgeon was proposed for listing as threatened under the Federal ESA on April 7, 2006 (FR 17757) which then took effect June 6, 2006. Pacific Lamprey (*Entosphenus tridentatus*) are thought to be extirpated from at least 55% of their historical habitat and have been recognized by the USFWS as a species needing a comprehensive plan to conserve and restore these fish (Goodman and Reid 2012).

The objectives of this compendium report are to: (1) summarize the estimated abundance of all four runs of Chinook salmon and *O. mykiss* passing RBDD for brood

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[2] Real-time biweekly reports located for download at: http://www.fws.gov/redbluff/rbdd_biweekly_final.html

years (BY) 2002 through 2012, (2) estimate annual relative abundance of Green Sturgeon and Lamprey species production for eleven consecutive years, (3) define temporal patterns of abundance for all anadromous species passing RBDD, (4) correlate juvenile salmon production with adult salmon escapement estimates, (5) perform exploratory data analyses of potential environmental covariates driving juvenile fish migration trends, and (6) describe various life-history attributes of anadromous juvenile fish produced in the Upper Sacramento River as determined through long-term monitoring efforts at RBDD.

This compendium report addresses, in detail, our juvenile anadromous fish monitoring activities at RBDD for the period April 4, 2002 through September 30, 2013. This report includes JPI's and relative abundance estimates for the 2002-2012 brood year emigration periods and will be submitted to the California Department of Fish and Wildlife to comply with contractual reporting requirements for Ecosystem Restoration Program Grant Agreement Number P0685507 and to the US Bureau of Reclamation who funded in part or in full the surveys from years 2008 through 2013 (Interagency Agreement No. R10PG20172).

Study Area

The Sacramento River originates in Northern California near Mt. Shasta from the springs of Mt. Eddy (Hallock et al. 1961). It flows south through 370 miles of the state draining numerous slopes of the coast, Klamath, Cascade, and Sierra Nevada ranges and eventually reaches the Pacific Ocean via San Francisco Bay (Figure 1). Shasta Dam and its associated downstream flow regulating structure, Keswick Dam, have formed a complete barrier to upstream anadromous fish passage since 1943 (Moffett 1949). The 59-river mile (RM) reach between Keswick Dam (RM 302) and RBDD (RM 243) supports areas of intact riparian vegetation and largely remains unobstructed. Within this reach, several major tributaries to the Sacramento upstream of RBDD support various Chinook salmon spawning populations. These include Clear Creek and Cottonwood Creek (including Beegum Creek) on the west side of the Sacramento River and Cow, Bear, Battle and Payne's Creek on the east side (Figure 1). Below RBDD, the river encounters greater anthropogenic impacts as it flows south to the Sacramento-San Joaquin Delta. Impacts include, but are not limited to, channelization, water diversion, agricultural and municipal run-off, and loss of associated riparian vegetation.

RBDD is located approximately 1.8 miles southeast of the city of Red Bluff, California (Figure 1). The dam is 740-feet (ft) wide and composed of eleven, 60-ft wide fixed-wheel gates. Between gates are concrete piers 8-ft in width. The USBR's dam operators were able to raise the RBDD gates allowing for run-of-the-river conditions or lower them to impound and divert river flows into the Tehama-Colusa and Corning canals. USBR operators generally raised the RBDD gates from September 16 through May 14 and lowered them May 15 through September 15 during the years 2002-2008. As of the spring of 2009, the RBDD gates were no longer lowered prior to June 15 and were raised by the end of August or earlier (NMFS 2009) in an effort to reduce the impact to spring Chinook salmon and Green Sturgeon. Since the fall of 2011, the RBDD gates have been left in the raised position allowing unobstructed upstream and downstream passage of adult and juvenile anadromous fish. The RBDD has been replaced by a permanent pumping plant upstream of the RBDD and the facilities have been relinquished to the Tehama Colusa Canal Authority as of spring 2012. Mothballing of the RBDD infrastructure was scheduled to occur in 2014.

Methods

Sampling Gear.—Sampling was conducted along a transect using four 8-ft diameter rotary-screw traps (E.G. Solutions® Corvallis, Oregon) attached via aircraft cables directly to RBDD. The horizontal placement of rotary traps across the transect varied throughout the study but generally sampled in the river-margin (east and west river-margins) and mid-channel habitats simultaneously (Figure 2). Rotary traps were positioned within these *spatial zones* unless sampling equipment failed, river depths were insufficient (< 4-ft), or river hydrology restricted our ability to sample with all traps (water velocity < 2.0 ft/s).

Sampling Regimes.—In general, rotary traps sampled continuously throughout 24-hour periods and samples were processed once daily. During periods of high fish abundance, elevated river flows, or heavy debris loads, traps were sampled multiple times per day, continuously, or at randomly pre-selected periods to reduce incidental mortality. When abundance of Chinook was very high, sub-sampling protocols were implemented to reduce listed species take and incidental mortality in accordance with National Marine Fisheries Service (NMFS) Section 10(a)(1)(A) research permit terms and conditions. The specific sub-sampling protocol implemented was contingent upon the number of Chinook captured or the probability of successfully sampling various river conditions. Initially, rotary trap cones were structurally modified to only sample one-half of the normal volume of water entering the cones (Gaines and Poytress 2004). If further reductions in capture were needed, the number of traps sampled was reduced from four to three. During storm events and associated elevated river discharge levels, each 24-hour sampling period was divided into four or six non-overlapping strata and one or two strata was randomly selected for sampling (Martin et al 2001). Estimates were extrapolated to un-sampled strata by dividing catch by the strata-selection probability (i.e., $P = 0.25$ or 0.17). If further reductions in effort were needed or river conditions were intolerable, sampling was discontinued or not conducted. When days or weeks were unable to be sampled, mean daily passage estimates were imputed for missed days based on weekly or monthly mean daily estimates (i.e., interpolated).

Data Collection.—All fish captured were anesthetized, identified to species, and enumerated with fork lengths (FL) measured to the nearest millimeter (mm). When capture of Chinook juveniles exceeded approximately 200 fish/trap, a random sub-sample of the catch to include approximately 100 individuals was measured, with all additional fish being enumerated and recorded. Chinook salmon race was assigned using length-at-date criteria developed by Greene[3] (1992). Juvenile salmon were assigned to a fry or pre-smolt/smolt life stage based on their fork length. Individuals ≤ 45 mm were classified as fry, and individuals ≥ 46 mm were classified as pre-smolt/smolts.

O. mykiss between 80 and 200-mm fork length were weighed to the nearest gram using a digital scale with a stated accuracy of +/- 0.5 grams. This size range was selected to reduce the influence of measurement error for fish lengths <80 mm (Pope and Kruse 2007). Additionally, state and federal permit regulations restricted the use of anesthetizing agents for fish that may be consumed by the public (i.e., fish >200mm). *O. mykiss* were visually assessed and assigned a life-stage rating based on morphological features following protocols developed by the Comprehensive Assessment and Monitoring Program (CAMP; USFWS 1997). Furthermore, *O. mykiss* annual weight-length regression coefficients were generated by transforming (Log_{10}) the weight and fork length data to create a linear regression equation:

$$\mathrm{Log}_{10}(\text{Total Weight}) = b(\mathrm{Log}_{10}\text{Fork Length}) + a$$

Confidence interval overlap between the annual slope coefficients was used to test if the annual *O. mykiss* growth rates between years were significantly different (Pope and Kruse 2007). If the 95% confidence intervals around any two slope coefficients did not overlap they were considered significantly different.

Green Sturgeon and Lamprey species were measured for total length (TL) to the nearest mm. Identification of Green Sturgeon larvae was possible based on meristics for individuals > 46 mm TL and assumed for all individuals <46 mm[4]. Lamprey species were identified to the genus level during the ammocoete stage and described as ammocoetes. Adult and macropthalmia (eyed juveniles) were identified to the genus and species level using dentition patterns, specifically by the number of inner lateral horny plates on the sucking disk (Moyle 2002).

Trap Effort. Data quantifying effort by each rotary trap were collected at each trap sampling and included the length of time each trap sampled (expressed as sample weight with 1440 minutes equal to 1.0 for 24-hour samples), water velocity immediately in front of the cone at a depth of 2-ft, and depth of cone “opening” submerged. Water velocity was measured using a General Oceanic® Model 2030 flowmeter. These data collectively were used to calculate the estimated volume of water sampled by traps (X_i)

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[3] Generated by Sheila Greene, California Department of Water Resources, Environmental Services Office, Sacramento (May 8, 1992) from a table developed by Frank Fisher, California Department of Fish and Game, Inland Fisheries Branch, Red Bluff (revised February 2, 1992). Fork lengths with overlapping run assignments were placed with the latter spawning run.

[4] To confirm the identification of larval sturgeon, samples were transferred to UC Davis to be grown-out between 1996 and 1997 (Gaines and Martin 2002) and annual subsamples of larvae were sent to UC Davis for genetic analyses between 2003 and 2012 (Israel et al 2004, Israel and May 2010). To date, all samples have been confirmed to be Green Sturgeon.

in acre-feet (ac-ft). Trap effort data were then standardized to a sample weight of 1.0 for within- and between-day comparisons. Individual (X_i) data were summed for the number of traps operating within a 24-hour sample period to estimate daily water volume sampled (X_d). The percent river volume sampled by traps (%Q_d) was estimated as the ratio of river volume sampled (X_d) to total river volume passing RBDD in acre-feet. River volume (Q_d) was obtained from the United States Geological Survey gauging station at Bend Bridge at RM 258 (USGS site no. 11377100, http://waterdata.usgs.gov/usa/nwis/uv?site_no=11377100). Daily river volume at RBDD was adjusted from Bend Bridge river flows by subtracting daily RBDD diversions, when applicable.

Sampling Effort.— Annual rotary trap sampling effort was quantified by assigning a value of 1.00 to a sample consisting of four, 8-ft diameter rotary-screw traps sampling 24 hours daily, three hundred and sixty-five days a year. Annual values <1.00 represent occasions where less than four traps were sampling, traps were structurally modified to sample only one-half the normal volume of water, or when less than the entire year were sampled. Annual passage estimate effort was calculated by summing the total number of days passage was estimated, based on 3 or 4 traps sampling (minimum required to generate passage estimate; Martin et al. 2001), and divided by the sum of the annual total number of days sampled plus the number of days unsampled.

Mark-Recapture Trials.— Chinook collected as part of daily samples were marked with bismark brown staining solution (Mundie and Traber 1983) prepared at a concentration of 21.0 mg/L of water. Fish were stained for a period of 45-50 minutes, removed, and allowed to recover in fresh water. Marked fish were held for 6-24 hours before being released 2.5-miles upstream from RBDD after official sunset. Recapture of marked fish was recorded for up to five days after release. Trap efficiency was calculated based on the proportion of recaptures to total fish released (i.e., mark-recapture trials). Trials were conducted as fish numbers and staffing levels allowed under a variety of river discharge levels and trap effort combinations.

Trap Efficiency Modeling.— To develop a trap efficiency model, mark-recapture trials were conducted as noted above. Estimated trap efficiency (i.e., the proportion of the juvenile population passing RBDD captured by traps; $\hat{T}_d$) was modeled with %Q to develop a simple least-squares regression equation (eq. 5). The equation (slope and intercept) was then used to calculate daily trap efficiencies based on daily estimated river volume sampled. Each successive year of mark-recapture trials were added annually to the original trap efficiency model developed by Martin et al. (2001) on July 1 of each year.

Daily Passage Estimates ($\hat{P}_d$).—The following procedures and formulae were used to derive daily and weekly estimates of total numbers of unmarked Chinook and *O. mykiss* passing RBDD. We defined C_{di} as catch at trap i (i = 1,…,t) on day d (d = 1,…,n), and X_{di} as volume sampled at trap *i* (*i* = 1,…*t*) on day *d* (*d* = 1,…*n*). Daily salmonid catch and water volume sampled were expressed as:

1. $$C_d = \sum_{i=1}^{t} C_{di}$$

and,

2. $$X_d = \sum_{i=1}^{t} X_{di}$$

The *%Q* was estimated from the ratio of water volume sampled (X_d) to river discharge (Q_d) on day *d*.

3. $$\%\hat{Q}_d = \frac{X_d}{Q_d}$$

Total salmonid passage was estimated on day *d* (*d* = 1,…,*n*) by

4. $$\hat{P}_d = \frac{C_d}{\hat{T}_d}$$

where,

5. $$\hat{T}_d = (a)(\%\hat{Q}_d) + b$$

and, $\hat{T}_d =$ estimated trap efficiency on day *d*.

Weekly Passage ($\hat{P}$).—Population totals for numbers of Chinook and *O. mykiss* passing RBDD each week were derived from $\hat{P}_d$ where there are *N* days within the week:

6. $$\hat{P} = \frac{N}{n} \sum_{d=1}^{n} \hat{P}_d$$

Estimated Variance.—

7. $$Var(\hat{P}) = (1 - \frac{n}{N}) \frac{N^2}{n} s^2_{\hat{p}_d} + \frac{N}{n} \left[\sum_{d=1}^{n} Var(\hat{P}_d) + 2 \sum_{i \neq j}^{n} Cov(\hat{P}_i, \hat{P}_j) \right]$$

The first term in eq. 7 is associated with sampling of days within the week.

8. $$s^2_{\hat{P}_d} = \frac{\sum_{d=1}^{n}(\hat{P}_d - \hat{\bar{P}})^2}{n-1}$$

The second term in eq. 7 is associated with estimating $\hat{P}_d$ within the day.

9. $$Var(\hat{P}_d) = \frac{\hat{P}_d(1-\hat{T}_d)}{\hat{T}_d} + Var(\hat{T}_d)\frac{\hat{P}_d(1-\hat{T}_d) + \hat{P}_d{}^2\hat{T}_d}{\hat{T}_d^3}$$

where,

10. $Var(\hat{T}_d) =$ error variance of the trap efficiency model

The third term in eq. 7 is associated with estimating both $\hat{P}_i$ and $\hat{P}_j$ with the same trap efficiency model.

11. $$Cov(\hat{P}_i, \hat{P}_j) = \frac{Cov(\hat{T}_i, \hat{T}_j)\hat{P}_i\hat{P}_j}{\hat{T}_i\hat{T}_j}$$

where,

12. $$Cov(\hat{T}_i, \hat{T}_j) = Var(\hat{\alpha}) + x_i Cov(\hat{\alpha}, \hat{\beta}) + x_j Cov(\hat{\alpha}, \hat{\beta}) + x_i x_j Var(\hat{\beta})$$

for some $\hat{T}_i = \hat{\alpha} + \hat{\beta}x_i$

Confidence intervals (CI) were constructed around $\hat{P}$ using eq. 13.

13. $$P \pm t_{\alpha/2, n-1}\sqrt{Var(\hat{P})}$$

Annual JPI's were estimated by summing $\hat{P}$ across weeks.

14. $$JPI = \sum_{week=1}^{52}\hat{P}$$

Fry-Equivalent Chinook Production Estimates.—The ratio of Chinook fry (<46 mm FL) to pre-smolt/smolts (>45 mm FL) passing RBDD was variable among years. Therefore, we standardized juvenile production by estimating a fry-equivalent JPI for among-year comparisons. Fry-equivalent JPI's were estimated by the summation of fry JPI and a weighted (1.7:1) pre-smolt/smolt JPI (inverse value of 59% fry-to-presmolt/smolt survival; Hallock undated). Rotary trap JPI's could then be directly compared to determine variability in production between years.

Relative Abundance.—Catch per unit volume (CPUV; Gaines and Martin 2002) was used as an index of relative abundance (RA) for Green Sturgeon and Lamprey species at RBDD.

15. $$RA_{dt} = \frac{C_{dt}}{V_{dt}}$$

RA_{dt} = relative abundance on day *d* by trap *t* (catch/acre-foot),
C_{dt} = number of fish captured on day *d* by trap *t*, and
V_{dt} = volume of water sampled on day *d* by trap *t*.

The volume of water sampled (V_{dt}) was estimated for each trap as the product of one-half the cross sectional area (wetted portion) of the cone, water velocity (ft/s) directly in front of the cone at a depth of 2-feet, cone modified (multiplied by 0.5) or not (multiplied by 1.0), and duration of sampling.

Exploratory Data Analyses.—The sampling of four runs of Chinook, *O. mykiss*, Green Sturgeon, and Lamprey occurred over 11 years and a variety of environmental conditions. Abiotic data collected or calculated throughout sample efforts included water temperature, flow, turbidity, and moon illuminosity (fraction of moon illuminated). The abiotic factors were analyzed to determine if patterns or trends existed throughout the migration periods of the various species. Additional statistical analyses were performed, when applicable, and additional methods are noted within the results section for species-specific data trends analyzed.

Results

Sampling Effort.—Annual sampling effort varied throughout the 11-year period of reporting. The reasons for less than 100% effort varied by time of year and run sampled due to numerous factors. These factors can be categorized as either intentional or unintentional decreases in effort. Intentional decreases in effort were primarily due to ESA Section 10(a)1(A) take and incidental mortality limits, the desire to decrease potential impacts to ESA listed fish or hatchery released production groups, or when staffing levels were not appropriate for the conditions encountered. Unintentional decreases in effort were due primarily to storm activity and related debris flows or conditions considered too dangerous to sample. Additionally, during the years RBDD was in operation (2002-2011), many days were not sampled due to operational requirements imposed by USBR operators (e.g., lowering or raising of the dam gates).

Annual sample effort was assigned a value of 1.0 based on sampling four traps 365 days a year. Annual sample effort values by salmonid species and run are described in Table 1. Overall, annual sample effort for all salmonids combined ranged from 0.53 to

0.91 (ȳ = 0.80, SD = 0.10) following annual juvenile salmonid brood year cycles. The lowest values corresponded to the year 2002 when sampling did not begin until mid-April of the year. The highest value corresponded to the year 2007 when flow events were mild, staffing levels were optimal, and permit restrictions did not dictate major sampling effort reductions (Table 1).

Mark-Recapture Trials.—Trap efficiency estimates were calculated by conducting mark-recapture trials (Volkhardt et al. 2007) using unmarked salmon collected from daily trap samples. Trials were conducted when trap catch values allowed the release of 1,000 fish per trial, generally, as well as when staffing and river conditions would allow. Mark-recapture trials were also employed to validate daily trap efficiency estimates by comparing actual with predicted (modeled) estimates. This was especially important during peak salmon outmigration periods.

The number of trials conducted each calendar year ranged from 0 in 2010 to 21 in 2004 (ȳ = 7.7) and totaled 85 trials between 2002 and 2013 (Table 2). Trials were conducted with four rotary traps (*N* = 74) or three traps (*N* = 11). Some trials were conducted with cones modified to sample half the volume of water (*N* = 25) or mixed (*N* = 1), but primarily unmodified and sampling full effort (*N* = 59). Trap efficiencies were tested with the RBDD gates raised (*N* = 72) and lowered (*N* = 13) during the years when RBDD was in operation (Table 2).

Trials were conducted through a variety of flow and trap effort conditions representing actual sampling conditions detected throughout various fish migration periods (Table 2). Estimates of the percentage of river water volume sampled by traps (*%Q*) ranged from 0.72 to 6.87% (ȳ = 3.10, SD = 1.32). Efficiency estimates for the 85 trials ranged from 0.34 to 5.48% (ȳ = 2.37%, SD = 0.01).

Released fish groups ranged from 340 to 5,143 individuals (ȳ = 1,598) and recaptured fish numbers ranged from 7 to 119 (ȳ = 36) per trial. Trials were conducted predominantly with fry size-class (<46 mm fork length), naturally produced fall Chinook (67%) and to a lesser extent winter Chinook (22%). Trials were conducted in some years using unmarked pre-smolt/smolts (11%) following annual Coleman National Fish Hatchery Fall Chinook production releases[5] during spring, as conditions and staffing levels allowed (Table 2).

Average fork lengths of release groups in the fry size-class had fork lengths ranging from 35.5 to 57.1 mm (ȳ = 37.2 mm). Recaptured fork lengths ranged from 34.6 to 62.4 mm (ȳ = 37.3 mm). Average fork lengths of fish released in the pre-smolt/smolt size-class ranged from 68.7 to 81.2 mm (ȳ = 75.3 mm). Recaptured fork lengths ranged from 61.3 to 80.2 mm (ȳ = 75.3 mm; Table 2). A paired t-test was performed on the average

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[5] Coleman National Fish Hatchery is located upstream of RBDD on Battle Creek a tributary to the Sacramento. Fall Chinook production fish (~12 million per year) were adipose clipped (i.e., marked) in varying proportions over the years of study between 0 and 25%. Unmarked fish were included in some efficiency trials as they could not be distinguished from naturally produced fish.

release and recaptured fish lengths for all trials and indicated no significant difference between the released and recaptured fish sizes ($P = 0.759, df = 83, t = -0.308$).

Trap Efficiency Modeling.—Between 1998 and 2000, Martin et al. (2001) developed a trap efficiency model for the RBDD rotary trapping operation by conducting 58 mark-recapture trials (one trial excluded due to zero efficiency value). These data were used as the basis of the trap efficiency model to calculate daily passage estimates. The model was further developed between 2002 and 2013 with the addition of 85 mark-recapture trials. Trap efficiency was positively correlated to (*%Q)*, with higher efficiencies occurring as the relative percentage of discharge volume sampled by rotary traps increased. Trap efficiency was inversely related to river discharge (*Q*), as river discharge increased, trap efficiency decreased.

As mark-recapture trials were conducted, the trap efficiency model was typically updated one time each year. The newest model was applied on July 1 of each year, the beginning of the annual winter Chinook juvenile brood year period. Between 2002 and 2013 nine different models were utilized. The specific dates and model parameters with *P*-values used throughout the reporting period are listed chronologically below the groups of mark-recapture trials incorporated into the models in Table 2. The net result over the 11-year period was stabilization and improvement of the trap efficiency model with the addition of 85 mark-recapture trials. Overall, the *P*-values indicated a high level of significance for the parameter *%Q* in all years ($P< 0.001$). The model's *r*-squared value dropped in the first few years and then improved greatly with the addition of numerous naturally produced fry size-class mark-recapture trials over a variety of river discharge levels (Table 2; Figure 3).

Over the 11 years' data was collected a wide range of *%Q* values were sampled (0.44 to 6.86%, $\bar{y}$ = 2.90, SD = 0.01). On 10 occasions, extremely low *%Q* values (<0.72%) were sampled outside of the range of values tested through efficiency trials (Figure 3). The net result was that trap efficiency values were extrapolated outside the range of the model on a mere 10 of 3,315 days sampled (0.3%).

Chinook Capture Fork Length Analyses.—Chinook run assignment based on length-at-date (LAD) criteria was originally developed from growth data in the Upper Sacramento River at the Tehama Colusa Fish Facility using fall Chinook production records from 1972 through 1981 (Fisher 1992). An estimate of apparent growth rate was originally developed from fall Chinook < 90 mm FL as fish migrated or were depleted from the spawning channels by this size (Fisher 1992). Johnson et al. (1992) further developed (extrapolated) the data to predict run for fish ≥ 90 mm and ≤ 250 mm FL. The data was further refined by Frank Fisher of the California Department of Fish and Game, whereby estimated growth curves were produced for all runs based on adult timing, water temperatures, and juvenile emergence timing and growth (Brown and Greene 1992). The growth curves were fitted to a table of daily growth increments (i.e., fork length at age in days) by the California Department of Water Resources in the early

1990's (Brown and Greene 1992; Greene 1992). The following fork length data encompassed fish sampled by rotary traps using the LAD tables up to 180 mm FL, as fish were rarely captured above this length (i.e., extreme outliers).

Fall Chinook sampled from brood years 2002-2012 were heavily weighted to the fry size-class category (<46mm). On average, 75.7% of all fish sampled as fall could be described as fry (SD = 6.9) with 71.0% of the fry measuring less than 40 mm FL (Figure 4a). The remaining 24.3% (SD = 6.9) were attributed to the pre-smolt/smolt category (>45 mm) with fish between 70 and 89 mm composing 71.0% of that value. Overall, fall Chinook were sampled between 30 and 134 mm annually, with trivial numbers below or above this range (Figure 4b). Fall Chinook showed little growth, on average, between December and March, followed by a significant increase in length in April, followed by more moderate and variable growth through November (Figure 4c). The growth pattern exhibited by fall Chinook appears strongly influenced by the duration of the fall Chinook spawning period and the LAD criteria. Beginning on April 1, newly emerged fry were classified as late-fall Chinook instead of fall Chinook thereby significantly increasing the median fork length of fall Chinook during the first two weeks of April.

Late-fall Chinook sampled from brood years 2002-2012 were not heavily weighted to the fry size-class category (<46mm). On average, 24.9% of all fish sampled as late-fall could be described as fry (SD = 12.8) with 96.3% of the fry measuring less than 40 mm FL (Figure 5a). The remaining 75.1% (SD = 12.8) were attributed to the pre-smolt/smolt category (>45 mm) with fish between 70 and 89 mm composing 48.3% of that value. Overall, late-fall Chinook were sampled between 26 and 180 mm annually (Figure 5b). Late-fall Chinook showed little growth, on average, between April and May, followed by a significant increase in length in June and July, followed by more moderate and variable growth between late-September and February (Figure 5c). The growth pattern exhibited by late-fall Chinook appears modestly influenced by the LAD criteria. Beginning on July 1, newly emerged fry were classified as winter Chinook instead of late-fall Chinook slightly increasing the median fork length of late-fall Chinook during the first few weeks of July. In mid-September and to a lesser extent in late-December, the overall fork length distribution for late-fall Chinook increases from one week to the next and was likely a result of decreased sampling effort due to RBDD gate operations and initial winter storms.

Winter Chinook sampled from brood years 2002-2012 were heavily weighted to the fry size-class category (<46mm). On average, 77.9% of all fish sampled as winter could be described as fry (SD = 8.8) with 92.8% of the fry measuring less than 40 mm FL (Figure 6a). The remaining 22.1% (SD = 8.8) were attributed to the pre-smolt/smolt category (>45 mm) with fish between 46 and 69 mm composing 85.3% of that value. Overall, winter Chinook were sampled between 27 and 162 mm annually (Figure 6b). Winter Chinook showed little growth, on average, between July and October, followed by a significant increase in length in mid-October, followed by more moderate growth through December. The growth pattern was then highly variable between January and

April (Figure 6c). The growth pattern exhibited by winter Chinook appears moderately influenced by the LAD criteria. Beginning on October 16, newly emerged fry were classified as spring Chinook instead of winter Chinook thereby significantly increasing the median fork length of winter Chinook during the last two weeks of October.

Spring Chinook sampled from brood years 2002-2012 were slightly weighted to the fry size-class category (<46mm). On average, 58.6% of all fish sampled as spring could be described as fry (SD = 19.6) with 90.0% of the fry measuring less than 40 mm FL (Figure 7a). The remaining 41.4% (SD = 19.6) were attributed to the pre-smolt/smolt category (>45 mm) with fish between 70 and 89 mm composing 69.2% of that value. Overall, spring Chinook were sampled between 28 and 143 mm annually (Figure 7b). Spring Chinook showed moderate growth, on average, between October and mid-December, followed by more consistent increasing growth through May (Figure 7c). Spring Chinook disappear from the catch typically by June with sporadic capture of large smolts in July of some years. The growth pattern exhibited by spring Chinook appears moderately influenced by the LAD criteria. Beginning on December 1, newly emerged fry were classified as fall Chinook instead of spring Chinook likely resulting in positive size-class bias for spring Chinook.

O. mykiss Capture Size Analyses.—Following the conventions used by Gaines and Martin (2002) size categorization for *O. mykiss* followed a slightly different pattern than Chinook and was organized by fork length as fry (<41 mm), sub-yearling (41–138 mm), and yearling (>138 mm). Moyle (2002) described Sacramento River *O. mykiss* populations as highly variable, but typically reaching 140-150 mm FL in their first year. The focus of our data reporting is age-0 and the focus of our size-class analyses was primarily < 139mm and secondarily < 200 mm for length-weight analyses.

O. mykiss sampled from calendar years 2002-2012 were heavily weighted towards the 41-80 mm size-class (79.2%; Figure 8a) which fell into the sub-yearling category (Figure 8b). On average, a modest 8.2% could be categorized as fry (Table 3). Overall, *O. mykiss* yearling and estimated age-2 fish were annually sampled at rates of 2.4% and 0.6%, respectively (Table 3). There was little variation detected within any size-class between categories, yet variance in weekly captures was high throughout the year (Figure 8c). The variable life-history strategies of *O. mykiss* resident and anadromous forms was evident from our size-class capture data. In general, newly emerged fry occurred in early-April and increased in size to early July. Thereafter, a second cohort of either resident trout or summer steelhead[6] was sampled which demonstrated a secondary growth pattern through December (Figure 8c).

O. mykiss CAMP Program Life-Stage Comparisons.— *O. mykiss* capture patterns appeared to be different than that of Chinook salmon as relatively few *O. mykiss* were captured as fry ($\bar{y}$ = 8.3%) and the majority were sampled as sub-yearlings ($\bar{y}$ = 88.7%;

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[6] Summer steelhead are believed to be extirpated since the construction of dams blocked access to headwater habitat (Moyle 2002).

Table 3; Figure 8b). Fry capture was highest in 2002 and 2006 (11.2% and 17.5%) although these years sampled the first and third fewest *O. mykiss* of the 11 years, respectively. Yearling and age-2 capture was generally low averaging only 3.0%.

Life stage classification of fry was uniform throughout all years ($\bar{y}$ = 6.8%, SD = 2.6%) and did not vary greatly in 2002 and 2006 in contrast to age classification. Parr and silvery-parr accounted for 91.5% of the *O. mykiss* handled at RBDD although there was a large difference between the two categories, 74.0% and 17.5% respectively. Annual variability in parr and silvery-parr classifications (SD = 15.5 and 16.8) seemed to change after 2005 and was likely due to a protocol change or interpretation of morphological characteristics by field staff. Juveniles showing signs of anadromy (i.e., smolts) made up only 1.6% of individuals sampled.

O. mykiss Weight-Length Analysis.—Log $_{10}$ transformed *O. mykiss* weight-length data showed a strong overall relationship between the two variables (r^2 = 0.942, Table 4). The annual slope coefficients for the 11-year period varied slightly, ranging from 2.858 to 3.052. The variability in growth was not considered significant as the 95% CI annual slope coefficients encompassed the slope coefficient of the overall mean (Table 4). Typical of most weight-length models (Pope and Kruse 2007), the variability about the regression increased with the overall length of the fish (Figure 9).

Salmonid Passage.—Passage estimates for the four runs of Chinook were calculated weekly as fry and pre-smolt/smolt passage. The sum of the weekly fry and pre-smolt/smolt passage values equal the weekly *total* passage values. Confidence intervals (CI) were calculated at the 90% level for all runs for weekly passage estimates. Weekly CI values were summed to obtain the annual CI's around the annual passage estimate (i.e., summed weekly passage estimates). Negative CI values were set to zero and result in some years CI's being asymmetrical around the annual passage estimate. Annual passage estimates (i.e., total passage estimates), by brood year, with CI's and annual effort values are presented for Chinook within Tables 5a-5d and graphically in Figures 10, 12, 14, and 16. Fry and pre-smolt/smolt Chinook passage estimates with 90% CI's summarized annually by run can be found in Appendix 1 (Tables A1-A8). Comparisons of relative variation within and between runs of Chinook were performed by calculating Coefficients of Variation (Sokal and Rohlf 1995) of passage estimates.

Fall Chinook annual passage estimates ranged between 6,627,261 and 27,736,868 juveniles for brood years 2002-2012 ($\bar{y}$ = 14,774,923, CV = 46.2%; Table 5a). On average, fall Chinook passage was composed of 74% fry and 26% pre-smolt/smolt size-class fish (SD = 10.3). Proportions as low as 56% and as high as 87% fry were detected (Table 5a). Annual effort values resulted in interpolations of between 9 and 60% of annual passage estimates ($\bar{y}$ = 28%). In general, the effect of annual effort on CI width indicated greater spread of CI's with decreasing effort (Figure 10).

On average, weekly fall passage equated to 5% of total annual fall Chinook passage between mid-January and early March (Figure 11a). Weekly passage varied considerably during this period with some weeks' passage totals accounting for >25% of annual passage values. Between BY 2002 and 2012, 75% of average annual passage occurred by the end of March, signifying January through March as the greatest period of migration. A second, albeit much diminished, mode of passage occurred between late April and May of each year due to the release of unmarked fall Chinook production fish from Coleman National Fish Hatchery. These fish could not be distinguished from wild fish due to fractional marking processes that varied over the 11-year period from 0 to 25%. Overall, fall passage was complete by the end of July each year with sporadic small pulses of smolts through November (Figure 11b).

Late-fall Chinook annual passage estimates ranged between 91,995 and 2,559,519 juveniles for brood years 2002-2012 ($\bar{y}$ = 447,711, CV = 159.9%; Table 5b). On average, late-fall Chinook passage was composed of 38% fry and 62% pre-smolt/smolt size-class fish (SD = 22.5). Proportions as low as 11% and as high as 72% fry were detected (Table 5b). Annual effort values resulted in interpolations of between 9 and 56% of annual passage estimates ($\bar{y}$ = 31%). The effect of annual effort on CI width indicated greater spread of CI's with decreasing effort due to hatchery fish releases, in general (Figure 12).

On average, weekly late-fall passage started abruptly and held at ≤ 5% of total annual passage between April and May (Figure 13a). Weekly passage varied considerably during this period with some weeks' passage totals accounting for >35% of annual passage values. A second, similar magnitude mode of passage occurred between July and August in most years. A third, albeit diminished, mode occurred during October and November with passage accounting for up to 35% of the annual run in some years. Between BY 2002 and 2012, 75% of average annual passage occurred by mid-September, signifying April through September as the greatest period of migration. Overall, late-fall passage was complete by the end of December each year with sporadic small pulses of smolts through February (Figure 13b).

Winter Chinook annual passage estimates ranged between 848,976 and 8,363,106 juveniles for brood years 2002-2012 ($\bar{y}$ = 3,763,362, CV = 73.2%; Table 5c). On average, winter Chinook passage was composed of 80% fry and 20% pre-smolt/smolt size-class fish (SD = 11.2). Proportions as low as 53% and as high as 90% fry were detected (Table 5c). Annual effort values resulted in interpolations of between 8 and 42% of annual passage estimates ($\bar{y}$ = 18%). The effect of annual effort on CI width indicated greater spread of CI's with decreasing effort due to subsampling measures during peak migration periods (i.e., take or impact reduction), in general (Figure 14).

On average, weekly winter passage increased consistently through September to a peak into early October. Weekly passage varied considerably during August through December with some weeks' passage totals accounting for >20% of annual passage values. Between BY 2002 and 2012, 75% of average annual passage occurred by mid-

October. Weekly passage between October and December indicated wide variability over the 11-year period, yet the trend showed steady decreases followed by a second increase or mode of winter passage in November and December (Figure 15a). Overall, winter passage was 99% complete by the end of December each year with sporadic pulses of smolts through March that contributed minimally to the annual total winter passage estimate (Figure 15b).

Spring Chinook annual passage estimates ranged between 158,966 and 626,925 juveniles for brood years 2002-2012 ($\bar{y}$ = 364,508, CV = 45.0%; Table 5d). On average, spring Chinook passage was composed of 54% fry and 46% pre-smolt/smolt size-class fish (SD = 20.0). Proportions as low as 24% and as high as 91% fry were detected (Table 5d). Annual effort values resulted in interpolations of between 1 and 49% of annual passage estimates ($\bar{y}$ = 29%). The effect of annual effort on CI width indicated a slightly greater spread of CI's with decreasing effort due to subsampling during winter storm events, in general (Figure 16).

On average, weekly spring passage started abruptly and held at roughly 5% of total annual passage between mid-October and mid-November (Figure 17a). Weekly passage varied somewhat during this period with some weeks' passage totals accounting for up to 20% of annual passage values. A second, increased magnitude mode of passage occurred during December in most years with a single week accounting for nearly 50% of the annual passage estimate. Between BY 2002 and 2012, 75% of average annual passage occurred by mid-April, signifying October through April as the greatest period of migration. A third mode of similar magnitude to the second mode occurred during April and May with passage accounting for up to 45% of the annual run in some years. This could be characterized as an erroneous increase in spring passage. Unmarked fall production fish exceeded the size-class for fall run and therefore fell within the spring run category using LAD criteria. Between 2007 and 2012, on average, 4.3% of the marked fall production fish fell within the spring-run size-class using LAD criteria. Assumedly, a similar proportion of the unmarked fish were added into the spring-run passage estimates as they could not be distinguished from naturally produced fish. Overall, spring Chinook passage was complete by the end of May each year (Figure 17b).

O. mykiss passage estimates were generated using trap efficiency estimates calculated using the Chinook-based trap efficiency model. Caution should be exercised when interpreting the following results as Chinook and *O. mykiss* trap efficiency values likely differ, perhaps greatly. Irrespective of the accuracy of the magnitude of passage estimates based on Chinook efficiency trials, the trends in abundance remain plausible due to the standardization of effort and catch. Unlike Chinook, *O. mykiss* were not attributed to a fry or pre-smolt/smolt category and passage estimates with 90% CI's were calculated that included all size-classes and life-stages combined.

Annual passage estimates for *O. mykiss* ranged between 56,798 and 151,694 juveniles for calendar years 2002-2012 ($\bar{y}$ = 116,272, CV = 25.7%; Table 5e). Annual effort values resulted in interpolations of between 4 and 56% of annual passage estimates ($\bar{y}$ = 22%). The effect of annual effort on CI width indicated a slightly greater spread of CI's with decreasing effort, in general (Figure 18).

On average, weekly *O. mykiss* passage was low (<5% on average) from April through July of each year with some variability. In 11 years of sampling only once did passage exceed 10% of annual passage during these months. Weekly passage between July and August increased to peak values ranging from 5% to nearly 25% (Figure 19a). Between 2002 and 2012, 75% of average annual passage occurred by mid-August. Weekly passage generally declined between September and October. Overall, *O. mykiss* passage was negligible between December and the following February each year (Figure 19b).

Fry-Equivalent Chinook Production Estimates.—Juvenile Chinook passage values were standardized to *fry-equivalent* production estimates for within- and between-year comparisons. As noted above, the various runs were sampled with oftentimes considerable variability in fry to pre-smolt/smolt ratios over the 11–year sample period (Table 5a-5d). By multiplying 1.7 to all fish sampled in the pre-smolt/smolt category (>45mm) within each run, annual Chinook production above the RBDD transect could be estimated. These standardized production estimates could then be compared to adult escapement estimates calculated from the California Central Valley Chinook Population Report (Azat 2013) or carcass survey data in the case of winter Chinook (USFWS 2006-2011 and 2013). Moreover, by comparing production to the number of adult Chinook females each year (by run) and estimating fecundity data from CNFH and Livingston Stone National Fish Hatchery (LSNFH) hatchery production records, estimated recruits per female and egg-to-fry survival estimates were generated.

Fall Chinook fry-equivalent production estimates between 2002 and 2012 ranged from 7,554,574 to 30,624,209 ($\bar{y}$ = 17,262,473, CV = 43.2%). Lower and upper 90% CI's were generated for each week, summed annually, and averaged between 6,670,475 and 30,707,529 (Table 6a).

Adult fall Chinook escapement estimates above RBDD (mainstem Sacramento River plus tributaries reported) estimated escapement between 12,908 and 458,772 ($\bar{y}$ = 93,661) for the same years. Fall Chinook carcass survey data collected by California Department of Fish and Wildlife (CDFW) provided annual female:male sex ratio estimates averaging 0.46:0.54 (D. Killam, unpublished data). A significant relationship between estimated number of females and fry-equivalent fall Chinook production estimates was detected (r^2 = 0.53, df = 10, P = 0.01; Figure 20a). Recruits per female were calculated ranging from 89 to 1,515 ($\bar{y}$ = 749). Assuming an average female fecundity value of 5,407, based on fall Chinook spawning records from CNFH between 2008 and 2012 (K. Brown, unpublished data), resulted in an egg-to-fry survival estimate averaging 13.9% for fall Chinook (Table 6a).

Late-fall Chinook fry-equivalent production estimates between 2002 and 2012 ranged from 116,188 to 4,041,505 ($\bar{y}$ = 669,939, CV = 169.8%). Lower and upper 90% CI's were generated for each week, summed annually, and averaged between 222,044 and 1,236,432 (Table 6b).

Adult late-fall Chinook escapement estimates above RBDD estimated escapement between 2,931 and 36,220 ($\bar{y}$ = 9,108) for the same years. Late-fall Chinook annual female:male sex ratio estimates relied on an assumption of the average ratio found for fall Chinook (i.e., 0.46:0.54). A significant relationship between estimated number of females and fry-equivalent late-fall Chinook production estimates was detected ($r^2 = 0.67$, df = 10, $P = 0.002$; Figure 20b). Recruits per female were calculated ranging from 47 to 243 ($\bar{y}$ = 131). Assuming an average female fecundity value of 4,662 based on late-fall Chinook spawning records from CNFH between 2008 and 2012 (K. Brown, unpublished data) resulted in an egg-to-fry survival estimate averaging 2.8% for late-fall Chinook (Table 6b).

Winter Chinook fry-equivalent production estimates between 2002 and 2012 ranged from 996,621 to 8,943,194 ($\bar{y}$ = 4,152,547, CV = 70.1%). Lower and upper 90% CI's were generated for each week, summed annually, and averaged between 2,265,220 and 6,124,494 (Table 6c).

Adult winter Chinook escapement estimates above RBDD (USFWS/CDFW carcass survey data; available at http://www.fws.gov/redbluff/he_reports.aspx) estimated escapement between 824 and 17,205 ($\bar{y}$ = 6,532) for the same years. Winter Chinook annual female:male sex ratio estimates were estimated during the annual carcass surveys (Table 6c). A highly significant relationship between estimated number of females and fry- equivalent winter Chinook production estimates was detected ($r^2 = 0.90$, df = 10, $P < 0.001$; Figure 20c). Recruits per female were calculated ranging from 846 to 2,351 ($\bar{y}$ = 1,349). Annual female fecundity values were estimated based on winter Chinook spawning records from LSNFH between 2008 and 2012 (USFWS Annual Propagation Reports; available at http://www.fws.gov/redbluff/he_reports.aspx) and resulted in an egg-to-fry survival estimate averaging 26.4% for winter Chinook (Table 6c).

Spring Chinook fry-equivalent production estimates between 2002 and 2012 ranged from 207,793 to 747,026 ($\bar{y}$ = 471,527, CV = 40.9%). Lower and upper 90% CI's were generated for each week, summed annually, and averaged between 199,365 and 792,668 (Table 6d).

Adult spring Chinook escapement estimates above RBDD (mainstem Sacramento River plus tributaries reported) estimated escapement between 77 and 399 ($\bar{y}$ = 195) for the same years. Spring Chinook annual female:male sex ratio estimates relied on an assumption of the average ratio found for fall Chinook (i.e., 0.46:0.54). No significant relationship between estimated number of females and fry-equivalent spring Chinook production estimates was detected ($r^2 = 0.00$, df = 10, $P = 0.971$; Figure 20d). Recruits per female were calculated ranging from 1,112 to 8,592 (ȳ = 3,122). Assuming an average female fecundity value of 5,078, based on averaging of 5 years of fall and late-fall Chinook spawning records from CNFH and 10 years of winter Chinook spawning records from LSNFH, resulted in an egg-to-fry survival estimate averaging 61.5% for spring Chinook (Table 6d).

Green Sturgeon Data.—Capture of young of the year sturgeon occurred annually between calendar years 2002 and 2012, except in 2008. Catch was highly variable, not normally distributed, and ranged between 0 and 3,701 per year (median = 193; Table 7). Sturgeon sampled by rotary traps could be positively identified as Green Sturgeon in the field *above* total length of 46 mm. At this size, lateral scutes were fully developed and could be counted to distinguish between White (*Acipenser transmontanus*) and Green Sturgeon (Moyle 2002). Of 2,912 sturgeon measured in the field, 99.14% were less than 46 mm. In all years, except 2007 and 2008, sub-samples of larval and/or juvenile sturgeon rotary trap catch (up to 50% in some years) were supplied to UC Davis for genetic research and all were determined to be Green Sturgeon (See Israel et al. 2004; Israel and May 2010). We therefore assumed all sturgeon captured in rotary traps were Green Sturgeon based on the results of genetic analyses. Moreover, Green Sturgeon were the only confirmed spawning Acipenserids sampled at or above the RBDD transect between 2008 and 2012 during sturgeon spawning surveys (Poytress et al. 2009-2013).

Green Sturgeon catch was primarily composed of recently emerged, post-exogenous feeding larvae with a 10-year median capture total length averaging 27.3 mm (SD = 0.8; Table 7). Sturgeon were sampled between 18 and 188 mm, but those sampled above 40 mm were considered outliers (N = 51; Table 7; Figure 21a).

The temporal pattern of Green Sturgeon captures occurred, on average, between May 1 and August 28 of each year. Green Sturgeon capture trends indicated annual variability, but on average 50% were sampled by the end of June each year and nearly 100% by the end of July (Figure 21b), with outliers (i.e., juveniles) captured in August, September and as late as November (e.g., 188 mm TL) in some years.

Relative abundance of Green Sturgeon was measured as catch per estimated water volume sampled (CPUV in ac-ft) through rotary trap cones and summed daily. Daily values were summed annually to produce each year’s annual index of abundance. Absolute abundance estimates, via trap efficiency trials, could not be calculated due to low numbers of sturgeon sampled on a daily basis and the fragile nature of newly emerged exogenous feeding larvae.

Green Sturgeon annual CPUV was typically low and ranged from 0.0 to 20.1 fish/ac-ft (ȳ = 2.5 fish/ac-ft, SD = 5.9). Data were positively skewed and median annual CPUV was 0.8 fish/ac-ft. Relative abundance distribution data were highly influenced by samples collected in 2011 that equated to two orders of magnitude higher than any other year's index (Figure 21c). Overall, variability in CPUV between years was relatively high as the CV was 236% for the eleven-year period (Table 7).

Lamprey Species Data.—Capture of multiple lamprey species occurred between water year (WY; October - September) 2003 and 2013. WY 2002 was excluded from analyses as less than 50% of the entire year was sampled. Lamprey species sampled included adult and juvenile Pacific Lamprey and to a much lesser extent River Lamprey (*Lampetra ayresi*), and Pacific Brook Lamprey (*Lampetra pacifica)*. Unidentified lamprey ammocoetes and Pacific Lamprey (PL) composed 99.8% of all captures, 24% and 75%, respectively. River Lamprey and Pacific Brook Lamprey combined, composed the remaining 0.2% of all captures. Annual catch, length, and relative abundance information for River and Pacific Brook Lamprey can be found in Appendix 1 (Tables A9 and A10) and are not discussed further due to very low capture rates.

Annual catch of ammocoetes was relatively stable and ranged between 385 and 1,415 individuals per year ($\bar{y}$ = 757, median = 657; Table 8a). The catch coefficient of variation for ammocoetes was 38.5%. Minimum TL of lamprey ammocoetes was 14 mm and maximum TL was 191. Over the eleven complete years sampled, the average minimum and maximum TL's were 32 and 164 mm, respectively ($\bar{y}$ =105, SD = 4.7; Figure 22a).

Annual catch of PL macropthalmia and a small fraction of adults was variable and ranged between 204 and 5,252 individuals per year ($\bar{y}$ = 2,335, median = 2,747; Table 8b). The catch coefficient of variation for PL was 75.3%. Minimum TL of PL was 72 mm and maximum TL was 834. Over the eleven years sampled, the average minimum and maximum TL's were 88 and 665 mm, respectively ($\bar{y}$ = 150, SD = 37.3; Figure 23a).

Lamprey captures occurred throughout the year between October and September. Ammocoete capture trends indicated annual variability, but on average 25% were sampled by the end of January, 50% were sampled by the end of March, 75% were sampled by the end of May and 100% by the end of September (Figure 22b). Transformed PL (macropthalmia and adult) capture trends indicated a different pattern of capture and annual variability compared to ammocoetes. On average, 5% were sampled through October, 50% were sampled through December, 75% were sampled through February, 90% by the beginning of April with a 100% by the end of September (Figure 23b).

Relative abundance of ammocoetes and PL were measured as CPUV through individual rotary trap cones and summed daily. Daily values were summed annually to produce each year's annual index of abundance. Absolute abundance estimates employing mark-recapture methods could not be calculated due to the sporadic capture of adequate numbers of juveniles (e.g., > 1,000 individuals) that would be needed for mark-recapture trials. Moreover, emphasis was placed on conducting Chinook mark-recapture trials at times of pronounced lamprey abundance.

Ammocoete annual relative abundance ranged from 3.6 to 11.7 fish/ac-ft (ȳ = 6.8 fish/ac-ft, SD = 2.6; Figure 22c). Overall, ammocoete data were normally distributed as median CPUV was 6.5 fish/ac-ft, similar to the mean value. Variability in CPUV between years was modest and the coefficient of variation was 39% for the eleven-year period (Table 8a).

PL annual relative abundance was generally higher than ammocoete relative abundance and ranged from 2.1 to 112.8 fish/ac-ft (ȳ = 41.0 fish/ac-ft, SD = 34.7; Figure 23c). Overall, PL data was slightly positively skewed and median CPUV was 34.1 fish/ac-ft. Variability in CPUV between years was moderate and the coefficient of variation was 85% for the eleven-year period (Table 8b).

Abiotic Conditions.—Tabular summaries of the abiotic conditions that were encountered during each annual capture period were summarized for each run of salmon, *O. mykiss*, Green Sturgeon and Lamprey species. Tabular summaries associated with each species annual captures are located in Tables 9a-9f and include: dates of capture, peak daily water temperature, peak daily river discharge levels and mean daily turbidity values. A series of exploratory plots comparing the above daily environmental data variables plus an index of moon illuminosity were generated for fry and pre-smolt Chinook daily passage estimates for visual analyses. Winter Chinook fry and pre-smolt/smolt plots are included in Appendix 2 (Figures A1-A23) for reference.

Annual environmental covariate data for fall Chinook salmon can be found in Table 9a. Results presented below describe data averaged over 11 brood years. Fall Chinook were sampled over a period of 250 to 273 days per year (ȳ = 264 days, SD = 7). Water temperatures ranged from 45 to 62 °F (ȳ = 55°F, SD = 0.8). Sacramento River discharge ranged from 5,605 to 72,027 CFS (ȳ = 14,844 CFS, SD = 5,442). Turbidity values ranged from 1.5 to 298.7 NTU (ȳ = 14.4 NTU, SD = 6.3).

Annual environmental covariate data for late-fall Chinook salmon can be found in Table 9b. Results presented below describe data averaged over 11 brood years. Late-fall Chinook were sampled over a period of 270 to 338 days per year (ȳ = 300 days, SD = 24). Water temperatures ranged from 46 to 62 °F (ȳ = 56°F, SD = 0.7). Sacramento River discharge ranged from 5,536 to 67,520 CFS (ȳ = 12,580 CFS, SD = 2,829). Turbidity values ranged from 1.4 to 272.0 NTU (ȳ = 11.3 NTU, SD = 6.2).

Annual environmental covariate data for winter Chinook salmon can be found in Table 9c. Results presented below describe data averaged over 11 brood years. Winter Chinook were sampled over a period of 207 to 278 days per year (ȳ = 250 days, SD = 20). Water temperatures ranged from 46 to 61 °F (ȳ = 55°F, SD = 0.8). Sacramento River discharge ranged from 5,349 to 66,800 CFS (ȳ = 11,952 CFS, SD = 3,767). Turbidity values ranged from 1.3 to 290.2 NTU (ȳ = 12.5 NTU, SD = 5.1).

Annual environmental covariate data for spring Chinook salmon can be found in Table 9d. Results presented below describe data averaged over 11 brood years. Spring Chinook were sampled over a period of 221 to 250 days per year ($\bar{y}$ = 232 days, SD = 9). Water temperatures ranged from 46 to 62 °F ($\bar{y}$ = 53°F, SD = 0.6). Sacramento River discharge ranged from 5,349 to 68,720 CFS ($\bar{y}$ = 13,370 CFS, SD = 6,116). Turbidity values ranged from 1.4 to 305.9 NTU ($\bar{y}$ = 16.0 NTU, SD = 7.0).

Annual environmental covariate data for *O. mykiss* can be found in Table 9e. Results presented below describe data averaged over 10 calendar years. *O. mykiss* were sampled over a period of 331 to 363 days per year ($\bar{y}$ = 349 days, SD = 12). Water temperatures ranged from 46 to 63 °F ($\bar{y}$ = 56°F, SD = 0.8). Sacramento River discharge ranged from 5,333 to 67,610 CFS ($\bar{y}$ = 12,519 CFS, SD = 3,551). Turbidity values ranged from 1.4 to 263.7 NTU ($\bar{y}$ = 11.4 NTU, SD = 4.1).

Annual environmental covariate data for Green Sturgeon can be found in Table 9f. Results presented below describe data averaged over 11 calendar years. Green Sturgeon were sampled over a period of 56 to 151 days per year ($\bar{y}$ = 88 days, SD = 27). Water temperatures ranged from 55 to 61 °F ($\bar{y}$ = 58°F, SD = 0.9). Sacramento River discharge ranged from 9,639 to 23,538 CFS ($\bar{y}$ = 13,483 CFS, SD = 2,181). Turbidity values ranged from 2.4 to 93.9 NTU ($\bar{y}$ = 8.5 NTU, SD = 6.9).

Due to the large amount of variability and lack of a normal distribution, all environmental covariate CPUV data analyses for Green Sturgeon were performed using natural log transformed data (Sokal and Rohlf 1995). Environmental covariates were regressed against the natural log of daily CPUV estimates for Green Sturgeon in a linear regression setting (Figure 24). Maximum daily water temperature was the only variable found to be significantly related to Green Sturgeon relative abundance, albeit the relationship explained ~5% of the variability around daily relative abundance (r^2= 0.045, df = 315, $P < 0.001$).

Annual environmental covariate data for Lamprey *spp.* can be found in Table 9g. Results presented below describe data averaged over 11 water years. Lamprey were sampled over a period of 358 to 364 days per year ($\bar{y}$ = 362 days, SD = 2). Water temperatures ranged from 46 to 63 °F ($\bar{y}$ = 56°F, SD = 0.7). Sacramento River discharge ranged from 5,347 to 68,873 CFS ($\bar{y}$ = 12,595 CFS, SD = 4,177). Turbidity values ranged from 1.2 to 306.8 NTU ($\bar{y}$ = 11.9 NTU, SD = 4.4).

Due to the variability and lack of a normal distribution, all environmental covariate CPUV data analyses for Lamprey *spp.* were performed using natural log transformed data. Environmental covariates were regressed against the natural log of daily CPUV data for Lamprey *spp.* in a linear and multiple regression setting. All four independent variables appear to contribute to predicting Lamprey *spp*. relative abundance and were significantly related to abundance levels (r^2= 0.223, df = 1999, $P < 0.001$). Individual variable linear regression analyses indicated turbidity, water temperature, discharge, and full moon illuminosity were correlated in descending order of magnitude (Figure 25). None of the covariates tested explained more than ~16% of the variability associated with daily CPUV data.

Discussion

Trap Efficiency Modeling.—Over the past 11 years, annual mark-recapture trials added 85 data points to the RBDD rotary trap efficiency linear regression model (Figure 3). Explanation of the variability associated with trap efficiency and *%Q*, in terms of the associated r-squared value, was reduced for the first few years and then steadily increased in more recent years. The reduction was due, in part, to more precise *%Q* calculations over the initial model when diversions from RBDD were not subtracted from daily river discharge values. Diversions were able to be removed from the total discharge (*Q*) passing the transect as these data became available in real-time starting in 2002.

The addition of a multitude of fry size-class trials over a variety of discharge levels greatly increased the accuracy of trap efficiency estimates. Fry size-class fish are the predominant size-class sampled at RBDD (i.e., fall and winter Chinook) thereby making them the best representatives for use in mark-recapture trials. The original trap efficiency model developed by Martin et al. (2001) employed primarily hatchery-raised smolts, as these fish were all that were available in large quantities and permitted for use in experiments to develop the initial model. However, hatchery fish weakly represented the primary fish size-class sampled by RBDD rotary traps. Roper and Scarnecchia (1996) and Whitton et al. (2008) found significant differences in trap efficiency when conducting paired mark-recapture trials using hatchery and wild caught fish. The most recent years of RBDD data support this concept.

While a simple linear regression model has worked well over the years for our real-time data output needs, analysis of the data within the model, other possible covariates, and other more advanced modeling techniques has been warranted. Analysis incorporating additional potential explanatory variables was conducted using a generalized additive model technique (GAM; Hastie and Tibshirani 1990). From this analysis, variables including turbidity, fish size and run, water temperature, weather condition, lunar phase, and river depth were explored in addition to *%Q*. The result was that only *%Q* and weather were found to be significant model explanatory variables ($r^2 = 0.68$; df = 141, $P < 0.01$). The weather variable needs focused testing by conducting more mark-recapture trials under a variety of weather conditions to determine the applicability or mechanism of this variable. The GAM modeling technique may be employed in the future as an improved statistical format to interpolate missed sample days.

At minimum, an update to the 142 trial linear trap efficiency model (Figure 3) needs to be implemented for future passage estimate calculations. The update will include the removal of hatchery fish trials (*N*=23) used as surrogates for natural stocks. Removal of all RBDD "gates in" mark-recapture trials (*N*=31) due to the cessation of RBDD dam operations since 2011 (NMFS 2009) is also warranted.

The loss of annual maintenance and RBDD gate lowering operations at the rotary trap sample site (Figure 1) will allow the river channel's geometry to change more frequently due to natural flow driven substrate transport mechanisms. RBDD operations of the past virtually "reset" the sample site to facilitate pumping during the gates-out period and improve fish passage at the fish ladders during the gates-in period. As the sample site's channel configuration is allowed to fluctuate in the absence of dam operations, the overall effect could be differing trap efficiency values in relation to flow compared to previous years' data. Annual mark-recapture trials will be needed to evaluate this phenomenon, which has been observed in other uncontrolled channel sampling locations (e.g., Clear Creek; Greenwald et. al. 2003). The use of a GAM model may also be of benefit in this situation as it could be constructed and employed annually to account for wide variation in annual trap efficiency values; albeit at the expense of being able to produce real-time data summaries.

A linear model that also removed the remaining pre-2002 trials (*N*=16) which estimated *%Q* in a less precise manner, would result in the most representative trap efficiency model. A post-RBDD wild Chinook model of this type would incorporate 72 mark-recapture trials with a high degree of significance (*N*=72, $r^2 = 0.669$, F = 141.5, $P < 0.001$) and be most representative of current sampling conditions in terms of fish size-class and environmental conditions.

Chinook Capture Size Analyses.—Overall capture of Chinook salmon by RBDD rotary traps was heavily weighted towards fry size-class less than 40mm in fork length. All four runs' greatest proportion of fish were found in this size-class, albeit in a range of proportions from 24% for late-fall (Figure 5b) to over 72% for winter run (Figure 6b). The capture size-class results fit well with the migratory strategies of 'stream' and 'ocean type' as noted in Moyle (2002) for late-fall/spring and fall/winter Chinook, respectively. The question of size selectivity or capture bias of rotary traps, a passive sampling gear (Hubert 1996), comes into question when dealing with two very different migration strategies.

A two sample t-test was performed to evaluate the potential for size-class bias by comparing fry (fall and winter Chinook) size-class trap efficiency values (*N*=43) to pre-smolt/smolt (fall) trap efficiency values (*N*=10) between similar river discharge conditions. The t-test results did not indicate any significant difference between the mean efficiency values (t = -0.398, df = 51, $P = 0.624$). Interestingly, the mean efficiency and standard deviation of the values were identical ($\bar{y} = 2.1\%$, SD = 0.01) between groups. We recommend further study of the relationship between pre-smolt/smolt size-class and trap efficiency to determine if differences or bias may exist between or among Chinook runs. Additional sampling effort would be needed to capture substantially more pre-smolts in the numbers required for efficiency trials in the Sacramento River to further test this potential bias. Smolting salmonids also appear to succumb to stress induced mortality at a much greater rate than fry, particularly in warmer water conditions due to relatively high respiration levels, adding to the difficulty in testing this potential bias.

O. mykiss Life-Stage and Growth.— Catch of *O. mykiss* was scattered throughout the year with multiple modes in abundance of predominately sub-yearling parr and silvery-parr occurring in early May and August. *O. mykiss* fry (<41 mm) made up 17.5% of the total *O. mykiss* catch in 2006 and was 2.4 standard deviations from the 11-year mean. In contrast, yolk-sac fry, made up only 9.4% of the *O. mykiss* catch in 2006 and varied less than 1 standard deviation from the 11-year mean (Table 3). Elevated spring discharge resulted in poor sampling conditions which reduced sampling effort, possibly scoured redds, and ultimately resulted in low overall *O. mykiss* catch in 2006. Regardless of the cause of low catch rates, it is unlikely the migration patterns of *O. mykiss* changed in 2006 and the variability in age-class distribution was likely due to our sampling effort in that year.

The small percentage of *O. mykiss* smolts that showed signs of anadromy were generally migrating during March through June which was consistent with outmigrating smolts found in Battle, Mill, and Deer Creeks (Johnson and Merrick 2012; Colby and Brown 2013). Interpretation of *O. mykiss* data collected at the RBDD was complicated as a robust resident (non-anadromous) population exists throughout the Upper Sacramento River and its' tributaries. Populations of anadromous and resident *O. mykiss* life history forms are often sympatric and may inter-breed (Zimmerman and Reeves 2000; Docker and Heath 2003), thereby reducing our abilities to separate the anadromous and non-anadromous components of this species. Donahue and Null (2013) conducted research using otolith Strontium/Calcium ratios to determine whether *O. mykiss* returning to a hatchery were progeny of anadromous or resident females. A similar analysis could be conducted using juvenile *O. mykiss* collected at the RBDD. Data from juveniles might provide incite as to whether temporal separation in spawn timing exists between anadromous and resident forms of O. mykiss coexisting within the Upper Sacramento River basin.

Linear regression equations developed using weight-length data obtained from *O. mykiss* showed a strong correlation between the two variables (r^2= 0.942). The annual slope coefficient varied slightly between 2.858 and 3.052. Carlander (1969) suggested that slopes less than 3.0 might indicate a crowded or stunted population. However, permit restrictions may have introduced bias into our results as we were unable to anesthetize and weigh fish >200 mm thereby reducing the slope of the regression compared to that of a complete analysis of the population.

Sample Effort Influence on Passage Estimates.—Sampling effort had profound effects on the precision of passage estimates and confidence intervals (Figures 10, 12, 14, 16, and 18). In general, as sampling effort decreased, variance within weekly passage estimates increased and the width of confidence intervals subsequently increased. This effect was most prominent when effort was reduced during peak periods of outmigration or for long periods of time (> 1 week) when sharp increases or decreases in fish abundance occurred. Unfortunately, sampling of outmigrant Chinook on a large river system such as the Sacramento River is invariably subject to discharge events that are insurmountable for variable periods of time.

Logistical factors including staffing and permitting restrictions can also have significant effects on the precision of estimates. For example, a comparison of BY 2002 and BY 2005 winter Chinook passage with equivalent effort values (0.64) shows less precision of BY 2002 passage estimates over BY 2005 (Table 5c). The basis of the relatively low effort in 2002 was capture restrictions prompted by ESA Section 10(a)(1)(A) NMFS permits for endangered winter Chinook. Moreover, staff levels were initially low as the program was reinstated after a nearly two-year hiatus and substantial sub-sampling measures (i.e., standardized sub-sampling of repeated weeks) had to be taken during record abundance levels. The net effect was that sampling of fry, the predominant size-class of ocean type Chinook (Moyle 2002; Figure 6a/b), was reduced in terms of the number of days each week and hours of each night sampled during the peak emigration period. The overall net effect was 20% wider CI's about the 2002 estimate (i.e., less precision) compared to BY 2005. This was due to interpolation of 45% of the fry data which comprised 90% of the 2002 annual estimate. In contrast, BY 2005 sampled 90% of the fry data which comprised 90% of the annual estimate. Effort was reduced 36% in 2005 as a result of winter storms whereby sampling ceased for 3 straight weeks due to high river discharge levels. The effect of that lost sampling time in January did little to reduce the precision of the BY 2005 estimate as it was during a period when a mere fraction of a percent of total passage for winter Chinook typically occurs (Figure 15). The impact to the BY 2005 *fall Chinook* passage estimate, on the other hand, was very wide CI's about the estimate due to the lowest effort of all 11 years during a critical time period for that run's outmigration (Table 5a, Figure 11).

In summary, the precision of passage estimates can vary widely for numerous reasons within runs and among years. Inter-annual variability in environmental conditions will always be a factor when attempting to sample a riverine environment. Making good sampling decisions with knowledge of the species of interest and riverine conditions coupled with tenacity to sample critical periods of outmigration (Volkhardt et al. 2007) are key to generating passage estimates with an acceptable level of precision. Applying effort throughout each period of interest needs to be balanced between the value of data collected, an acceptable level of precision required of the data, the cost to attain the required precision, the impact sampling may have to a particular species, and the feasibility to appropriately sample the species of interest.

Chinook Passage Variability.—Juvenile Chinook passage by one to four runs occurs every single day of the year in varying proportions at RBDD. The sources and degree of variability of juvenile Chinook passage are as diverse as the life-history and migration strategies of the runs they encompass. The magnitude of run-specific adult spawners appears to have the greatest influence on the overall magnitude of juvenile Chinook passage and associated variability.

In recent decades, fall Chinook adults consistently dominated the Upper Sacramento River spawning salmon populations (Williams 2006, Azat 2013). Throughout the past decade, we witnessed a 'collapse' of the Sacramento River fall Chinook adult population and accordingly tracked declines in juvenile passage (Figure 10). Lindley et al. (2009) analyzed the freshwater and marine components of fall Chinook outmigrants from BY 2004 and 2005 through their return as adults in 2007 and 2008. They indicated BY 2004 and 2005 juveniles encountered poor marine conditions upon ocean entry in the spring of 2005 and 2006 which resulted in the marked decline in fall Chinook adult abundance starting in 2007.

Juvenile fall Chinook had the greatest mean annual passage value (14,774,923) of the four runs sampled at RBDD (Table 5a). Fall Chinook passage also exhibited the second smallest degree of variability with a CV of 46.2%. Notably, fall Chinook annual production by the CNFH averages 12 million juveniles, a similar value to the mean passage value of unmarked fall Chinook[7]. Fall Chinook production fish from CNFH contributed heavily to the relative stability of the annual returning fall Chinook adult population (Williams 2006) and, consequently, juvenile passage estimates over the past eleven years (i.e., basis of fall Chinook population).

Temporal abundance patterns of fall Chinook indicate the primary passage of juveniles occurs between late December and March (Figure 11a/b). Over half the run passed RBDD by mid-February, yet this varied over the 11-year period by +/- one month. Fall run passage on the American River (Williams 2006), Clear Creek (Earley et al. 2013a) and Stanislaus River (Pyper and Justice 2006) in California generally subsides to low values by the end of March. This would be consistent with the ocean type migration strategy as noted by Moyle (2002). The remaining fall run smolts and subsequent 'jump' in abundance in April to May was a result of the unmarked proportion of the CNFH production releases. Reduced variability in weekly passage was observed in the final 20% of annual fall Chinook passage (Figure 11b).

Spring Chinook had the lowest average passage value of 364,000 juveniles and the lowest CV of 45% (Table 5d). The low value of spring Chinook passage at RBDD can be attributed to a relatively small number of adults spawning primarily in Battle and Clear Creeks (Figure 1). Some extant populations appear to inhabit Beegum Creek, a tributary to Cottonwood Creek (CDFG 2001), and in the mainstem Sacramento River (Killam 2009, Azat 2013). Of particular interest with respect to the accuracy of spring Chinook

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[7] Fall Chinook passages estimates do not include the marked proportion (0-25%) of CNFH production fish. Unmarked fish of hatchery origin are included in annual passage estimates and their occurrence is evidenced by increased passage values primarily in May through June of each calendar year (Figure 11b).

juvenile passage at RBDD is the annual spawn timing of adult spring Chinook and expected juvenile emergence timing. USFWS rotary trapping operations on Battle and Clear Creeks between 2003 and 2012 have not predicted emergence (i.e., through temperature unit analyses; Beacham and Murray 1990) nor sampled juvenile spring Chinook prior to November of each year. On average, the first spring Chinook juvenile migrants from Battle and Clear Creeks were sampled during the week of November 26th each year (USFWS, unpublished data). As a result, LAD criteria used to identify juvenile spring Chinook at RBDD are noticeably inaccurate as fish sampled prior to late November were not sampled upstream in primary production areas at that time of year.

Simulating a removal of all LAD spring run between October 16 and November 25 of each year sampled would result in *decreased* spring run passage estimates by 19%, on average (range 2.6 to 44.2%). The effects of removing incorrectly assigned fry annually did not indicate a statistically significant difference between annual estimates (paired *t*-test, $N = 11$, $P < 0.001$). When incorrectly assigned fry are removed, the slightly more accurate simulated spring Chinook annual passage values remain within the 90% CI of standard estimates.

Furthering the simulation by adding the weekly October through November spring Chinook estimated passage to the winter Chinook passage estimates (i.e., late spawning or emerging winter run most likely candidate; see USFWS 2013), had minimal effect on the magnitude of winter Chinook passage. The average *increase* to winter Chinook passage was a mere 2.6% (range 0.6 to 8.8%) and simulated passage remained within the 90% CI of the annual winter Chinook estimates in all years.

Winter Chinook average annual juvenile passage was the second highest of the four runs estimated at 3,763,362 (Table 5c). The CV of the annual estimates was 73.2%; higher than fall or spring, but moderately dispersed. Overall, passage in years 2002, 2003, 2005, and 2006 surpassed the highest previous value of winter Chinook passage since juvenile monitoring began in 1995 (Gaines and Martin 2002). Similar to fall Chinook, winter Chinook adult escapement and subsequent juvenile passage began a marked decline in 2007 (Figure 16). Juvenile winter Chinook have been determined to enter the ocean during March and April of each spring (Pyper et al. 2013). Overall, it is believed that juvenile winter Chinook suffered the same fate as juvenile fall Chinook with poor marine conditions upon ocean entry in the spring of 2005 and 2006. Winter Chinook juvenile cohort replacement rates dropped below 1.0 starting with BY 2007, similar to adult fall run as noted in Lindley et al. (2009). The lowest passage estimate between 2002 and 2012 for winter Chinook occurred in 2011 at 848,976. Not until 2014 will we know if adult or juvenile cohort replacement rates will improve to a value of 1.0 or greater. Winter Chinook passage estimates between BY 1999 to BY 2002 (Gaines and Poytress 2003) indicate that replacement rates can vary substantially and replacement rates of 3.0 or greater have been estimated between juvenile cohorts.

Late-fall Chinook passage averaged 447,711 juveniles for the 11-year period and exhibited the greatest amount of variability with a CV of 159.9%. Late-fall Chinook juvenile passage estimates are likely affected by LAD criteria similar to spring Chinook in terms of potential for overestimation. The variability associated with weekly late-fall passage shows a decrease in median abundance by the beginning of June each year which may be more representative of actual late-fall emergence. Additionally, as demonstrated by Figures 13 a/b, the late-fall migration starts abruptly unlike for fall and winter Chinook which follow a more bell-shaped pattern in abundance (See Figures 11a/b and 15 a/b). It was highly likely that early emergent late-fall fry were, in fact, late emerging fall Chinook. Run specific genetic monitoring (Banks et al. 2000, Banks and Jacobsen 2004) could assist in determining the magnitude of the error in run assignment.

Sampling effort during mid-April to mid-May, the early late-fall run emergent period, was also typically low in an effort to reduce impacts to CNFH fall Chinook production fish caught in rotary traps. Within trap predation of fry by CNFH production smolts could also negatively bias late-fall juvenile production estimates. Sub-sampling of portions of the day and night (≤25% of each period) were only feasible with full staffing in some years which can reduce potential bias. During all other years, multiple sample days were typically sacrificed to allow peaks in CNFH production fish to recede ultimately reducing the accuracy of late-fall passage estimates.

Fry-Equivalent Chinook Production Estimates.—Estimation and analyses of the productivity of salmon runs in the Upper Sacramento River basin can provide valuable information to a variety of interests. Management of California’s complex water resources for agriculture, municipal, commercial, and ecological uses is an increasingly controversial and complex endeavor. Knowledge of the effects of manipulating water storage and river processes on the productivity of the Sacramento River fish populations can only benefit fishery and water operations managers in an attempt to balance the competing demands on the system. Reducing uncertainty associated with threatened and/or endangered fish population dynamics by employing knowledge of the abundance, migration timing, and variability of those populations over time can then inform the decision making processes guiding management of water and fishery resources into the future.

Fall Chinook fry-equivalent juvenile production indices (FEJPI; Table 6a) indicate a significant and moderate correlation with fall Chinook escapement estimates (Figure 20a). Approximately 53% of the variation associated with fall FEJPI’s was attributed to the estimated number of females in the system above RBDD each year (Figure 20a). The CV of estimated fall run females was greater than 132% indicating wide dispersion of contributors to the juvenile population over the eleven-year period. Conversely, the CV of FEJPI’s was relatively low valued at 43%. Furthermore, recruits per female and similarly egg-to-fry survival demonstrated moderately low average values of 749 and

13.9%, respectively, when compared to the estimated values for winter Chinook (Table 6a).

As noted in Kocik and Taylor (1987), factors limiting production are typically a combination of biotic and abiotic factors. The sources of variability relating to fall FEJPIs are directly and indirectly related to adult abundance, but abundance alone does not explain the low CV in fall run juvenile production. A simple, albeit incorrect, conclusion might be that adult escapement of fall Chinook in some years exceeds the useable spawning area of the system (Bovee 1982, Connor et al. 2001) or optimal spawning efficiency (Wales and Coots 1955). Upon closer examination of the likely origin(s) of juvenile production, the data indicate substantial variability in the distribution of fall run adults between the mainstem Sacramento River and tributaries, including Clear Creek and Battle Creek, between years. Proportions of returning adults within the mainstem and Battle Creek have demonstrated high degrees of variability (Figure 26). The overwhelming return of fall run to Battle Creek in 2002 resulted in the lowest value of fall Chinook recruits per female (*N* = 89) which was outside two standard deviations of the average (Table 6a). The number of adults returning to the CNFH clearly overwhelmed the capacity of Battle Creek to produce juveniles. Sub-optimal wetted useable spawning area (Bovee 1982), red superimposition (McNeil 1968, Heard 1978), and female stress resulting in egg retention (Neave 1953, Foerster 1968) were likely just some of the factors that reduced the overall productivity of the 2002 fall Chinook adults returning to the Upper Sacramento River.

In years when estimates of fall Chinook production were at their highest in terms of recruits/females (Table 6a), the proportions spawning in the mainstem and combined tributaries were closest to 50:50. Further examination indicates that when contributions from the Battle and Clear Creeks accounted for equal proportions (i.e., 25% each), peak values of ~1,500 recruits/females were estimated to have been produced resulting in the highest net spawning efficiency (Wales and Coots 1955). Optimal natural juvenile fall Chinook production values in the Upper Sacramento River system could result under some conditions if integration of restoration projects on Battle and Clear Creeks integrate with mitigation projects (e.g., CNFH production) for the mainstem Sacramento River. The effect of consistent hatchery fall Chinook production on Battle Creek irrespective of natural fish production in the Sacramento and Chinook-bearing tributaries should be considered for further evaluation as was noted in Williams (2006). The effects of restoration of Clear Creek appear to be providing production benefits on stream and basin wide scales. Management prerogatives and actions related to the CVP affect both factors, to varying degrees, and decisions should be prioritized to attain optimal results for both fisheries and water operations.

Late-fall Chinook FEJPIs indicated high variability (CV = 170%; Table 6b), but a strong correlation with escapement estimates (r^2=0.67; Figure 20b). The magnitude of late-fall FEJPIs were consistently an order of magnitude less than FEJPIs of fall Chinook. One exception was 2002, which increased the CV for the eleven-year period by 100%

(Table 6b). The fall and late-fall adult Chinook escapement values of 2001 and 2002 were high compared to the other 10 years of data (Azat 2013). A large run of late spawning fall run may also have contributed to the large number of juvenile fish falling within the late-fall size-class according to LAD criteria, but the adult estimate could have suffered similar inaccuracies in run assignment. Variability in CV values of anadromous fish was described by Rothchild and Dinardo (1987) as being inversely related to the number of years included within the time series analyses. While 2002 appears to be an outlier in this data set, it is likely with more years of data collection and analyses the CV associated with late-fall production would be more commensurate with other runs of Chinook.

The stream-type migration strategy noted by Moyle (2002) and our size classification method categorized the majority of late-fall outmigrants as smolts ($\bar{y}$ = 62%) which inflated the late-fall FEJPIs greatly at times (Table 5b, Table 6b). Recruits per female and similarly egg-to-fry survival had low CVs and the lowest average values of 131 and 2.8%, respectively, in comparison to other runs (Table 6b). This was unexpected as this metric does not appear to apply well to a run that was sampled primarily as smolts ($\bar{y}$ = 62%) over eleven years. Moreover, fry-equivalent calculations based on a static fry-to-smolt survival estimate of 59% (Hallock undated) was unlikely to be an accurate constant for late-fall Chinook as it was calculated from hatchery-based fall Chinook survival data. The fact that correlations with adult escapement were determined to be significant and moderately strong was unexpected given the vagaries of sampling late-fall Chinook smolts and the use of the static 59% survival estimate inversely applied to the majority of the run sampled. Additionally, difficulties with performing carcass surveys for late-fall Chinook due to low visibility, winter flow events or logistical issues (Killam 2009 and 2012) typically result in sub-optimal sampling conditions and, assumedly, would reduce the accuracy of the adult estimate.

Overall, production of late-fall Chinook appears low and the run has been characterized by some as vulnerable to extinction (Moyle et al. 2008, Katz et al. 2012). Greater attention to the relatively low abundance levels and juvenile rearing habitat needs of this genetically distinct run (Banks et al. 2000, Garza et al. 2007, Smith et al. 2009) with its unique over-summering, relatively long freshwater residency (Randall et al. 1987) and large size-at-outmigration strategy (Zabel and Achord 2004) should be afforded. The life-history strategies of late-fall Chinook have likely allowed them to persist in the Upper Sacramento River system as they occupy a distinct ecological niche. Juvenile monitoring of this run could benefit greatly if confidence in the accuracy of run assignment of juveniles was examined using non-lethal genetic techniques (Harvey and Stroble 2013).

Comparisons between winter Chinook adults and juvenile production began early using data generated by this monitoring project. Martin et al. (2001) demonstrated a strong relationship with only 5 years of data. The annual analyses of the winter FEJPI and adult estimates continually indicated a strong relationship with the addition of each year’s data (See Gaines and Poytress 2003, Poytress and Carrillo 2008, Poytress and Carrillo 2012). The analysis of the most recent 11 years of data continues to indicate a strong relationship between the two variables even as adult escapement values have varied an order of magnitude.

Winter Chinook FEJPIs indicated mild variability (CV = 67%; Table 6c) and a very strong level of significance and correlation with female adult escapement estimates (r^2 =0.90; Figure 20c). Intensive adult and juvenile monitoring for this ESA listed endangered species coupled with superlative sampling conditions, in most years, appears to have resulted in very high quality information regarding the status and trends in adult and juvenile population abundance.

Egg-to-fry survival estimates generated from annual winter Chinook data indicate a range of values between 15 and 49% (Table 6c). At first glance, this appeared counterintuitive based on the highly regulated Sacramento River system (e.g., flow and water temperatures) that typically exists during the winter Chinook spawning period. The average egg-to-fry survival estimate of 26% is considerably higher than that determined from other studies on Pacific salmonids ($\bar{y}$ = 15%; e.g., Wales and Coots 1955) but was consistent with highly regulated aquatic systems (Groot and Margolis 1991). A very low CV of 38% also appeared consistent with a regulated system. Recruits per female, similarly, indicated a low CV of 36% and the second highest average value of 1,349 (Table 6c).

Natural log transformed adult female estimates influenced juvenile production and a significant relationship was determined accounting for roughly half of the variability associated with egg-to-fry survival rates (r^2 = 0.51, *df* = 10, *P* = 0.012). Densities of winter Chinook spawners are much lower currently than in the years estimated following the completion of Shasta Dam (USFWS 2001). Completion of the re-engineered Anderson-Cottonwood Irrigation District fish ladders in 2001 resulted in greater access and subsequently a greater concentration of spawners in the uppermost reaches accessible to anadromous fish (USFWS 2006-2011). Competition for optimal spawning habitat can result in lower juvenile production if sub-optimal wetted useable spawning area (Bovee 1982), red superimposition (McNeil 1968, Heard 1978), and female stress resulting in egg retention (Neave 1953, Foerster 1968) occur to varying degrees. Low resolution carcass recovery data (e.g., reach specific) indicate an abundance of spawners utilizing the uppermost 6 river miles of the Sacramento River (USFWS 2006-2011) even as seemingly suitable habitat has been made available for approximately 20+ river miles downstream of the terminus at Keswick Dam (RM 302). Geist et al. (2002) studied physiochemical characteristics affecting redd site selection preferences by Chinook and different growth and development rates have been attributed to different segments within the same river (Wells and McNeil 1970). High resolution redd surveys or spawning area mapping employing a GIS spatial analytical framework (Earley et al. 2013b) may shed light on the variability associated with winter Chinook spawning habitat over a variety of adult abundance levels. Analyses of these types of data could result in less uncertainty over the annual specific density dependent mechanisms affecting juvenile production and provide direction for future restoration activities for winter Chinook.

Spring run Chinook FEJPIs were the lowest of all four runs monitored and indicated the lowest variability (CV = 41%; Table 6d). No relationship with female adult escapement estimates was detected (r^2 =0.00; Figure 20d) and may be attributed substantially to measurement error (Sokal and Rohlf 1995). Estimates of recruits per female averaged 3,122 and the egg-to-fry survival value averaged 61.5%. These values appear unreasonable outside of a hatchery environment and well above those found for other runs (this report) and other studies (e.g., Wales and Coots 1955, Groot and Margolis 1991). Individual annual estimates varied moderately (CV= 70.8%) and nearly half appeared highly unlikely, with some values exceeding the number of eggs deposited by spawners (Table 6d).

Spring Chinook juvenile fish production estimates at RBDD were the least accurate and currently constitute 2.1%, on average, of total annual Chinook production above RBDD. Mainstem Sacramento River spawner estimates ranged from a low of 0 to a high of 370 between 2002 and 2012. Annual indexes of spring Chinook adult abundance above RBDD during the same years constitute 2.7% of the total escapement estimated in the Sacramento River system (Azat 2013). Given the relatively sporadic and low adult abundance levels, vagaries of using LAD criteria and annual CNFH fall Chinook production releases with fractional mark rates, no relationship could be found between adult escapement and spring Chinook FEJPIs when attempting to use methods to correct for these inaccuracies. The effects of inaccurate spring run assignment did not appear to affect the FEJPIs of other runs (e.g., winter or fall run) and therefore were not considered biologically significant. Genetic monitoring of fry in the fall after emergence from tributaries where emergence and migration data is collected (e.g., Earley et al. 2013a) may allow for more accurate estimation of the contributions of this run to the Upper Sacramento River outmigrant population.

Green Sturgeon Capture Dynamics.—Rotary traps were originally constructed to sample outmigrating salmonid smolts, but have been effective in sampling a variety of downstream migrating fish (Volkhardt et al. 2007). Rotary traps sampling at RBDD have been effective at monitoring temporal and spatial trends in relative abundance of Green Sturgeon since 1995 (Gaines and Martin 2002).

Annual adult Green Sturgeon aggregations were observed behind the RBDD when gates were lowered each spring (Brown 2007). Green sturgeon larvae were captured in 2012 (Table 7), the first year the RBDD gates were not lowered as it was replaced by a permanent pumping plant (NMFS 2009). Spawning was determined to have occurred in multiple locations as far as 20 river miles upstream of RBDD (Poytress et al. 2009-2013). The location of the RBDD rotary traps has been confirmed to be within the Green

Sturgeon spawning grounds as eggs were sampled directly below the RBDD and upstream of the RBDD traps in multiple years (Poytress et al. 2009, 2010, 2012).

Total length distribution data from Green Sturgeon collections at RBDD indicate a narrow and consistent size-class of larvae (Figure 21a). These data are consistent with laboratory-based studies conducted by Kynard et al. (2005) on the behavior of early life intervals of Klamath River Green Sturgeon. Their study determined that larvae migrated during two distinct periods (i.e., two-step migration). The first migration of newly exogenous feeding larvae was determined to be an initial dispersion from production areas. The second migration (of juveniles) to overwintering areas occurred in the fall some 180 days after hatching, on average. Our rotary trap data suggest we are sampling exclusively the initial redistribution of larvae from egg incubation and hatching areas.

Benthic D-net sampling conducted by Poytress et al. (2010-2011) targeted the lowest portion of the water column (inverse of rotary traps) and consistently captured Green Sturgeon larvae of the same size-class and temporal distribution pattern as rotary traps. D-net samples were collected between May and early-August (See Figure 21b for corresponding RST data only) downstream of spawning areas in years 2008-2011; even as no larvae were collected by rotary traps in 2008. Larvae were sampled by both methods primarily in the thalweg and in river velocities >/= 1.3 ft/sec[8]. Conversely, zero *juveniles* were collected with benthic D-nets in a pilot study (Poytress et al. 2013) targeting this life-stage and habitat type in the benthos during the fall period. Rotary traps have collected a few sporadic juveniles (e.g., outliers; Figure 21a) over the entire sample record of the project. These data indicate that Green Sturgeon juveniles are no longer utilizing our sampling region or more likely using a different habitat type (Hayes et al. 1996). Accordingly, rotary traps appear to be a relatively ineffective gear type for sampling the secondary juvenile sturgeon migration.

Protections afforded to ESA listed southern distinct population segment of Green Sturgeon (since 2006), limited quantities of larvae, and the small size at capture have not allowed their drift distances (Auer and Baker 2002), rates (Braaten et al. 2008), or rotary trap efficiencies to be calculated for the initial dispersion migration of Sacramento River Green Sturgeon at RBDD. Relative abundance indices for Green Sturgeon were highly variable, typically low valued at <1.0 fish/ac-ft sampled (Table 7), and contained one extraordinarily strong year-class (Figure 21c). As noted by Allen and Hightower (2010), variations in recruitment by orders of magnitude between years is common among fish stocks. Moreover, strong and weak year classes greatly influence adult fish populations. Green sturgeon relative abundance indices should not be interpreted as recruitment to the adult population, but should be viewed as a production metric influencing recruitment (e.g., age-0 year class strength). Alternately,

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[8] Rotary traps generally require a minimum water velocity of 1.2 ft/sec to operate properly. D-nets sampled velocities ranging from 1.3 – 6.6 ft/sec. RST' sampled velocities ranging from 1.3 – 6.3 ft/sec.

Green Sturgeon larvae relative abundance indices could be viewed as an indirect metric for adult spawning population densities *upstream* of RBDD if genetic monitoring were conducted consistently (Israel and May 2010).

Lamprey Capture Dynamics.— Similar to Green Sturgeon, rotary trap sampling for Chinook salmon has provided the additional benefit of capturing out-migrating lamprey ammocoetes and juveniles. Greater attention to this ancestor of the earliest vertebrates (Moyle 2002) has recently been paid by the USFWS since it was petitioned for listing under the ESA in 2003 (Nawa et al. 2003). Although not listed due to inadequate data on the species' range and threats, the USFWS has engaged in a strategy to collaboratively conserve and restore Pacific Lamprey throughout their native range. Through the formation and development of the Pacific Lamprey Conservation Initiative, an assessment of Lamprey populations in California has recently been completed (Goodman and Reid 2012). The assessment noted that Lamprey species had been extirpated from at least 55% of their historical habitat north of Point Conception, CA by 1985. Long-term monitoring data sets including the RBDD rotary trap data, utilizing temporal and spatial distribution patterns as well as size-class and relative abundance levels of lamprey, can aid in the assessment and conservation of this ecologically vital species (Close et al. 2002).

Variability in annual size-class total length distributions was typically minor for both lamprey life stages sampled (Figure 22a and Figure 23a). Ammocoetes were slightly smaller than macropthalmia and slightly more variable in their annual average length distributions valued at 110 mm TL (CV= 4.6%; Table 8a). Pacific Lamprey macropthalmia were the dominant life stage sampled and the median size at capture was consistently near 125 mm TL (CV= 1.6%; Table 8b). Adults, typically noted as outliers, were encountered in much lower frequencies and were considered upstream migrants inadvertently captured when the RBDD gates were lowered as they sought upstream passage around the partial migration barrier.

Temporal distribution patterns indicated that ammocoetes and macropthalmia migrate past RBDD year-round. Ammocoetes, on average, were sampled regularly throughout the year (Figure 22b), whereas macropthalmia moved, en masse, episodically between November and March (Figure 23b). These data are consistent with studies of macropthalmia in the Columbia River system as noted by Close et al. (1995) and Kostow (2002).

Relative abundance indices of ammocoetes (Figure 22c) varied little between years and little overall when compared with macropthalmia (Figure 23c). Macropthalmia abundance indices varied considerably between years (Table 8b). On average, macropthalmia relative abundance was six times that of ammocoetes indicating metamorphosis and redistribution to different habitats from those used for rearing by ammocoetes (Goodman and Reid 2012). Differences in the relative abundance CV's of the two life stages likely indicates differences in catchability (Hubert and Fabrizio 2007) or habitat use (Hayes et al. 1996), variable migration trigger effects, or variability in sampling effort that often occurred during periods of macropthalmia migration.

Water Temperature and Juvenile Fish Dynamics.—Slight variation within and among salmonid runs (including *O. mykiss*) and years was noted for water temperatures found at RBDD (Tables 9a-e). Nonetheless, Upper Sacramento River salmonids were subjected to a relatively wide 20 degree range of water temperatures. Temperatures were recorded between 44 and 64 degrees with the average being 55 degrees each year. As summarized in Vogel and Marine (1991), the range of temperatures experienced by Chinook fry and pre-smolt/smolts in the last 11 years of passage at RBDD have been within the optimal range of thermal tolerances for survival.

Sacramento River water temperatures below Shasta/Keswick dams can be managed at certain times of the year under some conditions through discharge management to provide selective withdrawal at submerged intakes (USBR 1991 & 1994, Vermeyen 1997). Ambient air temperatures typically regulate river water temperatures during winter and early spring periods while storage and flood control operations are preeminent. The water temperatures recorded during the last 11 years appear to have been favorable for extant spring run spawners, and more so for fall and late-fall run Chinook and *O. mykiss* spawner and outmigrant populations.

The most vulnerable Chinook run to temperature management operations conducted by the USBR is winter Chinook (NMFS 2009). Temperature management of the Sacramento River via Shasta/Keswick releases by the USBR for winter Chinook appeared to be effective during the last 11 years as evidenced by the relatively favorable and stable egg-to-fry survival estimates (Table 6c). Moreover, temperature management of the upper 50 river miles of the Sacramento River aimed at winter Chinook resulted in benefits to over-summering late-fall Chinook pre-smolts and a relatively small proportion of fall Chinook smolts.

Temperature management during the summertime aimed at winter Chinook may have indirectly favored the resident form of *O. mykiss*. As noted by Lieberman et al. (2001), altering the thermal regime and food web structure by way of temperature management likely affects the proportion of anadromous to resident forms in large rivers. Lamprey species have likely benefitted from temperature management as temperatures for early life stages of lamprey in the mainstem Sacramento River appear to have been, on average, optimal (Meeuwig et al. 2005) in the last 11 years (Table 9g).

Green Sturgeon have likely benefitted from temperature management efforts aimed at winter Chinook spawning and production, albeit less comprehensively. Van Ennennaam et al. (2005) determined Green Sturgeon egg development temperatures to be optimal between 57.0 and 63.5° F. Mayfield and Cech (2004) determined optimal temperatures for larval development to be between 59.0 and 66.2°F. Temperatures recorded at RBDD during larval capture periods averaged 58.3°F and were generally within sub-optimal (lower end) to optimal ranges (Table 9f). A weak negative relationship between Green Sturgeon CPUV and water temperatures was detected in our analysis indicating greater capture rates at lower water temperatures (Figure 24d). The slightly sub-optimal temperatures might result in larvae migrating from incubation areas prematurely. Conversely, the optimal thermal environment of the lab-based migration data from Kynard et al. (2005) resulted in very similar migration timing between the lab and larval captures in rotary traps in terms of days post hatch (Poytress et al. 2013). Sacramento River Green Sturgeon larvae appear to be following their natural life-history migration patterns as opposed to being coerced from their incubation areas due to sub-optimal water temperatures at RBDD. This may not be true for larvae migrating some 20 miles upstream where the effects of temperature management may have a more pronounced negative effect on Green Sturgeon larvae (Poytress et al. 2013). Temperature management for Chinook may also have the indirect negative effect of redirecting the spawning habitat of Green Sturgeon adults by 20 river miles. A habitat comparison study on the relative value of the upper 20 river miles of the Sacramento River versus 20 lower river miles of habitat currently benefitting Green Sturgeon adult spawners and eggs from temperature management efforts should be conducted.

River Discharge, Turbidity, and Juvenile Fish Dynamics.—Volkhardt et al. (2007) stated that “flow” (i.e., discharge) was a dominant factor in juvenile trapping operations. Trapping efficiency and migration rates are affected by flow and the RBDD rotary trap passage data reflect these statements well. Exploratory plots demonstrating fry (Appendix 2, Figures A1-A11) and pre-smolt/smolt winter Chinook passage (Appendix 2, Figures A12-A23) were produced to illustrate the effects of environmental variables on fish migration. Turbidity was plotted, but not included in the final plots presented as the effects could not be deciphered from discharge at the daily scale of analyses.

The effects of river discharge on turbidity and resultant fish passage are complex in the Upper Sacramento River where ocean and stream-type Chinook of various size-classes (i.e., runs, life stages and ages) migrate daily throughout the year. Decreases in discharge in the Shasta/Keswick dam regulated Sacramento River, typical of late summer to early winter periods, appear to coincide with relatively clear water conditions and low turbidity (e.g., ~ 1.5 NTU) at RBDD. Fall or early winter freshets and winter rain-driven storm events result in highly variable increases in discharge levels and turbidity measures in terms of the magnitude and duration depending upon the source(s) of run-off.

A course scale analyses of fish passage and river discharge and turbidity measurements during storm events typically indicates a pattern that fish passage increases with simultaneous increases in both variables. Inspection of Chinook passage on a daily time step typically demonstrate a reduction in fish passage a day prior to a storm or rain-event during periods of stable river discharge. As storms produced increases in run-off or discharge from tributary inputs outside of the Shasta/Keswick dam complex, mean daily turbidity typically increased and fish passage began to increase. When storm related increases in discharge diminished, turbidity diminished, but Chinook passage often increased greatly for 24-72 hours after the peak flow event.

One problem confounding the results of storm and fish passage observations and analyses was that sampling during large storm run-off/discharge events often ceased due to safety concerns, concerns for fish impacts or simply due to the inability to sample the river when woody debris stop rotary traps from operating properly. In some years, storm events resulted in discharge levels too great to sample effectively or damaged traps which resulted in numerous days or weeks un-sampled afterwards. The results are typically negative bias in passage estimates if days following the peak discharge or concurrent turbidity events are un-sampled. Alternately, the direction of bias can be positive depending on time of year, interpolation methods, sample effort during extended storm periods, or fish developmental stage.

A fine scale, hourly analysis of fish passage, river discharge and turbidity during storm events indicated a more intricate relationship between the variables. As a comparison, two separate storm events (December 2005 and November 2012) were analyzed (Figure 27a/b). In 2005, 24-hour samples were conducted prior to and after the peak flow period which was missed due to an inability to sample the river as it more than quintupled in discharge (i.e., 7,000 CFS to ~35,000 CFS). During this storm event, sampling was conducted following the peak of river discharge as river stage decreased, but while turbidity continued to peak (Figure 27a). The planned 24-hour sample had to be cut short due to the huge influx of fry and smolt passage that occurred during the turbidity increase (i.e., from 10’s to 1,000’s per hour) and the need to reduce the potential impact to listed winter Chinook.

During a November 2012 storm event, a different strategy was employed to collect data more effectively throughout the storm period. For this event, we randomly sampled portions of the day and night in an attempt to manage the huge influx of fish anticipated to occur during the year’s first storm event. Between 11/17/12 and 11/23/12, the project was able to collect 7-randomly selected samples that occurred throughout the first major river stage increase (Figure 27b). Samples were collected during increases and decreases in river stage. Samples were also collected prior to, during, and following a substantial increase in turbidity that lagged behind the initial stage increase by nearly 12 hours (Figure 27b). Fry and pre-smolt/smolt Chinook and juvenile lamprey fish passage increased exponentially. The peak period of fish capture occurred following the peak in river stage and during the increase and peak periods of turbidity measurements taken at RBDD. Capture rates subsided in the following days, but then increased greatly during the night-time period at the beginning of the next stage increase (Figure 27b).

Overall, it appears that flow and turbidity are important drivers for fish passage. The RBDD rotary trap data indicate that increased turbidity often results in greater fish passage than increases in river discharge or stage alone which often occur as part of water management operations at Shasta Dam. The two variables generally increase sequentially with discharge increases followed by turbidity increases (Figure 27a/b). Fish passage increases often coincide with the increase in turbidity which can often be sampled more effectively than increases in river discharge and may result in positive bias of juvenile fish passage estimates if the peak turbidity event is sampled compared to the peak flow event.

The importance of the first storm event of the fall or winter period cannot be overstated. Chinook smolt and juvenile lamprey passage increased exponentially and fry passage can be significant if first storms occur as fall Chinook begin to emerge. Fishery and water operations managers should be aware of the importance of the first Sacramento River stage increases following the summer and fall Sacramento River flow regulation period. The redistribution of winter and over-summering fall and late-fall Chinook smolts, or more generally, all anadromous juvenile fish[9] migrating from the Upper Sacramento River to the lower river and Sacramento San-Joaquin Delta with the first storm events of each water year should be incorporated into management plans for Delta operations.

Moon Illuminosity and Juvenile Fish Dynamics.—As noted in Hubert and Fabrizio (2007), species and life stages within species exhibit differing behaviors and therefore catchability in response to light levels. Gaines and Martin (2002) determined that Chinook passage occurred primarily during nocturnal periods except when turbidity levels and discharge increased with storm events. Further analyses of the effects of moon phase and ambient light levels in a statistical framework may be warranted for Chinook salmon as trends were detected based on observations. Rotary trap passage data indicated winter Chinook fry exhibit decreased nocturnal passage levels during and around the full moon phase in the fall (Appendix 3, Figures A1-A11). Pre-smolt/smolt winter Chinook appeared less influenced by night-time light levels and much more influenced by changes in discharge levels (Appendix 3, Figures A12-A23). A similar phenomenon was noted by Reimers (1971) for juvenile fall Chinook in Edson Creek, Oregon. Alternately, more data concerning night time cloud cover may further clarify the behavior associated with moon illuminosity as pre-smolt/smolts were more likely to encounter unclear night time weather between late October and December each year.

Spring, fall and late-fall Chinook fry exhibited varying degrees of decreased passage during full moon periods, albeit storms and related hydrologic influx dominated peak migration periods. *O. mykiss* relative abundance was not analyzed with respect to moon illuminosity. Lamprey CPUV regression analyses indicated a significant, but nearly imperceptible relationship (Figure 25a) likely due to the fact that lamprey are captured throughout the year under nearly all conditions. Green Sturgeon regression analysis

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[9] Juvenile Green Sturgeon have been captured sporadically during the first flow events along with large numbers of Pacific Lamprey juveniles and ammocoetes.

indicated no significant linear relationship between moon illuminosity and relative abundance (Figure 24a). Migration of age-0 Green Sturgeon larvae has been determined to occur during nocturnal hours (Kynard et al. 2005) primarily between 21:00 and 02:00 using D-nets (Poytress et al. 2011) and was presumed to be similar for rotary traps as periodic diel sampling events have not collected sturgeon during daytime sample periods.

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Literature Cited

Allen, M. S. and J.E. Hightower. 2010. Fish Population Dynamics:Mortality, Growth and Recruitment. Pages 43-79 *in* W.A. Hubert and M. C. Quist, editors. Inland Fisheries Management, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Auer, N.A., and E.A. Baker. 2002. Duration and drift of larval lake sturgeon in the Sturgeon River, Michigan. Journal of Applied Ichthyology 18:557-564.

Azat, J. 2013. GrandTab 2013.04.18. California Central Valley Chinook Population Database Report. California Department of Fish and Wildlife. http://www.calfish.org/tabid/213/Default.aspx

Banks, M.A., Rashbrook, V.K., Calvaetta, M.J., Dean, C.A., and D. Hedgecock. 2000. Analysis of microsatellite DNA resolves genetic structure and diversity of chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Canadian Journal of Fisheries and Aquatic Sciences 57:915-927.

Banks M.A. and D.P. Jacobson. 2004. Which genetic markers and GSI methods are more appropriate for defining marine distribution and migration of salmon? North Pacific AnadromousFish Commission Technical Note 5, 39-42.

Beacham, T.D. and C.B. Murray. 1990. Temperature, Egg Size, and Development of Embryos and Alevins of Five Species of Pacific Salmon: A Comparative Analysis. CTransactions of the American Fisheries Society. 119:6: 927-945.

Borthwick, S. M. and R. R. Corwin. 2011. Fish entrainment by Archimedes lifts and an internal helical pump at Red Bluff Research Pumping Plant, Upper Sacramento River, California: February 1997 – May 2000. Red Bluff Research Pumping Plant Report Series, Volume 13. U.S. Bureau of Reclamation, Red Bluff, CA.

Bovee KD. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Washington, DC:U.S. Fish and Wildlife Service, FWS/OBS-82/26.

Braaten, P. J., Fuller, D.B., Holte, L.D., Lott, R.D., Viste, W., Brandt, T.F. and R.G. Legare. 2008. Drift Dynamics of Larval Pallid Sturgeon and Shovelnose Sturgeon in a Natural Side Channel of the Upper Missouri River, Montana. North American Journal of Fisheries Management. 28:808-826.

Brown, K. 2007. Evidence of spawning by green sturgeon, *Acipenser medirostris,* in the Upper Sacramento River, California. Environmental Biology of Fishes 79:297-303.

Brown, R. L. and S. Greene. 1992. Biological Assessment:Effects of the Central Valley Project and State Water Project Delta Operations on Winter-Run Chinook Salmon. California Department of Water Resources.

California Department of Fish and Game (CDFG). 2001. Spring-run Chinook Salmon. Annual Report Prepared for the Fish and Game Commission. Habitat Conservation Division, Native Anadromous Fish and Watershed Branch. March, 2001.

Carlander, K. D. 1969. Handbook of freshwater fishery biology. Volume One. The Iowa State University Press, Ames.

Close, D. A., M. S. Fitzpatrick, H. W. Li, B. Parker, D. Hatch, and G. James. 1995. Status report of the Pacific lamprey (*Lampetra tridentata*) in the Columbia River Basin. (Project No. 94−026,Contract No. 95BI9067). Prepared for U.S. Department of Energy, Bonneville Power Administration, Portland, Oregon. 35 pp.

Close, D. A., M. S. Fitzpatrick, and H. W. Li. 2002. The ecological and cultural importance of a species and risk of extinction, Pacific lamprey. Fisheries 27(7):19-25.

Colby, D. J., and M. R. Brown. 2013. Juvenile salmonid monitoring in Battle Creek, California, November 2010 through June 2011. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Connor, W. P. , Garcia, A. P., Connor, A. H., Garton, E. O., Groves, P, A, and Chandler, J.A. 2001. Estimating the carrying capacity of the Snake River for fall chinook salmon redds. Northwest Science. 75: 363-371.

Docker, M. F., and D. D. Heath. 2003. Genetic comparison between sympatric anadromous steelhead and freshwater resident rainbow trout in British Columbia, Canada. Conservation Genetics 4:227–231.

Donohoe, C. J., and R. Null. 2013. Migratory history and maternal origin of rainbow trout (Oncorhynchus mykiss) returning to Coleman National Fish Hatchery in 2008. Institute of Marine Sciences, University of California, Santa Cruz, Santa Cruz, California.

Earley, J. T., D. J. Colby, and M. R. Brown. 2013a. Juvenile salmonid monitoring in Clear Creek, California, from October 2010 through September 2011. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Earley, L. A., S.L. Giovannetti, and M.R. Brown. 2013b. Fall Chinook Salmon Redd Mapping for the Clear Creek Restoration Project, 2008-2012. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Fisher, F.W. 1992. (DRAFT) Chinook Salmon, Oncorhynchus Tshawytscha, Growth and Occurrence in the Sacramento-San Joaquin River System. Inland Fisheries Division of California Department of Fish and Game. June, 1992.

Foerster, R. E. 1968. The sockeye salmon, *Oncorhynchus nerka*, Fisheries Research Board of Canada Bulletin 162.

Gaines, P.D. and C. D. Martin. 2002. Abundance and Seasonal, Spatial and Diel Distribution Patterns of Juvenile Salmonids Passing the Red Bluff Diversion Dam, Sacramento River. Red Bluff Research Pumping Plant Report Series, Volume 14, U.S. Fish and Wildlife Service, Red Bluff, CA.

Gaines, P.D. and W.R. Poytress. 2003. Brood-year 2002 winter Chinook juvenile production indices with comparisons to adult escapement. U.S. Fish and Wildlife Service report to California Bay-Delta Authority. San Francisco, CA.

Gaines, P.D. and W.R. Poytress. 2004. Brood-year 2003 winter Chinook juvenile production indices with comparisons to adult escapement. U.S. Fish and Wildlife Service report to California Bay-Delta Authority. San Francisco, CA.

Garza, J.C., Blankenship, S.M. Lemaire, C., and G. Charrier. 2007. Genetic population structure of Chinook salmon (*Oncorhynchus tshawytscha*) in California's Central Valley. Draft Final Report for CalFed Project "Comprehensive Evaluation of Population Structure and Diversity for Central Valley Chinook Salmon". 82pp.

Geist, D.R., T.P. Hanrahan, E.V. Arntzen, G.A. McMichael, C.J. Murray, and Y.J. Chien. 2002. Physiochemical characteristics of the hyporheic zone affect redd site selection by chum salmon and fall Chinook salmon in the Columbia River. North American Journal of Fisheries Management 22: 1077-1085.

Goodman, D.H. and S.B. Reid. 2012. Pacific Lamprey (*Entosphenus tridentatus*) Assessment and Template for Conservation Measures in California. U.S. Fish and Wildlife Service, Arcata, California. 117 pp.

Greene, S. 1992. Daily fork-length table from data by Frank Fisher, California Department of Fish and Game. California Department of Water Resources, Environmental Services Department, Sacramento.

Greenwald, G. M., J.T. Earley, and M.R. Brown. 2003. Juvenile salmonid monitoring in Clear Creek, California, from July 2001 to July 2002. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Groot, C. and L.Margolis. 1991. Pacific Salmon Life Histories. UBC Press, Vancouver, B.C.

Hallock, R.J. Undated. The status of inland habitat and factors adversely impacting salmon resources. Anadromous Fisheries Program, California Department of Fish and Game, Red Bluff, CA.

Hallock, R.J., W.F. Van Woert, and L. Shapolov. 1961. An Evaluation of Stocking Hatchery-reared Steelhead Rainbow Trout (*Salmo gairdnerii gairdnerii*) in the Sacramento River System. California Department of Fish and Game. Fish Bulletin 114. 74 p.

Harvey, B. and C. Stroble. 2013 Comparison of genetic versus Delta Model Length-at-Daterun assignments for juvenile Chinook salmon at state and federal south Delta salvage facilities. California Deparment of Water Resources. Submitted to Interagency Ecological Program for the San Francisco Bay/Delta Estuary. Technical Report 88, March 2013.

Hastie, T.J. and Tibshirani, R.J (1990) *Generalized Additive Models,* London: Chapman and Hall.

Hayes. D. B., C. Paolo Ferreri, and W. M. Taylor. 1996. Active Fish Capture Methods. Pages 193-220 *in* B.R. Murphy and D. W. Willis, editors. Fisheries Techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Heard. W. R. 1978. Probable case of streambed overseeding-1967 pink salmon, *Oncorhynchus gorbuscha*, spawners and survival of their progeny in Sashin Creek, southeastern Alaska. U.S. National Marine Fisheries Service Fishery Bulletin 76:569-582.

Hubert, W. A. 1996. Passive capture techniques. Pages 157-192 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Hubert, W. A. and M.C. Fabrizio. 2007. Relative abundance and catch per unit effort. Pages 279-326 *in* C.S. Guy and M.L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Israel, J.A., J.F. Cordes, M.A. Blumberg, and B. May. 2004. Geographic patterns of genetic differentiation among collections of green sturgeon. North American Journal of Fisheries Management 24:922-931.

Israel, J.A. and B. May. 2010. Indirect genetic estimates of breeding population size in the polyploidy green sturgeon (*Acipenser medirostris*). Molecular Ecology 19, 1058-1070.

Johnson, R. R. D.C. Weigand and F. W. Fisher. 1992. Use of growth data to determine the spatial and temporal distribution of four runs of juvenile chinook salmon in the Sacramento River, California. Report No. AFF1/FRO-92-15. U. S. Fish and Wildlife Service, Northern Central Valley Fishery Resource Office, Red Bluff, CA.

Johnson, R. R. and C. D Martin. 1997. Abundance and seasonal, spatial and diel distribution patterns of juvenile salmonids passing Red Bluff Diversion Dam, Sacramento River, July 1994 - June 1995. Red Bluff Research Pumping Plant Report Series, Volume 2. U. S. Fish and Wildlife Service, Red Bluff, CA.

Johnson M. R. and K. Merrick. 2012. Juvenile Salmonid Monitoring Using Rotary Screw Traps in Deer Creek and Mill Creek, Tehama County, California, Summary Report: 1994-2010. RBFO Technical Report No. 04-2012.

Katz, J., Moyle, P. B., Quinones, R.M., Israel, J.A. and S.E. Purdy. 2012. Impending extinction of salmon, steelhead and trout (Salmonidae) in California. Environmental Biology of Fish. Published online January 2012.

Killam, D. 2009. Chinook Salmon Populations for the Upper Sacramento River Basin 2008. Revised 1-11-2010. Northern Region-Department of Fish and Game, Sacramento River Salmon and Steelhead Assessment Project Technical Report No. 09-1.

Killam, D. 2012. Chinook Salmon Populations for the Upper Sacramento River Basin 2011. Northern Region-Department of Fish and Game, Sacramento River Salmon and Steelhead Assessment Project Technical Report No. 03-2012.

Kocik, J.F. and W.W. Taylor. 1987. Effect of Fall and Winter Instream Flow on Year-Class Strength of Pacific Salmon Evolutionarily Adapted to Early Fry Outmigration: A Great Lakes Perspective. American Fisheries Society Symposium 1 :430-440.

Kostow, K. 2002. Oregon lamprey: natural history status and analysis of management issues. Oregon Department of Fish and Wildlife, Corvallis, Oregon. 112 pp.

Kynard, B., E. Parker, and T. Parker. 2005. Behavior of early life intervals of Klamath River green sturgeon, *Acipenser medirostris*, with a note on body color. Environmental Biology of Fishes 72:85-97.

Lieberman, D. M., M. J. Horn, S. Duffy. 2001. Effects of a temperature control device on nutrients, POM, and plankton in the tailwaters below Shasta Lake, California. Hydrobiologia 452:191–202.

Lindley, S. T., C. B. Grimes, M. S. Mohr, W. Peterson, J. Stein, J. T. Anderson, L.W. Botsford, , D. L. Bottom, C. A. Busack, T. K. Collier, J. Ferguson, J. C. Garza,

A. M. Grover, D. G. Hankin, R. G. Kope, P. W. Lawson, A. Low, R. B. MacFarlane, K. Moore, M. Palmer-Zwahlen, F. B. Schwing, J. Smith, C. Tracy, R. Webb, B. K. Wells, T. H. Williams. 2009. What caused the Sacramento River Fall Chinook stock collapse? Pre-publication report to the Pacific Fishery Management Council.

Martin, C.D., P.D. Gaines and R.R. Johnson. 2001. Estimating the abundance of Sacramento River juvenile winter Chinook salmon with comparisons to adult escapement. Red Bluff Research Pumping Plant Report Series, Volume 5. U.S. Fish and Wildlife Service, Red Bluff, CA.

Mayfield, R.B. and J.J. Cech. 2004. Temperature effects on green sturgeon bioenergetics. Transactions of the American Fisheries Society 133:961-970.

McNeil, W. J. 1968. Migration and distribution of pink salmon spawners in Sashin Creek in 1965, and survival of their progeny. U.S. Fish and Wildlife Service Fishery Bulletin 66:575-586.

Meeuwig, M. H., J. M. Bayer, and J. G. Seelye. 2005. Effects of temperature on survival and development of early life stage Pacific and western brook lamprey. Transactions of the American Fisheries Society 134:19-27.

Moffett, J.W. 1949. The First Four Years of King Salmon Maintenance Below Shasta Dam, Sacramento River, California, California Department of Fish and Game 35(2): 77-102.

Moyle, P. B. 2002. Inland fishes of California. University of California press. Berkeley, California.

Moyle, P.B., J.A. Israel, and S.E. Purdy. Salmon, Steelhead, and Trout in California in California, Status of an Emblematic Fauna. Report Commissioned by California Trout, 2008. Center for Watershed Sciences, University of California, Davis. Davis, CA.

Mundie, J.H. and R.E. Traber. 1983. Movements of coho salmon *Onchorhynchus kisutch* fingerlings in a stream following marking with a vital stain. Canadian Journal of Fisheries and Aquatic Science 40:1318-1319.

National Marine Fisheries Service (NMFS). 2009. Biological Opinion on the Long-term Central Valley Project and State Water Project Operations Criteria and Plan. NOAA (National Oceanic and Atmospheric Administration), National Marine Fisheries Service, Southwest Fisheries Service Center, Long Beach, California.

Nawa, R. K., J. E. Vaile, P. Lind, T. M. K Nadananda, T. McKay, C. Elkins, B. Bakke, J. Miller, W.Wood, K. Beardslee, and D. Wales. 2003. A petition for rules to list:

Pacific lamprey (*Lampetratridentata*); river lamprey (*Lampetra ayresi*); western brook lamprey (*Lampetra richardsoni*); and Kern brook lamprey (*Lampetra hubbsi*) as threatened or endangered under the Endangered Species Act. January 23, 2003.

Neave, F. 1953. Principles affecting the size of pink and chum salmon populations in British Columbia. Journal of Fisheries Research Board of Canada. 9:450-491.

Pope, K. L., C. G. Kruse. 2007. Condition. Pages 423-471 *in* C. S. Guy and M. L. Brown, editors. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland.

Poytress, W.R., and F. D. Carrillo. 2008. Brood-year 2006 winter Chinook juvenile production indices with comparisons to juvenile production estimates derived from adult escapement. Report of U.S. Fish and Wildlife Service report to California Bay-Delta Authority and California Department of Fish and Game, Sacramento, CA.

Poytress, W.R., and F. D. Carrillo. 2012. Brood-year 2010 winter Chinook juvenile production indices with comparisons to juvenile production estimates derived from adult escapement. Report of U.S. Fish and Wildlife Service report to California Department of Fish and Game and US Bureau of Reclamation.

Poytress, W.R., J.J. Gruber, D.A. Trachtenbarg, and J.P. Van Eenennaam. 2009. 2008 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to US Bureau of Reclamation, Red Bluff, CA.

Poytress, W.R., J.J. Gruber, and J.P. Van Eenennaam. 2010. 2009 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Poytress, W.R., J.J. Gruber, and J.P. Van Eenennaam. 2011. 2010 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Poytress, W.R., and F. D. Carrillo. 2012. Brood-year 2010 winter Chinook juvenile production indices with comparisons to juvenile production estimates derived from adult escapement. Report of U.S. Fish and Wildlife Service report to California Department of Fish and Game and US Bureau of Reclamation.

Poytress, W.R., J.J. Gruber, and J.P. Van Eenennaam. 2012. 2011 Upper Sacramento River Green Sturgeon Spawning Habitat and Larval Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation, Red Bluff, CA.

Poytress, W.R., J.J. Gruber, C.E. Praetorius, and J.P. Van Eenennaam. 2013. 2012 Upper Sacramento River Green Sturgeon Spawning Habitat and Young-of-the-Year Migration Surveys. Annual Report of U.S. Fish and Wildlife Service to U.S. Bureau of Reclamation,Red Bluff, CA.

Pyper, B. and C. Justice. 2006. Analyses of rotary screw trap sampling of migrating juvenile Chinook salmon in the Stanislaus River, 1996-2005. Cramer Fish Sciences, Gresham, Oregon.

Pyper, B., T. Garrison., S. Cramer, P.L. Brandes., D.P. Jacobsen., and M. A. Banks. 2013. Absolute abundance estimates of juvenile spring-run and winter-run Chinook salmon at Chipps Island. Cramer Fish Sciences Technical Report for U.S. Fish and Wildlife Service, Lodi, CA. 89 pp.

Randall, R. G., Healey, M.C., and J.B. Dempson. 1987. Variability in Length of Freshwater Residence of Salmon, Trout, and Char. American Fisheries Society Symposium 1:27-41.

Reimers, P.E. 1971. The Length of Residence of Juvenile Fall Chinook Salmon in Sixes River, Oregon. Doctoral Thesis submitted to Oregon State University.

Roper, B and D. L. Scarnecchia. 1996. A comparison of trap efficiencies for wild and hatchery age-0 Chinook salmon. North American Journal of Fisheries Management 16:214-217.

Rothchild, B. J. and G.T. DiNardo. 1987. Comparison of Recruitment Variability and Life History Data among Marine and Anadromous Fishes. American Fisheries Society Symposium 1 :531-546.

Smith, C.T., LaGranve, A.R., and W. R. Ardren in Cooperation with M.A. Banks and D.P. Jacobsen. 2009. Run Composition of Chinook salmon at Red Bluff Diversion Dam during gates-in operations: A comparison of phenotypic and genetic assignment to run type. U.S. Fish and Wildlife Service, Abernathy Fish Technology Center, Longview, WA. CY 2007 Report prepared for U.S. Bureau of Reclamation-Mid Pacific Region, Red Bluff, CA.

Snider, B., B. Reavis, and S. Hamelburg, S. Croci, S. Hill, and E. Kohler. 1997. 1996 Upper Sacramento River winter-run Chinook salmon escapement survey. California Department of Fish and Game, Environmental Services Division, Sacramento, CA.

Sokal, R. R. and F. J. Rohlf. 1995. Biometry the principles and practice of statistics in biological research, 3rd edition. W. H. Freeman and Company.

United States Bureau of Reclamation. 1991. Planning report and final environmental statement:Shasta Outflow Temperature Control. USBR, Mid-Pacific Region. Shasta County, California.

United States Bureau of Reclamation. 1994. Sacramento Basin Fish Habitat Improvement Study – Final Environmental Assessment. USBR, Mid-Pacific Region.

United States Fish and Wildlife Service (USFWS). 1995. Working Paper on Restoration Needs. Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California, Vol. 2. Section 9. May, 1995. Prepared for the US Fish and Wildlife Service under the direction of the Anadromous Fish Restoration Program Core Group. Stockton, CA.

United States Fish and Wildlife Service (USFWS). 1997. Comprehensive Assessment and Monitoring Program (CAMP) Implementation Plan. March, 1997. Prepared by Central Valley Fish and Wildlife Restoration Program Office, Sacramento, CA. Prepared with technical assistance from Montgomery Watson, Jones & Stokes Associates, Inc., and CH2M Hill, Sacramento, CA.

United States Fish and Wildlife Service (USFWS). 2001. Final Restoration Plan for the Anadromous Fish Restoration Program. A plan to increase natural production of anadromous fish in the Central Valley of California. Prepared for the Secretary of the Interior by the United States Fish and Wildlife Service with the assistance from the Anadromous Fish and Restoration Program Core Group under authority of the Central Valley Project Improvement Act.

United States Fish and Wildlife Service (USFWS). 2006. Upper Sacramento River winter Chinook salmon carcass survey 2005 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2007. Upper Sacramento River winter Chinook salmon carcass survey 2006 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2008. Upper Sacramento River winter Chinook salmon carcass survey 2007 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2009. Upper Sacramento River winter Chinook salmon carcass survey 2008 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2010. Upper Sacramento River winter Chinook salmon carcass survey 2009 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2011. Upper Sacramento River winter Chinook salmon carcass survey 2010 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

United States Fish and Wildlife Service (USFWS). 2013. Upper Sacramento River winter Chinook salmon carcass survey 2012 annual report. USFWS, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Van Eenennaam, J.P., J. Linares-Casenave, X. Deng, and S.I. Doroshov. 2005. Effect of incubation temperature on green sturgeon embryos, *Acipenser medirostris*. Environmental Biology of Fishes 72:145-154.

Vermeyn, T. B. 1997. Use of Temperature Control Curtains to Control Reservoir Release Water Temperatures. Report R-97-09, United States Department of the Interior, Bureau of Reclamation. Water Resources Research Laboratory, Technical Services Center. Denver, Colorado.

Vogel, D.A. and K.R. Marine. 1991. Guide to Upper Sacramento River Chinook salmon life history. CH2M Hill for the U.S. Bureau of Reclamation Central Valley Project, Redding, CA.

Volkhardt, G. C., S.L. Johnson, B.A. Miller, T.E. Nickelson, and D. E. Seiler. 2007. Rotary screw traps and inclined plane screen traps. Pages 235-266 in D. H. Johnson, B. M. Shrier, J.S. O'Neil, J. A. Knutzen, X. Augerot, T. A. O'Neil and T. N. Pearsons. Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland.

Wales, J.H., and M. Coots. 1955. Efficiency of chinook salmon spawning in Fall Creek, California. Transactions of American Fisheries Society. 84:137-149.

Wells, R. A. and W. J. McNeil. 1970. Effect of quality of spawning bed on growth and development of pink salmon embryos and alevins. U.S. Fish and Wildlife Service Special Scientific Report Fisheries 616.

Whitton, K. S., D. J. Colby, J. M. Newton, and M. R. Brown. 2008. Juvenile salmonid monitoring in Battle Creek, California, November 2007 through June 2008. USFWS Report. U.S. Fish and Wildlife Service, Red Bluff Fish and Wildlife Office, Red Bluff, California.

Williams, J. G. 2006. Central Valley Salmon, A Perspective on Chinook and Steelhead in the Central Valley of California. San Francisco Estuary and Watershed Science. Volume 4, Issue 3, Article 2.

Zabel, R. W. and S. Achord. 2004. Relating size of juveniles to survival within and among populations of Chinook salmon. Ecology, 85 (3), pp. 795-806.

Zimmerman C.E., and G. H., Reeves. 2000. Population structure of sympatric anadromous and nonanadromous Oncorhynchus mykiss: evidence from spawning surveys and otolith microchemistry. Canadian Journal of Fisheries and Aquatic Sciences 57:2152–2162.

Tables

Table 1. Summary of annual RBDD rotary trap sample effort by run and species for the period April 2002 through September 2013, by brood year (BY).

BY	Fall	Late-Fall	Winter	Spring	*O. mykiss*
2002	0.76	0.57	0.64	0.75	0.53
2003	0.81	0.76	0.81	0.81	0.76
2004	0.85	0.88	0.84	0.85	0.83
2005	0.56	0.73	0.64	0.57	0.83
2006	0.90	0.70	0.83	0.89	0.59
2007	0.88	0.90	0.89	0.89	0.91
2008	0.79	0.89	0.87	0.85	0.89
2009	0.84	0.72	0.75	0.79	0.76
2010	0.75	0.86	0.81	0.77	0.85
2011	0.87	0.77	0.82	0.86	0.76
2012	0.85	0.89	0.89	0.86	0.86
Min	0.56	0.57	0.64	0.57	0.53
Max	0.90	0.90	0.89	0.89	0.91
Mean	0.81	0.79	0.80	0.81	0.78
SD	0.094	0.104	0.088	0.091	0.122
CV	11.7%	13.2%	10.9%	11.3%	15.6%

Table 2. Summary of mark-recapture experiments conducted by RBDD rotary trap project between 2002 and 2013. Summaries include trap effort data, fish release and recapture group sizes (*N*) and mean fork lengths (FL), percentage of river discharge sampled (%Q) and estimated trap efficiency for each trial (%TE). Model data below each trial period indicate dates model was employed, total trials incorporated into model and linear regression values of slope, intercept, p-value and coeeficient of determination.

Date	Run	# Traps Sampling	Traps Modified	RBDD Gates	Release Group		Recapture Group		%Q	%TE
					N	FL (mm)	*N*	FL (mm)		
6/26/2002	Fall[1]	4	Yes	Lowered	805	68.7	8	61.3	1.58	0.99
8/6/2002	Fall[1]	4	Yes	Lowered	743	69.7	16	80.2	1.66	2.15
8/20/2002	Fall[1]	3	Yes	Lowered	340	76.5	7	77.7	1.41	2.06

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2002 -	6/30/2003	61	0.00792	0.00003205	<0.0001	0.394

Date	Run	# Traps Sampling	Traps Modified	RBDD Gates	Release Group		Recapture Group		%Q	%TE
					N	FL (mm)	*N*	FL (mm)		
1/28/2003	Fall	4	Yes	Raised	5,143	36.8	33	37.0	0.75	0.64
2/5/2003	Fall	4	Yes	Raised	2,942	36.7	10	37.9	1.36	0.34
2/10/2003	Fall	4	Yes	Raised	3,106	37.8	29	37.9	1.59	0.93
2/21/2003	Fall	3	Yes	Raised	3,256	37.4	15	37.3	0.72	0.46
2/26/2003	Fall	4	Yes	Raised	2,019	37.0	22	37.2	1.14	1.09
3/1/2003	Fall	4	No	Raised	1,456	37.0	31	37.0	3.31	2.13
3/4/2003	Fall	4	No	Raised	1,168	37.1	28	37.4	3.76	2.40
3/7/2003	Fall	4	No	Raised	1,053	37.4	22	36.6	3.58	2.09
3/20/2003	Fall	3	No	Raised	1,067	38.2	17	38.3	2.83	1.59
9/2/2003	Winter	4	No	Lowered	1,119	37.1	14	36.1	2.03	1.25
9/5/2003	Winter	3	No	Lowered	1,283	36.7	26	37.2	2.52	2.03
9/8/2003	Winter	3	No	Lowered	1,197	37.3	30	37.1	2.57	2.51
9/23/2003	Winter	3	No	Raised	1,012	35.5	18	35.6	2.20	1.78

9/27/2003	Winter	4	No	Raised	1,017	36.9	28	36.6	2.93	2.75
10/1/2003	Winter	4	No	Raised	1,064	37.6	20	36.7	3.09	1.88
10/6/2003	Winter	4	No	Raised	999	37.2	22	36.8	2.82	2.20
10/10/2003	Winter	4	No	Raised	1,017	38.1	16	38.3	3.06	1.57
10/15/2003	Winter	4	No	Raised	1,209	38.0	26	37.6	2.98	2.15

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2003 -	6/30/2004	79	0.00752	0.00046251	<0.0001	0.426

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/18/2004	Fall	4	Yes	Raised	2,074	37.1	26	37.1	1.52	1.25
1/24/2004	Fall	4	Yes	Raised	2,018	38.4	36	37.4	1.79	1.78
1/31/2004	Fall	4	Yes	Raised	2,024	37.7	33	37.6	1.61	1.63
2/6/2004	Fall	4	Yes	Raised	1,999	37.9	31	38.0	1.61	1.55
2/9/2004	Fall	4	Yes	Raised	2,017	37.8	27	37.0	1.69	1.34
2/13/2004	Fall	4	Yes	Raised	2,009	37.2	31	38.3	1.87	1.54
3/14/2004	Fall	3	No	Raised	1,401	38.3	18	39.6	1.98	1.28
3/23/2004	Fall	3	No	Raised	815	38.8	15	39.1	2.50	1.84
4/28/2004	Fall[1]	4	Yes	Raised	1,304	72.9	33	71.7	1.94	2.53
5/4/2004	Fall[1]	4	No	Raised	814	75.5	18	75.1	3.35	2.21
5/18/2004	Fall[1]	4	No	Lowered	867	80.2	10	75.1	3.20	1.15
5/26/2004	Fall[1]	4	No	Lowered	1,096	81.2	27	80.2	2.83	2.46
6/2/2004	Fall[1]	4	No	Lowered	888	76.2	28	77.2	2.77	3.15
6/15/2004	Fall[1]	4	No	Lowered	691	76.4	12	79.1	2.17	1.74
8/31/2004	Winter	4	No	Lowered	1,096	36.5	41	36.0	3.00	3.74
9/3/2004	Winter	4	No	Lowered	1,153	36.6	50	35.6	3.23	4.34
9/17/2004	Winter	4	No	Raised	1,023	36.0	14	35.4	2.52	1.37

9/20/2004	Winter	4	No	Raised	1,017	35.8	21	35.4	2.48	2.06
9/23/2004	Winter	4	No	Raised	2,006	36.0	31	35.1	2.62	1.55
9/27/2004	Winter	4	No	Raised	1,918	36.1	36	36.1	2.77	1.88
10/1/2004	Winter	4	No	Raised	1,682	36.4	24	36.0	3.11	1.43

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2004 -	6/30/2006	99	0.007464	0.00087452	<0.0001	0.385

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/23/2005	Fall	4	No	Raised	1,283	36.6	41	37.2	4.21	3.20
2/1/2005	Fall	3	Yes	Raised	1,971	36.6	31	36.0	1.35	1.57
2/10/2005	Fall	4	No	Raised	1,763	36.6	46	36.7	4.06	2.61
3/10/2005	Fall	4	No	Raised	1,216	36.6	27	36.5	3.93	2.22
3/13/2005	Fall	4	No	Raised	1,328	36.3	43	35.6	4.06	3.24
4/1/2005	Fall	4	No	Raised	1,949	57.1	50	62.3	3.49	2.57
9/11/2005	Winter	4	No	Lowered	1,437	35.6	14	38.9	2.22	0.97
10/4/2005	Winter	4	No	Raised	1,587	35.9	14	36.1	1.83	0.88
10/13/2005	Winter	4	No	Raised	1,577	35.7	21	36.6	2.33	1.33
2/15/2006	Fall	4	No	Raised	1,610	37.4	33	36.6	3.19	2.05
2/23/2006	Fall	4	No	Raised	1,503	37.2	38	36.6	2.68	2.53
1/21/2007	Fall	4	No	Raised	1,520	0.0	33	37.8	4.02	2.17
1/28/2007	Fall	4	Yes	Raised	1,987	37.6	18	37.8	3.65	0.91
2/5/2007	Fall	3	Yes	Raised	2,909	37.5	29	37.3	1.62	1.00
2/16/2007	Fall	4	No	Raised	1,782	37.9	34	38.5	3.51	1.91
3/2/2007	Fall	4	No	Raised	1,591	38.5	54	38.6	3.68	3.39
3/15/2007	Fall	4	No	Raised	953	37.6	26	37.6	4.29	2.73
3/20/2007	Fall	4	No	Raised	835	37.6	23	38.8	4.18	2.75

3/24/2007	Fall	4	No	Raised	944	37.7	23	38.0	4.24	2.44

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2006 -	6/30/2007	118	0.006653	0.00240145	<0.0001	0.420

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/23/2008	Fall	4	No	Raised	2,234	38.4	50	38.2	3.99	2.24
2/7/2008	Fall	4	Yes	Raised	2,324	38.1	60	37.9	2.19	2.58
2/14/2008	Fall	4	Mixed	Raised	1,993	38.4	83	38.8	3.40	4.16
2/20/2008	Fall	4	No	Raised	1,703	37.2	48	36.8	5.29	2.82
2/28/2008	Fall	3	No	Raised	2,080	37.6	63	38.3	3.45	3.03

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2007 -	6/30/2008	123	0.00645	0.00303101	<0.0001	0.414

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/23/2009	Fall	4	No	Raised	1,923	36.1	54	37.1	4.53	2.81
2/5/2009	Fall	4	No	Raised	1,868	36.8	58	37.4	4.65	3.10

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2008 -	6/30/2010	125	0.006332	0.00328530	<0.0001	0.425

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/20/2011	Fall	4	No	Raised	1,834	36.9	79	35.9	3.92	4.31
1/26/2011	Fall	4	No	Raised	1,989	37.6	109	36.0	4.56	5.48
2/1/2011	Fall	4	No	Raised	1,593	36.4	61	36.0	5.04	3.83

2/11/2011	Fall	4	No	Raised	1,582	35.7	81	37.4	5.34	5.12

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2010 -	6/30/2012	129	0.007297	0.00123101	<0.0001	0.493

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/30/2012	Fall	4	No	Raised	1,319	36.3	46	36.1	4.08	3.49
2/4/2012	Fall	4	No	Raised	1,146	35.8	51	35.4	5.52	4.45
2/16/2012	Fall	4	No	Raised	1,465	35.7	73	35.0	5.36	4.98
2/28/2012	Fall	4	No	Raised	1,228	35.5	57	34.6	5.40	4.64

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2012 -	6/30/2012	133	0.007676	0.00037735	<0.0001	0.561

		# Traps	Traps		Release Group		Recapture Group			
Date	Run	Sampling	Modified	RBDD Gates	*N*	FL (mm)	*N*	FL (mm)	%Q	%TE
1/16/2013	Fall	4	Yes	Raised	1,991	35.6	72	35.8	2.56	3.62
1/23/2013	Fall	4	Yes	Raised	1,965	35.9	39	35.3	2.61	1.98
1/30/2013	Fall	4	Yes	Raised	1,981	36.3	44	35.6	2.57	2.22
2/3/2013	Fall	4	Yes	Raised	1,998	36.5	42	36.1	2.69	2.10
2/13/2013	Fall	4	Yes	Raised	2,079	36.3	48	36.2	2.62	2.31
2/18/2013	Fall	4	Yes	Raised	2,156	36.1	35	36.8	2.89	1.62
2/22/2013	Fall	4	No	Raised	2,439	36.7	119	36.6	6.52	4.88
2/26/2013	Fall	4	No	Raised	1,400	36.1	65	37.3	6.87	4.64
3/3/2013	Fall	4	No	Raised	899	36.5	37	36.9	6.71	4.12

Model	Employed	#Trials	Slope	Intercept	*P*	R^2
7/1/2013 -	9/30/2013	142	0.007255	0.00150868	<0.0001	0.587

[1] Denotes Coleman National Fish Hatchery Fall Chinook production fish used during trial.

Table 3. Annual capture fork length summary of *O. mykiss* by age and life-stage classification from the RBDD rotary trap project between April 2002 through December 2012 by calendar year (CY).

Age Classification (%)					Life Stage Classification (%)					
CY	Fry <41 mm	Sub-Yearling 41-138 mm	Yearling 139-280 mm	2+ >280 mm	CY	Yolk-sac Fry	Fry	Parr	Silvery-parr	Smolt
2002	11.2	86.7	1.6	0.5	2002	0.0	6.3	54.4	37.2	2.1
2003	8.1	89.5	2.3	0.0	2003	0.0	5.6	57.7	34.9	1.8
2004	9.8	89.7	0.5	0.0	2004	0.0	4.6	60.2	34.7	0.5
2005	3.5	93.2	3.1	0.2	2005	0.0	2.8	48.7	45.6	2.9
2006	17.5	75.3	5.6	1.5	2006	0.2	9.2	78.9	9.2	2.4
2007	6.5	91.2	1.7	0.6	2007	0.1	8.7	85.3	5.3	0.6
2008	6.3	92.3	0.9	0.5	2008	0.1	8.2	79.4	12.0	0.4
2009	9.0	87.7	2.1	1.2	2009	0.0	10.7	82.8	5.1	1.4
2010	7.7	89.8	1.7	0.8	2010	0.3	9.7	87.4	1.7	1.0
2011	4.6	89.7	5.0	0.6	2011	0.1	3.5	90.9	2.8	2.7
2012	6.6	90.0	2.3	1.1	2012	0.2	5.9	88.2	4.2	1.5
Mean	8.3	88.7	2.4	0.6	Mean	0.1	6.8	74.0	17.5	1.6
SD	3.8	4.8	1.6	0.5	SD	0.1	2.6	15.5	16.8	0.9

Table 4. Annual linear regression equations with 95% confidence intervals (CI) for Log_{10} transformed juvenile (80-200 mm) *O. mykiss* weight-length data sampled at the RBDD rotary traps from April 2002 through December 2012 by calendar year (CY).

CY	Weight-Length Equation	R^2	Slope Lower 95% CI	Slope Upper 95% CI
2002	$\text{Log}_{10}(\text{weight})=2.843(\text{Log}_{10}\text{FL})-4.616$	0.903	2.648	3.039
2003	$\text{Log}_{10}(\text{weight})=2.968(\text{Log}_{10}\text{FL})-4.886$	0.968	2.885	3.052
2004	$\text{Log}_{10}(\text{weight})=3.005(\text{Log}_{10}\text{FL})-4.941$	0.952	2.879	3.132
2005	$\text{Log}_{10}(\text{weight})=3.03(\text{Log}_{10}\text{FL})-5.009$	0.952	2.929	3.132
2006	$\text{Log}_{10}(\text{weight})=3.052(\text{Log}_{10}\text{FL})-5.085$	0.917	2.811	3.293
2007	$\text{Log}_{10}(\text{weight})=2.961(\text{Log}_{10}\text{FL})-4.864$	0.947	2.853	3.069
2008	$\text{Log}_{10}(\text{weight})=2.939(\text{Log}_{10}\text{FL})-4.819$	0.942	2.833	3.044
2009	$\text{Log}_{10}(\text{weight})=3.017(\text{Log}_{10}\text{FL})-4.981$	0.974	2.922	3.112
2010	$\text{Log}_{10}(\text{weight})=2.977(\text{Log}_{10}\text{FL})-4.911$	0.934	2.836	3.118
2011	$\text{Log}_{10}(\text{weight})=2.911(\text{Log}_{10}\text{FL})-4.778$	0.939	2.743	3.078
2012	$\text{Log}_{10}(\text{weight})=2.858(\text{Log}_{10}\text{FL})-4.662$	0.903	2.746	2.970
Mean	$\text{Log}_{10}(\text{weight})=2.946(\text{Log}_{10}\text{FL})-4.840$	0.942	2.913	2.979

Table 5a. RBDD rotary trap fall Chinook total annual effort and passage estimates (sum of weekly values), lower and upper 90% confidence intervals (CI), ratio of fry to pre-smolt/smolt passage and ratio of estimated passage (Est) and interpolated passage (Interp) for brood year (BY) 2002-2012.

BY	Effort	Total	Low 90%CI	Up 90% CI	Fry	Smolt	Est	Interp
2002	0.76	17,038,417	857,106	47,315,257	0.86	0.14	0.54	0.46
2003	0.81	27,736,868	8,839,840	50,653,446	0.85	0.15	0.74	0.26
2004	0.85	14,108,238	5,079,300	24,967,671	0.56	0.44	0.70	0.30
2005	0.56	18,210,294	3,500,275	39,096,017	0.64	0.36	0.40	0.60
2006	0.90	16,107,651	6,522,666	26,414,402	0.63	0.37	0.85	0.15
2007	0.88	12,131,603	6,130,892	18,170,520	0.79	0.21	0.84	0.16
2008	0.79	9,115,547	4,381,560	13,849,709	0.73	0.27	0.81	0.19
2009	0.84	8,532,377	3,064,273	14,052,588	0.81	0.19	0.56	0.44
2010	0.75	8,842,481	4,727,816	13,252,907	0.71	0.29	0.79	0.21
2011	0.87	6,271,261	3,431,940	9,125,109	0.71	0.29	0.82	0.18
2012	0.85	24,429,420	16,028,521	33,112,943	0.87	0.13	0.91	0.09
Mean	0.81	14,774,923			0.74	0.26	0.72	0.28
SD	0.09	6,825,382			0.10	0.10	0.16	0.16
CV	11.7%	46.2%			13.9%	40.3%	22.0%	57.4%

Table 5b. RBDD rotary trap late-fall Chinook total annual effort and passage estimates (sum of weekly values), lower and upper 90% confidence intervals (CI), ratio of fry to pre-smolt/smolt passage and ratio of estimated passage (Est) and interpolated passage (Interp) for brood year (BY) 2002-2012.

BY	Effort	Total	Low 90%CI	Up 90% CI	Fry	Smolt	Est	Interp
2002	0.57	2,559,519	659,986	4,953,910	0.17	0.83	0.52	0.48
2003	0.76	346,058	78,407	911,270	0.57	0.43	0.56	0.44
2004	0.88	147,160	74,930	220,231	0.17	0.83	0.91	0.09
2005	0.73	143,362	41,800	333,415	0.35	0.65	0.71	0.29
2006	0.70	460,268	125,197	902,089	0.62	0.38	0.44	0.56
2007	0.90	535,619	271,079	800,447	0.27	0.73	0.86	0.14
2008	0.89	91,995	46,660	138,310	0.11	0.89	0.89	0.11
2009	0.72	219,824	97,294	342,652	0.13	0.87	0.73	0.27
2010	0.86	183,439	61,775	305,937	0.62	0.38	0.61	0.39
2011	0.77	97,040	28,738	165,997	0.72	0.28	0.53	0.47
2012	0.89	140,534	42,673	249,500	0.48	0.52	0.80	0.20
Mean	0.79	447,711			0.38	0.62	0.69	0.31
SD	0.10	715,999			0.23	0.23	0.16	0.16
CV	13.2%	159.9%			58.8%	36.5%	23.8%	52.5%

Table 5c. RBDD rotary trap winter Chinook total annual effort and passage estimates (sum of weekly values), lower and upper 90% confidence intervals (CI), ratio of fry to pre-smolt/smolt passage and ratio of estimated passage (Est) and interpolated passage (Interp) for brood year (BY) 2002-2012.

BY	Effort	Total	Low 90%CI	Up 90% CI	Fry	Smolt	Est	Interp
2002	0.64	7,119,041	2,541,407	12,353,367	0.90	0.10	0.58	0.42
2003	0.81	5,221,016	3,202,609	7,260,798	0.85	0.15	0.86	0.14
2004	0.84	3,434,683	1,998,468	4,874,794	0.90	0.10	0.82	0.18
2005	0.64	8,363,106	4,558,069	12,277,233	0.90	0.10	0.89	0.11
2006	0.83	6,687,079	3,801,539	9,575,937	0.87	0.13	0.76	0.24
2007	0.89	1,440,563	931,113	1,953,688	0.80	0.20	0.92	0.08
2008	0.87	1,244,990	776,634	1,714,013	0.85	0.15	0.77	0.23
2009	0.75	4,402,322	2,495,734	6,311,739	0.81	0.19	0.74	0.26
2010	0.81	1,285,389	817,207	1,756,987	0.68	0.32	0.92	0.08
2011	0.82	848,976	576,177	1,122,022	0.75	0.25	0.88	0.12
2012	0.89	1,349,819	904,552	1,795,106	0.53	0.47	0.92	0.08
Mean	0.80	3,763,362			0.80	0.20	0.82	0.18
SD	0.09	2,753,256			0.11	0.11	0.11	0.11
CV	10.9%	73.2%			13.9%	57.5%	12.8%	59.6%

Table 5d. RBDD rotary trap spring Chinook total annual effort and passage estimates (sum of weekly values), lower and upper 90% confidence intervals (CI), ratio of fry to pre-smolt/smolt passage and ratio of estimated passage (Est) and interpolated passage (Interp) for brood year (BY) 2002-2012.

BY	Effort	Total	Low 90%CI	Up 90% CI	Fry	Smolt	Est	Interp
2002	0.75	277,477	110,951	494,590	0.57	0.43	0.59	0.41
2003	0.81	626,915	249,225	1,053,421	0.80	0.20	0.67	0.33
2004	0.85	430,951	174,174	710,419	0.36	0.64	0.78	0.22
2005	0.57	616,040	131,328	1,382,036	0.69	0.30	0.58	0.42
2006	0.89	421,436	239,470	603,952	0.41	0.59	0.80	0.20
2007	0.89	369,536	229,766	510,868	0.91	0.09	0.99	0.01
2008	0.85	164,673	66,515	262,959	0.24	0.76	0.62	0.38
2009	0.79	438,405	176,952	700,959	0.50	0.50	0.51	0.49
2010	0.77	158,966	62,563	261,105	0.56	0.44	0.67	0.33
2011	0.86	184,290	101,443	272,769	0.48	0.52	0.85	0.15
2012	0.86	320,897	173,312	469,137	0.42	0.58	0.74	0.26
Mean	0.81	364,508			0.54	0.46	0.71	0.29
SD	0.09	164,135			0.20	0.20	0.14	0.14
CV	11.3%	45.0%			36.4%	43.0%	19.7%	47.6%

Table 5e. RBDD rotary trap *O. mykiss* total annual effort and passage estimates (sum of weekly values), lower and upper 90% confidence intervals (CI), and ratio of estimated passage (Est) and interpolated passage (Interp) for calendar year (CY) 2002-2012.

CY	Effort	Total	Low 90%CI	Up 90% CI	Est	Interp
2002[1]	0.53	124,436	27,224	244,701	0.53	0.47
2003	0.76	139,008	54,885	243,927	0.78	0.22
2004	0.83	151,694	86,857	218,132	0.95	0.05
2005	0.83	85,614	32,251	152,568	0.76	0.24
2006	0.59	83,801	20,603	169,712	0.44	0.56
2007	0.91	139,424	73,827	205,647	0.89	0.11
2008	0.89	131,013	69,331	193,584	0.88	0.12
2009	0.76	129,581	62,350	197,795	0.83	0.17
2010	0.85	100,997	47,050	155,692	0.74	0.26
2011	0.76	56,798	23,494	89,369	0.76	0.24
2012	0.86	136,621	78,804	194,892	0.96	0.04
Mean	0.78	116,272			0.78	0.22
SD	0.12	29,912			0.16	0.16
CV	15.6%	25.7%			20.9%	72.2%

[1] Incomplete year; sampling began in April 2002.

Table 6a. Fall Chinook fry-equivalent production estimates, lower and upper 90% confidence intervals (CI), estimates of adults upstream of RBDD (Adult Estimate), estimated female to male sex ratios, estimated females, estimates of female fecundity, calculated juveniles per estimated female (recruits per female) and egg-to-fry survival estimates (ETF) by brood year (BY) for Chinook sampled at RBDD rotary traps between December 2002 and September 2013.

BY	FRY EQ Passage	Lower 90% CI	Upper 90% CI	Adult Estimate	Sex Ratio (F: M)[1]		Estimated Females	Fecundity[2]	Recruits per Female	ETF
2002	18,683,720	1,216,244	51,024,926	458,772	*0.46*	*0.54*	211,035	5,407	89	1.6%
2003	30,624,209	10,162,712	55,109,506	140,724	0.57	0.44	79,509	5,407	385	7.1%
2004	18,421,457	6,224,790	33,728,746	64,276	0.48	0.52	31,045	5,407	593	11.0%
2005	22,739,315	4,235,720	49,182,045	80,294	0.47	0.53	37,738	5,407	603	11.1%
2006	20,276,322	8,670,090	32,604,760	78,692	0.54	0.46	42,730	5,407	475	8.8%
2007	13,907,856	7,041,759	20,838,463	31,592	0.54	0.46	16,996	5,407	818	15.1%
2008	10,817,397	5,117,059	16,517,847	36,104	0.46	0.54	16,644	5,407	650	12.0%
2009	9,674,829	3,678,373	15,723,368	12,908	0.51	0.49	6,531	5,407	1,481	27.4%
2010	10,620,144	5,637,617	15,895,197	29,321	0.24	0.76	7,008	5,407	1,515	28.0%
2011	7,554,574	4,171,332	10,960,125	31,931	0.29	0.71	9,260	5,407	816	15.1%
2012	26,567,379	17,219,525	36,197,837	65,664	0.50	0.50	32,635	5,407	814	15.1%
Mean	17,262,473	6,670,475	30,707,529	93,662	0.46	0.54	44,648		749	13.9%
CV	43.2%	64.0%	51.7%	134.7%			132.4%		57.2%	57.2%

[1] Sex ratios based on RBDD fish ladder data between 2003 and 2007 and CNFH data between 2008 and 2012. Average, in italics, input for 2002 due to lack of available data.

[2] Female fecundity estimates based on average values from CNFH fall Chinook spawning data collected between 2008 and 2012.

Table 6b. Late-fall Chinook fry-equivalent production estimates, lower and upper 90% confidence intervals (CI), estimates of adults upstream of RBDD (Adult Estimate), estimated female to male sex ratios, estimated females, estimates of female fecundity, calculated juveniles per estimated female, and egg-to-fry survival estimates (ETF) by brood year (BY) for Chinook sampled at RBDD rotary traps between April 2002 and March 2013.

BY	FRY EQ Passage	Lower 90% CI	Upper 90% CI	Adult Estimate	Sex Ratio (F: M)[1]		Estimated Females	Fecundity[2]	Recruits per Female	ETF
2002	4,041,505	1,063,720	7,808,619	36,220	0.46	0.54	16,661	4,662	243	5.2%
2003	451,230	133,225	1,067,819	5,513	0.46	0.54	2,536	4,662	178	3.8%
2004	233,106	124,245	342,837	8,924	0.46	0.54	4,105	4,662	57	1.2%
2005	209,066	70,548	441,133	9,610	0.46	0.54	4,421	4,662	47	1.0%
2006	582,956	186,984	1,086,699	7,770	0.46	0.54	3,574	4,662	163	3.5%
2007	809,272	426,272	1,192,625	13,939	0.46	0.54	6,412	4,662	126	2.7%
2008	149,049	80,500	218,597	3,747	0.46	0.54	1,724	4,662	86	1.9%
2009	353,003	159,726	546,546	3,792	0.46	0.54	1,744	4,662	202	4.3%
2010	232,279	89,343	376,286	3,961	0.46	0.54	1,822	4,662	127	2.7%
2011	116,188	38,688	194,400	3,777	0.46	0.54	1,737	4,662	67	1.4%
2012	191,672	69,229	325,189	2,931	0.46	0.54	1,348	4,662	142	3.0%
Mean	669,939	222,044	1,236,432	9,108			4,190		131	2.8%
CV	169.8%	134.4%	178.7%	105.5%			105.5%		48.1%	48.1%

[1] Sex ratio value of (0.46:0.54) is equivalent to the average ratio for fall Chinook between 2003 and 2012 used in Table 6a.

[2] Female fecundity estimates based on average values from CNFH late-fall Chinook spawning data collected between 2008 and 2012.

Table 6c. Winter Chinook fry-equivalent production estimates, lower and upper 90% confidence intervals (CI), estimates of adults upstream of RBDD (Adult Estimate), estimated female to male sex ratios, estimated females, estimates of female fecundity, calculated juveniles per estimated female (recruits per female) and egg-to-fry survival estimates (ETF) by brood year (BY) for Chinook sampled at RBDD rotary traps between July 2002 and June 2013.

BY	FRY EQ Passage	Lower 90% CI	Upper 90% CI	Adult Estimate	Sex Ratio (F: M)[1]		Estimated Females	Fecundity[2]	Recruits per Female	ETF
2002	7,635,469	2,811,132	13,144,325	7337	0.77	0.23	5,670	4,923	1,347	27.4%
2003	5,781,519	3,525,098	8,073,129	8133	0.64	0.36	5,179	4,854	1,116	23.0%
2004	3,677,989	2,129,297	5,232,037	8635	0.37	0.63	3,185	5,515	1,155	20.9%
2005	8,943,194	4,791,726	13,277,637	15730	0.56	0.44	8,807	5,500	1,015	18.5%
2006	7,298,838	4,150,323	10,453,765	17205	0.50	0.50	8,626	5,484	846	15.4%
2007	1,637,804	1,062,780	2,218,745	2488	0.61	0.39	1,517	5,112	1,080	21.1%
2008	1,371,739	858,933	1,885,141	2850	0.51	0.49	1,443	5,424	951	17.5%
2009	4,972,954	2,790,092	7,160,098	4537	0.60	0.40	2,702	5,519	1,840	33.3%
2010	1,572,628	969,016	2,181,572	1533	0.53	0.47	813	5,161	1,934	37.5%
2011	996,621	671,779	1,321,708	824	0.51	0.49	424	4,832	2,351	48.6%
2012	1,789,259	1,157,240	2,421,277	2581	0.58	0.42	1,491	4,518	1,200	26.6%
Mean	4,152,547	2,265,220	6,124,494	6,532	0.56	0.44	3,623	5,167	1,349	26.4%
CV	70.1%	64.0%	74.9%	85.7%	17.9%	22.9%	83.4%	6.7%	35.5%	37.9%

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[1] Annual sex ratio values based on annual carcass survey estimates of female recoveries.

[2] Female fecundity estimates based on annual values from LSNFH winter Chinook spawning data collected between 2002 and 2012.

Table 6d. Spring Chinook fry-equivalent production estimates, lower and upper 90% confidence intervals (CI), estimates of adults upstream of RBDD (Adult Estimate), estimated female to male sex ratios, estimated females, estimates of female fecundity, calculated juveniles per estimated female (recruits per female) and egg-to-fry survival estimates (ETF) by brood year (BY) for Chinook sampled at RBDD rotary traps between October 16, 2002 and September 30, 2013.

BY	FRY EQ Passage	Lower 90% CI	Upper 90% CI	Adult Estimate	Sex Ratio (F: M)[1]		Estimated Females	Fecundity[2]	Recruits per Female	ETF
2002	360,352	142,134	657,043	608	0.46	0.54	280	5,078	1,288	25.4%
2003	714,086	293,095	1,187,827	319	0.46	0.54	147	5,078	4,866	95.8%
2004	624,079	255,886	1,029,162	575	0.46	0.54	265	5,078	2,359	46.5%
2005	747,026	146,488	1,695,236	189	0.46	0.54	87	5,078	8,592	169.2%
2006	594,511	328,845	860,757	353	0.46	0.54	162	5,078	3,661	72.1%
2007	392,451	242,563	544,184	767	0.46	0.54	353	5,078	1,112	21.9%
2008	251,795	96,737	406,863	305	0.46	0.54	140	5,078	1,795	35.3%
2009	591,549	238,710	945,904	314	0.46	0.54	144	5,078	4,095	80.7%
2010	207,793	80,320	344,475	208	0.46	0.54	96	5,078	2,172	42.8%
2011	251,444	130,051	382,077	167	0.46	0.54	77	5,078	3,273	64.5%
2012	451,705	238,187	665,825	868	0.46	0.54	399	5,078	1,131	22.3%
Mean	471,527	199,365	792,668	425			195		3,122	61.5%
CV	40.9%	41.7%	51.5%	56.8%			56.8%		70.8%	70.8%

[1] Sex ratio value of (0.46:0.54) is equivalent to the average ratio for fall Chinook between 2003 and 2012 used in Table 6a.

[2] Female fecundity estimates based on average of winter, fall, and late-fall hatchery data provided by CNFH and LSNFH; Table 6a-6c above.

Table 7. Green Sturgeon annual capture, catch per unit volume (CPUV) and total length summaries for sturgeon captured by RBDD rotary traps between calendar year (CY) 2002 and 2012.

CY	Captures	CPUV fish/ac-ft	Min TL (mm)	Max TL (mm)	Mean (mm)	Median (mm)
2002	35	0.3	23	52	28.8	27.5
2003	360	1.9	22	188	27.8	27
2004	266	1.0	21	58	30.5	29
2005	271	1.1	24	65	28.9	27
2006	193	0.8	21	79	30.5	28
2007	19	0.1	25	49	29.6	27
2008	0	0.0	-	-	-	-
2009	32	0.2	24	47	28.0	26
2010	70	0.5	20	36	27.1	27
2011	3701	20.1	18	86	27.4	27
2012	288	1.4	21	41	27.2	27
Ave	475.9	2.5	21.9	70.1	28.6	27.3
SD	1077.4	5.9	2.1	44.4	1.3	0.8
CV	226.4%	236.3%	9.7%	63.3%	4.5%	2.9%

Table 8a. Unidentified Lamprey ammocoetes annual capture, catch per unit volume (CPUV) and total length summaries for ammocoetes captured by RBDD rotary traps between water year (WY) 2003 and 2013.

WY	Captures	CPUV Fish/ac-ft	Min TL (mm)	Max TL (mm)	Mean (mm)	Median (mm)
2003	908	7.30	14	144	98	100
2004	925	6.80	27	191	105	108
2005	1415	11.65	22	159	104	108
2006	657	4.45	52	186	112	115
2007	556	5.16	29	155	105	111
2008	385	3.64	41	146	101	108
2009	593	5.53	41	150	106	112
2010	935	11.45	45	166	111	114
2011	859	7.07	30	186	111	117
2012	455	5.11	27	155	100	104
2013	632	6.45	25	160	103	107
Mean	756.4	6.8	32.1	163.5	105.1	109.5
SD	291.3	2.6	11.3	16.8	4.7	5.0
CV	38.5%	38.5%	35.1%	10.3%	4.5%	4.6%

Table 8b. Pacific Lamprey macrothalmia and adult annual capture, catch per unit volume (CPUV) and total length summaries for macrothalmia captured by RBDD rotary traps between water year (WY) 2003 and 2013.

WY	Captures	CPUV Fish/ac-ft	Min TL (mm)	Max TL (mm)	Mean (mm)	Median (mm)
2003	204	2.16	100	693	261	131
2004	478	3.91	96	630	149	125
2005	4645	45.00	72	665	137	126
2006	417	5.62	98	700	136	125
2007	3107	34.08	96	660	150	128
2008	5252	40.29	78	580	139	128
2009	2938	81.24	91	834	132	124
2010	699	32.30	80	819	136	125
2011	2747	68.18	92	620	140	129
2012	3464	112.76	86	500	136	127
2013	1734	25.63	88	617	131	127
Mean	2335.0	41.0	88.8	665.3	149.7	126.8
SD	1759.4	34.7	9.0	97.1	37.3	2.1
CV	75.3%	84.5%	10.2%	14.6%	24.9%	1.6%

Table 9a. Summary of fall Chinook abiotic sample conditions at RBDD rotary traps during dates of capture by brood year (BY).

	Dates of Capture			H$_2$0 Temperature (°F)			Discharge (CFS)			Turbidity (NTU)		
BY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002	4-Dec	30-Aug	269	47	61	55	6,390	86,500	17,471	0.5	240.2	19.6
2003	9-Dec	15-Aug	250	46	62	55	7,380	92,800	18,707	2.0	413.5	21.8
2004	8-Dec	29-Aug	264	46	63	56	5,390	76,200	13,315	1.9	626.5	24.6
2005	3-Dec	29-Aug	269	47	61	53	6,450	118,000	27,279	1.6	731.7	22.5
2006	10-Dec	26-Aug	259	46	62	55	6,030	45,400	10,628	1.6	90.0	8.0
2007	7-Dec	2-Sep	270	44	62	55	5,210	44,600	10,127	1.5	233.3	11.1
2008	5-Dec	4-Sep	273	45	64	56	4,160	33,000	9,297	2.1	129.8	12.0
2009	10-Dec	21-Aug	254	45	61	54	5,260	95,100	17,531	1.3	162.6	10.3
2010	7-Dec	29-Aug	265	45	61	54	5,260	95,100	17,331	1.3	162.6	10.2
2011	10-Dec	2-Sep	267	45	65	55	4,800	35,200	10,281	1.4	180.6	8.8
2012	2-Dec	23-Aug	264	44	64	56	5,330	70,400	11,323	1.5	315.5	9.9
Mean	7-Dec	27-Aug	264	45	62	55	5,605	72,027	14,844	1.5	298.7	14.4
SD			7	1.1	1.4	0.8	890	28,600	5,442	0.4	209.6	6.3
CV			3%	2%	2%	1%	16%	40%	37%	28%	70%	44%

Table 9b. Summary of late-fall Chinook abiotic sample conditions at RBDD rotary traps during dates of capture by brood year (BY).

	Dates of Capture			H_20 Temperature (^{o}F)			Discharge (CFS)			Turbidity (NTU)		
BY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002	19-Apr	14-Jan	270	47	62	57	6,176	86,500	12,981	0.4	59.7	11.3
2003	3-Apr	6-Mar	338	46	61	55	6,310	92,800	16,650	0.9	413.5	20.9
2004	2-Apr	21-Jan	294	46	62	57	5,170	57,000	10,983	1.4	470.0	8.0
2005	2-Apr	22-Jan	295	48	63	57	6,050	118,000	17,431	1.6	731.7	24.4
2006	1-Apr	13-Jan	287	46	61	55	6,610	80,900	15,374	2.0	178.0	8.8
2007	4-Apr	9-Jan	280	46	62	57	5,490	38,600	10,035	1.3	198.0	5.7
2008	2-Apr	2-Mar	334	45	64	56	4,160	33,000	8,775	1.5	129.8	6.9
2009	3-Apr	1-Mar	332	46	64	57	3,920	60,400	9,855	1.9	250.6	14.2
2010	1-Apr	12-Jan	286	47	62	56	5,900	50,600	11,831	1.1	220.3	7.3
2011	1-Apr	27-Jan	301	45	61	55	5,570	57,400	11,888	2.0	68.5	5.5
2012	2-Apr	11-Jan	284	46	62	56	5,536	67,520	12,580	1.4	272.0	11.3
Mean	4-Apr	29-Jan	300	46	62	56	5,536	67,520	12,580	1.4	272.0	11.3
SD			24	0.9	1.0	0.7	849	25,109	2,829	0.5	198.7	6.2
CV			8%	2%	2%	1%	15%	37%	22%	34%	73%	55%

Table 9c. Summary of winter Chinook abiotic sample conditions at RBDD rotary traps during dates of capture by brood year (BY).

	Dates of Capture			H_20 Temperature (^{o}F)			Discharge (CFS)			Turbidity (NTU)		
BY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002	4-Jul	8-Apr	278	47	61	55	6,176	86,500	14,081	0.4	240.2	13.5
2003	16-Jul	17-Mar	245	46	61	54	6,310	92,800	16,809	0.9	413.5	22.8
2004	22-Jul	25-Mar	246	46	62	55	5,170	57,000	9,817	1.4	470.0	12.1
2005	25-Jul	17-Feb	207	48	61	55	6,450	118,000	19,174	1.6	731.7	19.7
2006	16-Jul	10-Mar	237	46	59	54	6,030	45,400	9,788	1.6	90.0	7.2
2007	18-Jul	4-Apr	261	44	62	54	5,210	44,600	9,318	1.3	233.3	11.3
2008	30-Jul	24-Apr	268	45	64	55	4,160	33,000	7,647	1.5	129.8	8.2
2009	26-Jul	30-Mar	247	46	64	55	3,920	60,400	9,303	1.9	250.6	15.0
2010	18-Jul	7-Apr	263	45	61	54	5,260	95,100	14,941	1.1	162.6	8.6
2011	12-Aug	31-Mar	232	45	60	53	4,800	35,200	8,646	1.7	180.6	7.0
2012	23-Jul	19-Apr	270	46	61	55	5,349	66,800	11,952	1.3	290.2	12.5
Mean	22-Jul	28-Mar	250	46	61	55	5,349	66,800	11,952	1.3	290.2	12.5
SD			20	1.1	1.5	0.8	843	27,776	3,767	0.4	185.4	5.1
CV			8%	2%	2%	1%	16%	42%	32%	31%	64%	41%

Table 9d. Summary of spring Chinook abiotic sample conditions at RBDD rotary traps during dates of capture by brood year (BY).

	Dates of Capture			H_20 Temperature (^oF)			Discharge (CFS)			Turbidity (NTU)		
BY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002	16-Oct	29-May	225	47	61	54	6,176	86,500	16,877	0.4	240.2	19.1
2003	16-Oct	11-Jun	239	46	62	54	6,310	92,800	17,267	0.9	413.5	23.0
2004	16-Oct	3-Jun	230	46	63	54	5,170	76,200	11,612	1.4	626.5	27.6
2005	16-Oct	3-Jun	230	47	61	52	6,450	118,000	28,158	1.6	731.7	25.3
2006	16-Oct	26-May	222	46	62	53	6,030	45,400	8,630	1.6	90.0	8.3
2007	16-Oct	12-Jun	240	44	61	53	5,210	44,600	8,823	1.3	233.3	11.4
2008	16-Oct	7-Jun	234	45	64	54	4,160	33,000	7,841	1.7	129.8	10.1
2009	16-Oct	25-May	221	46	62	54	3,920	60,400	9,495	1.9	250.6	17.1
2010	16-Oct	12-Jun	239	45	61	53	5,260	95,100	16,656	1.3	162.6	9.9
2011	16-Oct	27-May	224	45	65	53	4,800	35,200	8,344	1.7	180.6	8.8
2012	16-Oct	23-Jun	250	46	62	53	5,349	68,720	13,370	1.4	305.9	16.0
Mean	16-Oct	4-Jun	232	46	62	53	5,349	68,720	13,370	1.4	305.9	16.0
SD			9	1.0	1.4	0.6	843	27,696	6,116	0.4	205.5	7.0
CV			4%	2%	2%	1%	16%	40%	46%	30%	67%	43%

Table 9e. Summary of *O. mykiss* abiotic sample conditions at RBDD rotary traps during dates of capture by calendar year (CY).

	Dates of Capture			$H_2$0 Temperature (^{o}F)			Discharge (CFS)			Turbidity (NTU)		
CY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002[1]	-	-	-	-	-	-	-	-	-	-	-	-
2003	19-Jan	30-Dec	345	46	61	56	6,310	56,800	13,677	0.9	240.2	16.4
2004	6-Jan	17-Dec	346	46	62	56	5,170	92,800	14,613	1.4	413.5	9.3
2005	1-Jan	29-Dec	362	46	63	56	5,890	94,700	12,661	1.6	626.5	20.1
2006	3-Jan	30-Dec	361	47	61	54	6,610	82,900	20,803	2.0	190.5	11.4
2007	16-Jan	27-Dec	345	46	62	56	5,510	45,400	9,596	1.3	74.5	6.4
2008	6-Jan	28-Dec	357	44	64	56	4,610	44,600	9,478	1.5	233.3	9.0
2009	12-Jan	25-Dec	347	45	64	57	4,020	33,000	8,775	1.9	129.8	10.3
2010	15-Jan	12-Dec	331	47	62	56	5,150	60,400	11,194	1.1	250.6	12.4
2011	1-Jan	30-Dec	363	45	61	55	5,260	95,100	13,833	1.3	162.6	7.2
2012	17-Jan	14-Dec	332	45	65	56	4,800	70,400	10,557	1.2	315.5	11.0
Mean	10-Jan	23-Dec	349	46	63	56	5,333	67,610	12,519	1.4	263.7	11.4
SD			12	0.9	1.3	0.8	783	22,986	3,551	0.3	159.1	4.1
CV			3%	2%	2%	1%	15%	34%	28%	24%	60%	37%

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[1] Sampling did not begin until mid-April of 2002 and this year not included in analyses.

Table 9f. Summary of Green Sturgeon abiotic sample conditions at RBDD rotary traps during dates of capture by calendar year (CY).

	Dates of Capture			$H_2$0 Temperature (^{o}F)			Discharge (CFS)			Turbidity (NTU)		
CY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2002	7-May	16-Jul	70	55	60	58	9,317	15,680	13,038	0.9	16.3	3.5
2003	13-Jun	11-Nov	151	52	61	58	6,950	16,000	10,802	0.9	48.6	6.5
2004	4-May	29-Jul	86	55	60	58	9,560	16,700	14,210	3.0	18.3	4.9
2005	7-May	13-Aug	98	54	61	58	10,200	76,200	18,614	2.3	626.5	26.4
2006	10-Jun	25-Aug	76	56	59	57	12,800	15,600	14,579	3.4	13.9	5.7
2007	11-May	24-Jul	74	55	61	58	9,790	17,000	12,905	1.7	50.4	4.5
2008	-	-	0	-	-	-	-	-	-	-	-	-
2009	11-May	16-Jul	66	58	64	61	9,460	13,700	11,226	4.1	34.4	13.5
2010	26-May	29-Aug	95	55	61	58	9,150	18,300	13,143	1.6	22.0	5.4
2011	16-May	27-Aug	103	52	61	58	10,400	24,800	14,059	3.6	23.5	6.8
2012	1-May	26-Jun	56	55	61	58	8,763	21,398	12,258	2.2	85.4	7.7
Mean	17-May	12-Aug	88	55	61	58	9,639	23,538	13,483	2.4	93.9	8.5
SD			27	1.7	1.2	0.9	1,464	18,782	2,181	1.1	188.4	6.9
CV			31%	3%	2%	2%	15%	80%	16%	47%	201%	81%

Table 9g. Summary of Lamprey *spp.* abiotic sample conditions at RBDD rotary traps during dates of capture by water year (WY).

	Dates of Capture			H_20 Temperature (^oF)			Discharge (CFS)			Turbidity (NTU)		
WY	Initial	Final	Days	Min	Max	Ave	Min	Max	Ave	Min	Max	Ave
2003	1-Oct	27-Sep	361	47	61	56	6,176	86,500	15,033	0.4	240.2	15.1
2004	1-Oct	29-Sep	364	46	62	55	6,310	92,800	15,528	0.9	413.5	16.3
2005	2-Oct	29-Sep	362	46	63	56	5,170	76,200	11,800	1.4	626.5	18.6
2006	1-Oct	29-Sep	363	47	61	54	6,450	118,000	22,724	1.6	731.7	17.9
2007	1-Oct	29-Sep	363	46	62	55	6,030	45,400	9,832	1.6	90.0	7.3
2008	1-Oct	29-Sep	364	44	63	56	5,210	44,600	9,342	1.3	233.3	8.8
2009	1-Oct	29-Sep	363	45	64	57	4,160	33,000	8,791	1.6	129.8	10.5
2010	1-Oct	30-Sep	364	46	62	56	3,920	60,400	10,241	1.1	250.6	12.1
2011	3-Oct	30-Sep	362	45	61	55	5,260	95,100	15,022	1.3	162.6	8.4
2012	3-Oct	27-Sep	360	45	65	55	4,800	35,200	9,753	1.2	180.6	7.1
2013	5-Oct	28-Sep	358	44	64	56	5,330	70,400	10,479	1.1	315.5	8.5
Mean	2-Oct	29-Sep	362	46	63	56	5,347	68,873	12,595	1.2	306.8	11.9
SD			2	1.1	1.3	0.7	843	27,701	4,177	0.3	205.5	4.4
CV			1%	2%	2%	1%	16%	40%	33%	29%	67%	37%

Figures

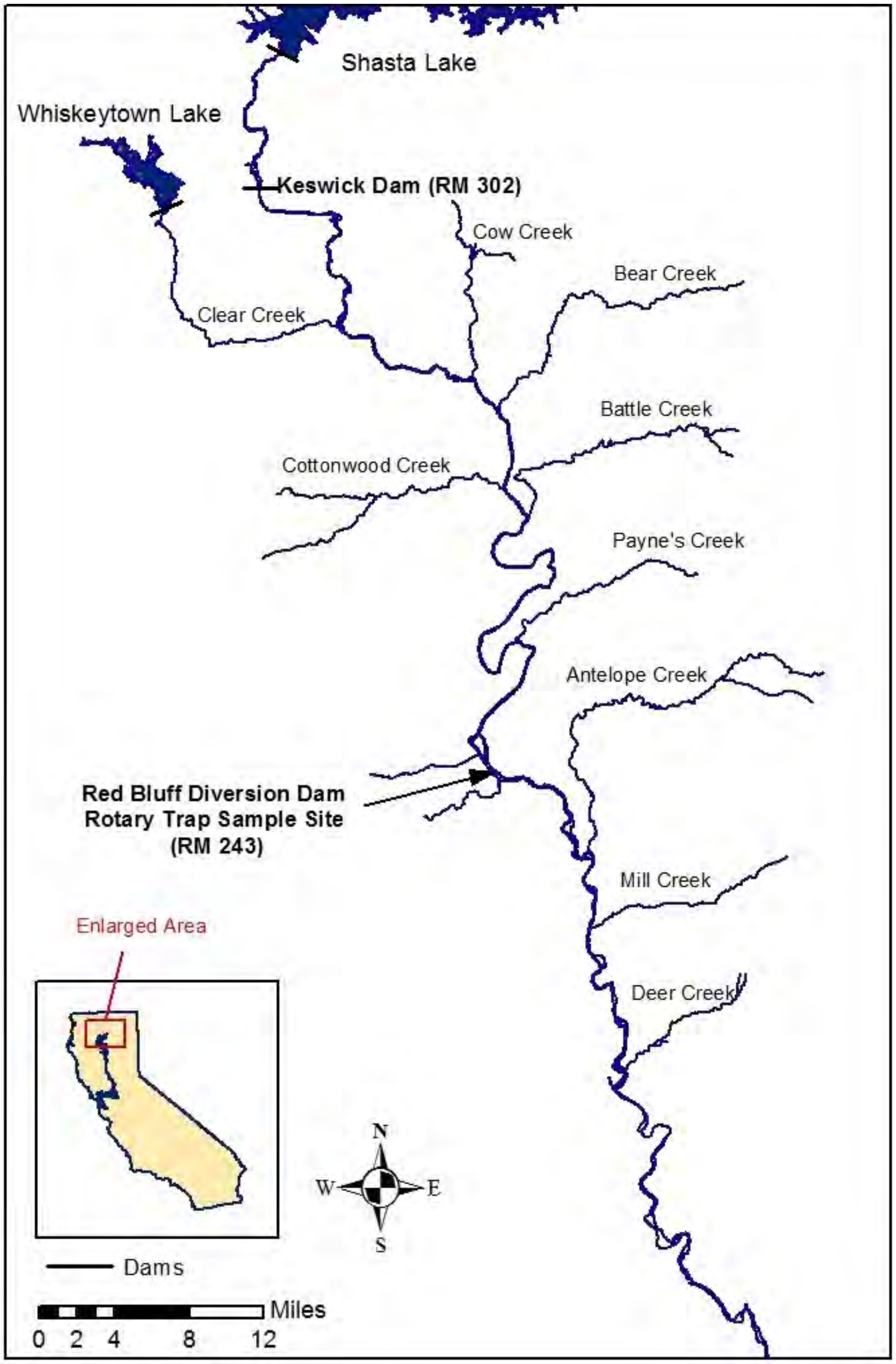

Figure 1. Location of Red Bluff Diversion Dam rotary trap sample site on the Sacramento River, California (RM 243).

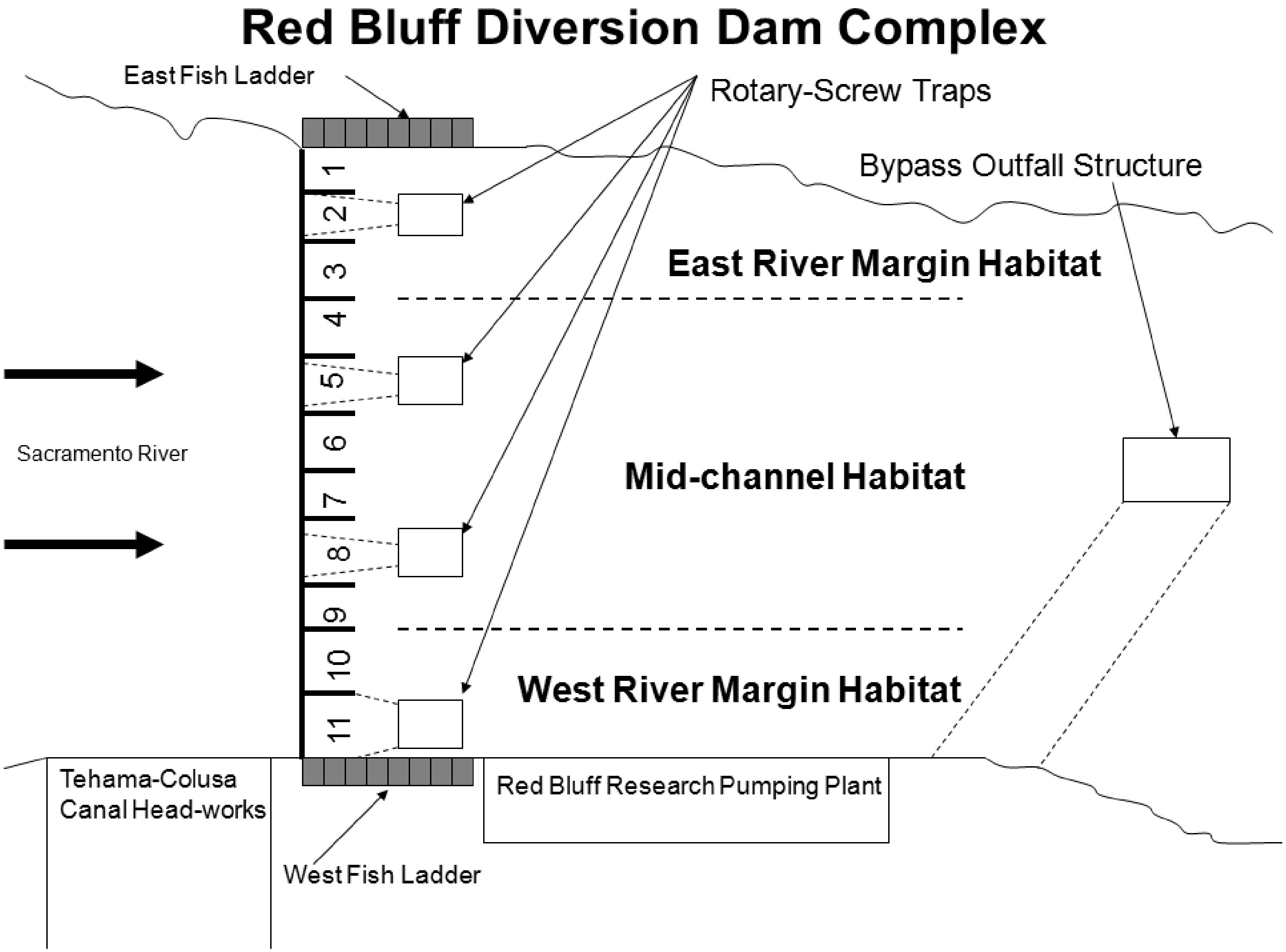

Figure 2. Rotary-screw trap sampling transect at Red Bluff Diversion Dam Site (RM 243) on the Sacramento River, California.

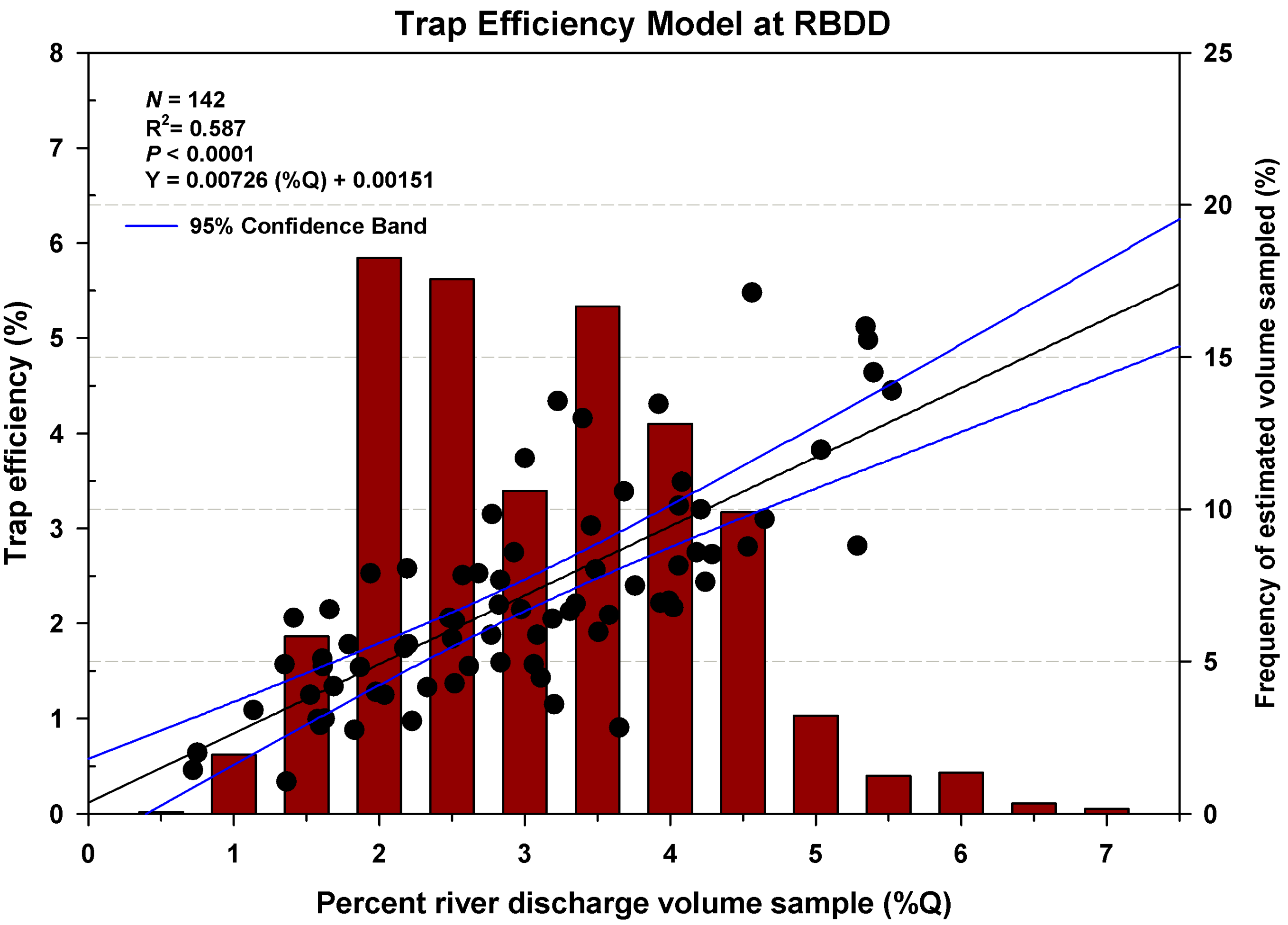

Figure 3. Trap efficiency model for combined 8-ft diameter rotary traps at Red Bluff Diversion Dam (RM 243), Sacramento River, CA. Mark-recapture trials (*N* = 142) were used to estimate trap efficiencies. Histogram indicates percentage of time traps sampled various levels (half percent bins) of river discharge between April 2002 and September 2013.

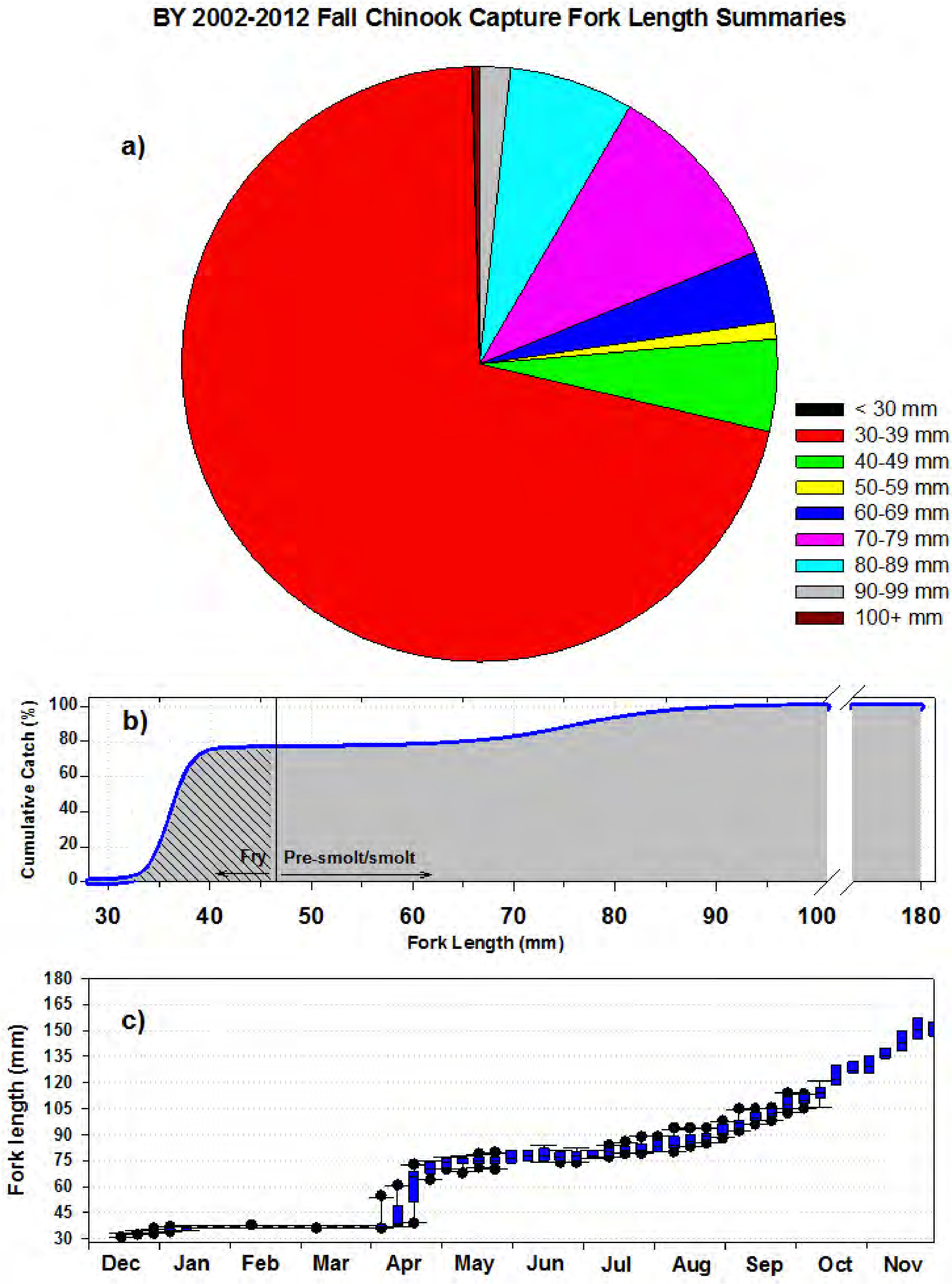

Figure 4. Fall Chinook fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for fall Chinook sampled by rotary traps at RBDD between December 2002 and September 2013.

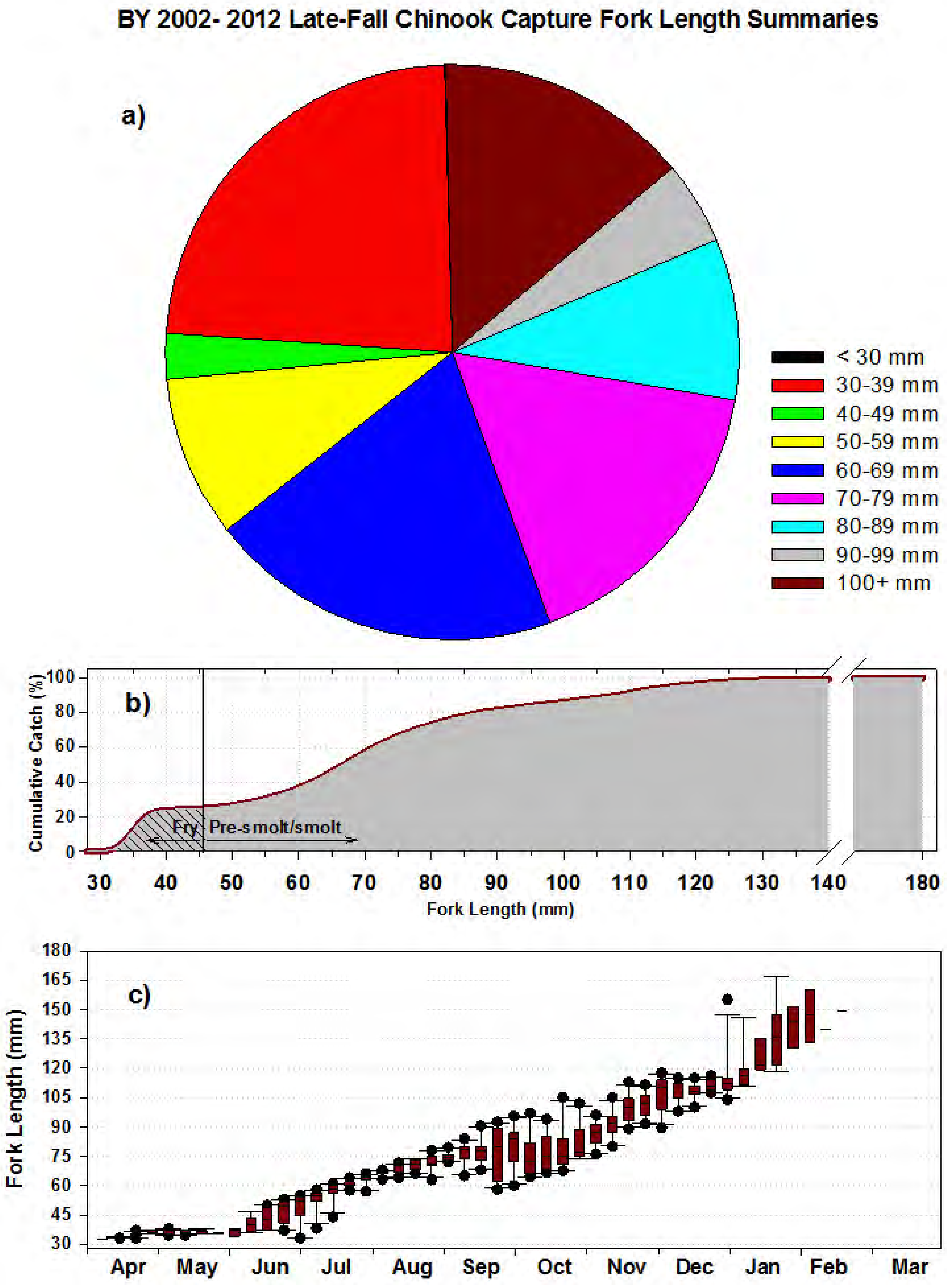

Figure 5. Late-fall Chinook fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for late-fall Chinook sampled by rotary traps at RBDD between April 2002 and March 2013.

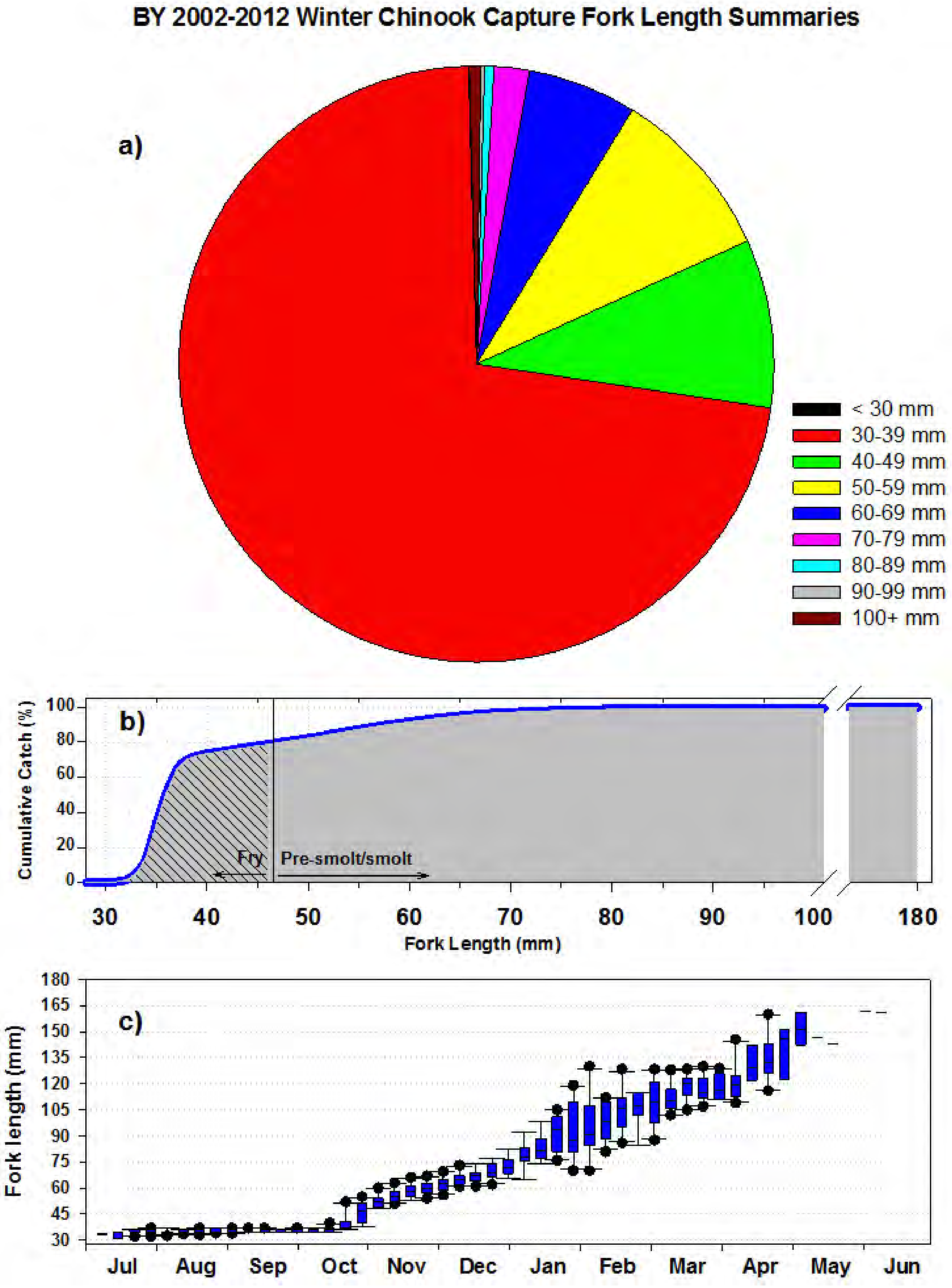

Figure 6. Winter Chinook fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for winter Chinook sampled by rotary traps at RBDD between July 2002 and June 2013.

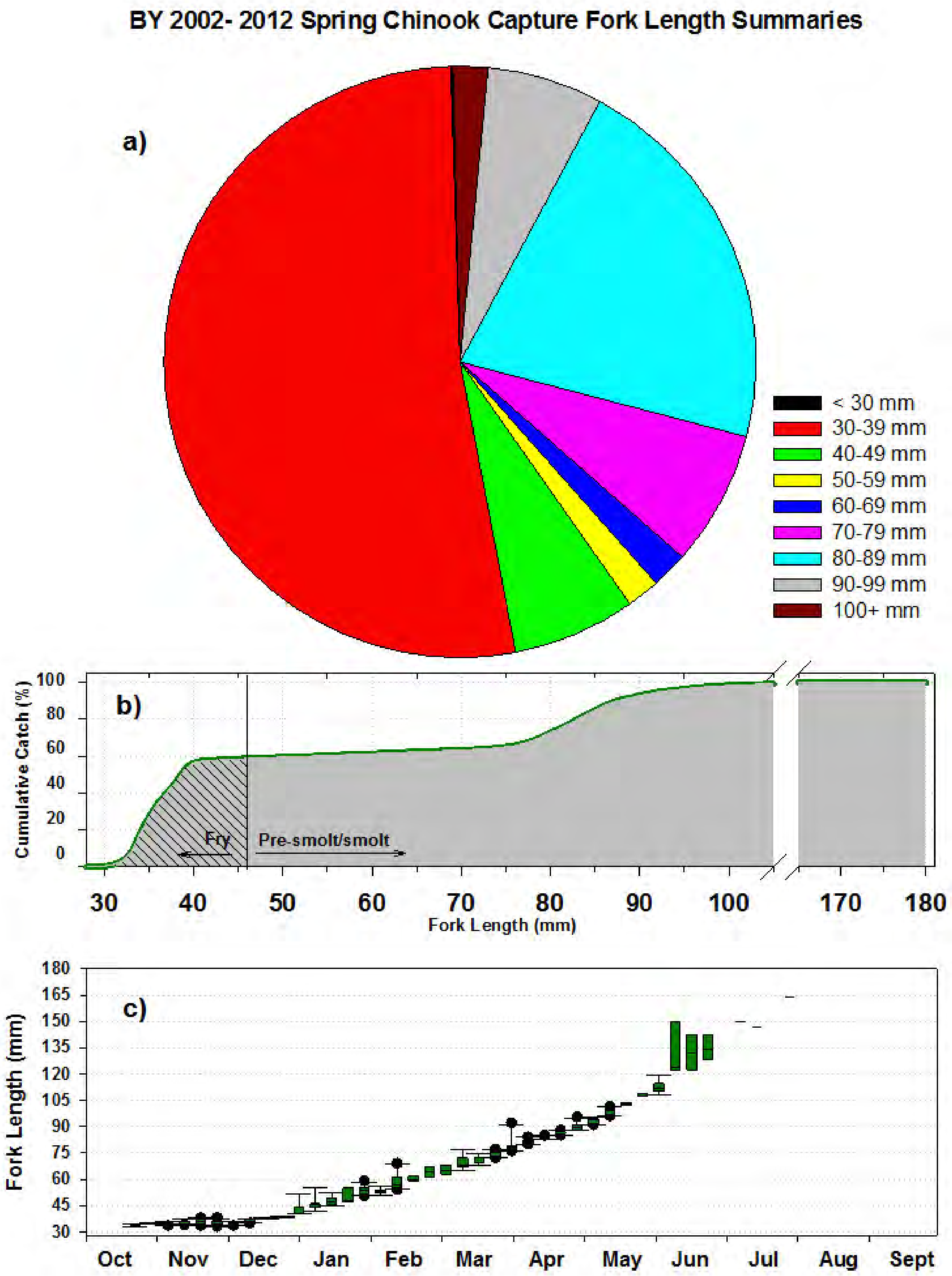

Figure 7. Spring Chinook fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for spring Chinook sampled by rotary traps at RBDD between October 2002 and September 2013.

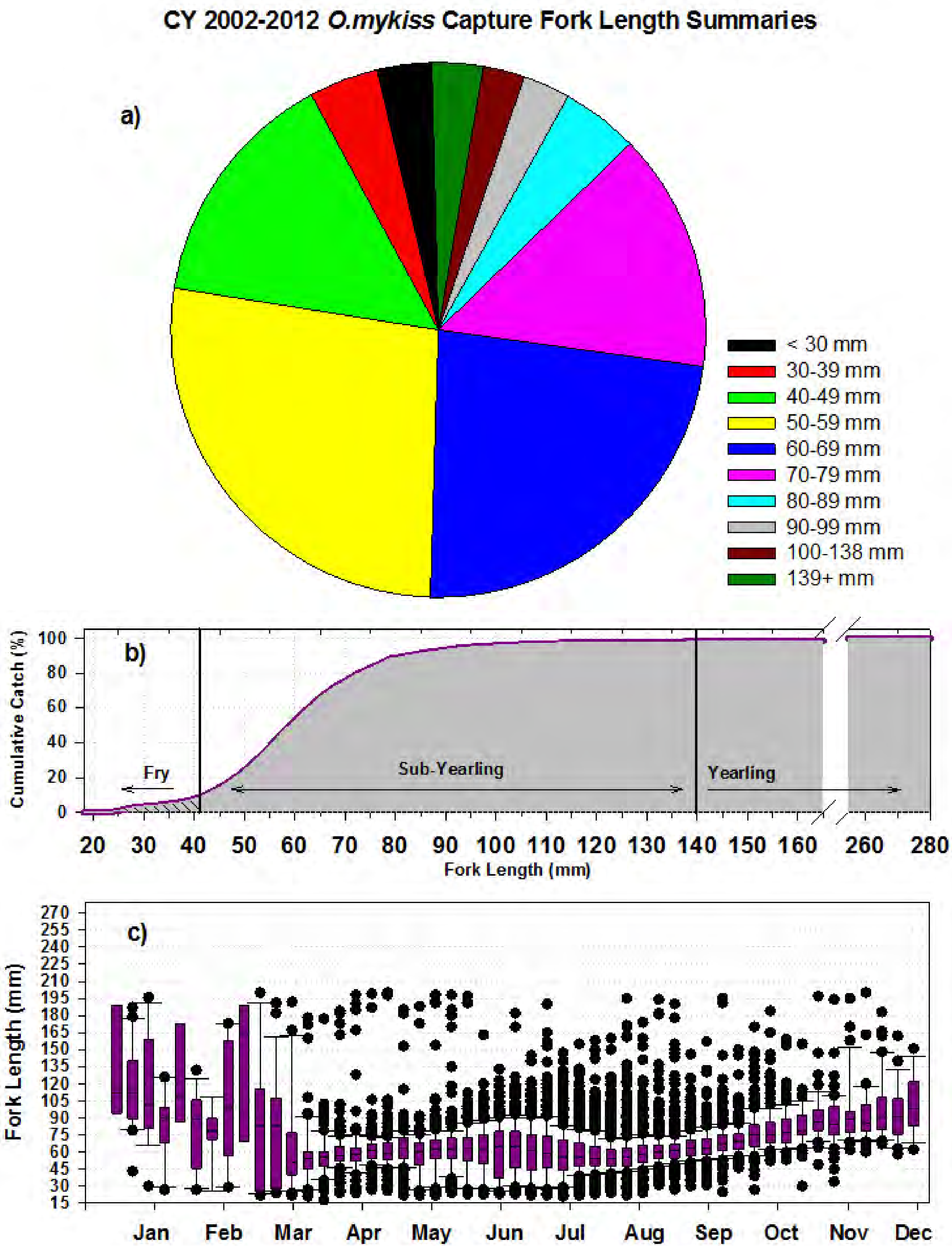

Figure 8. *O. mykiss* fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for *O. mykiss* sampled by rotary traps at RBDD between April 2002 and December 2012.

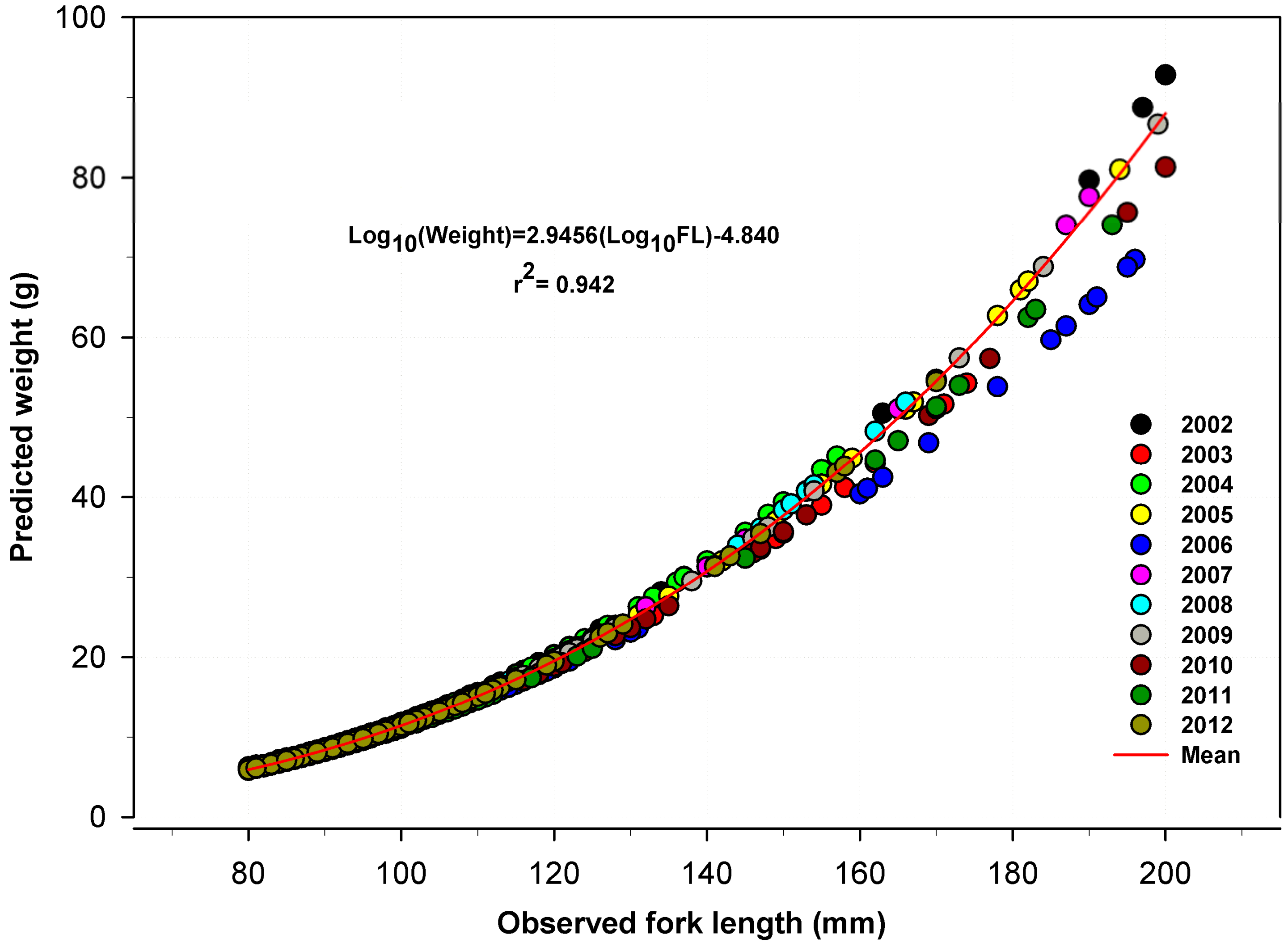

Figure 9. Predicted weight (g) for *O. mykiss* with measured fork lengths (FL) between 80 and 200 mm using annual weight-length regression equation.

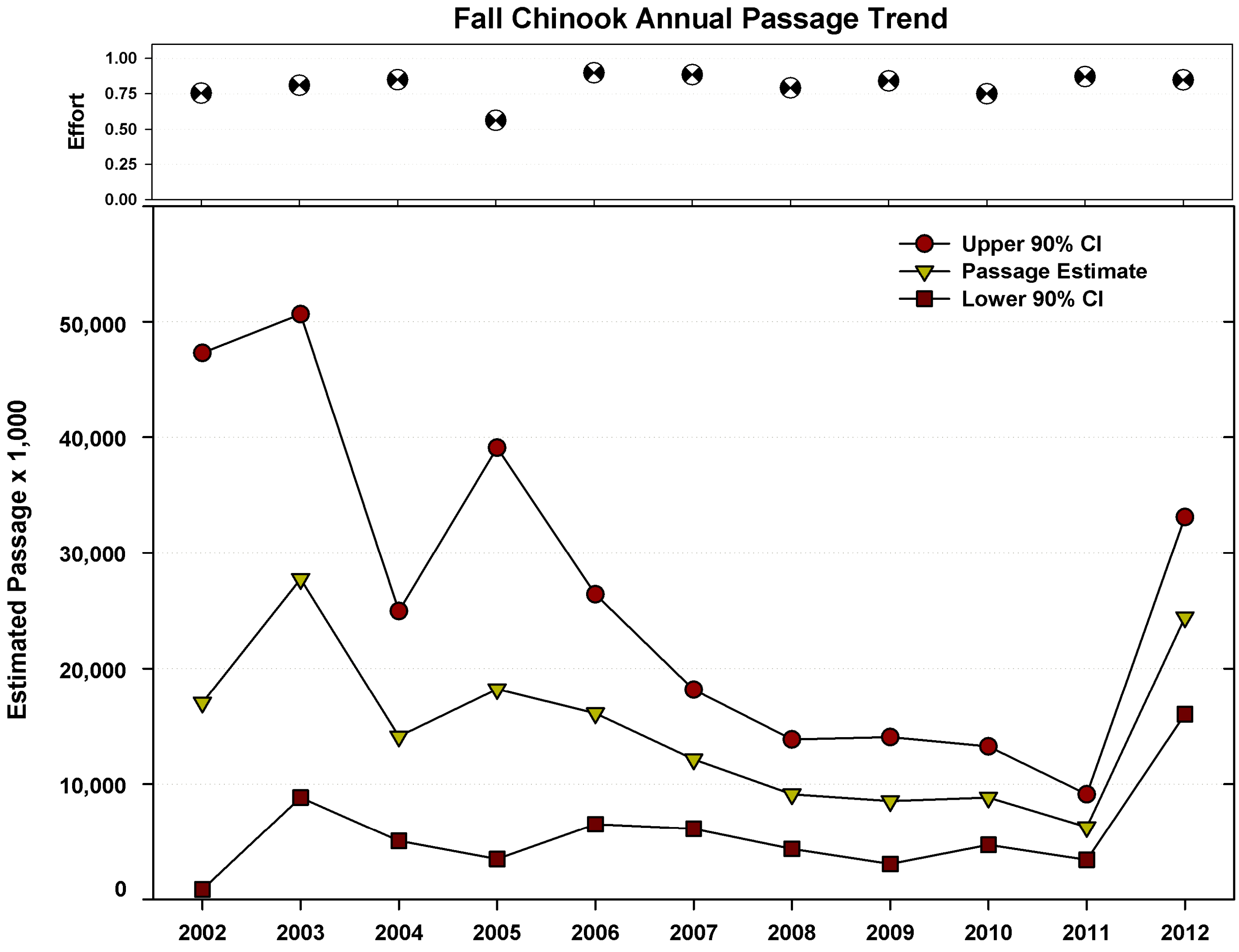

Figure 10. RBDD rotary trap fall Chinook annual sample effort and passage estimates with 90% confidence intervals (CI) for the period December 2002 through September 2013

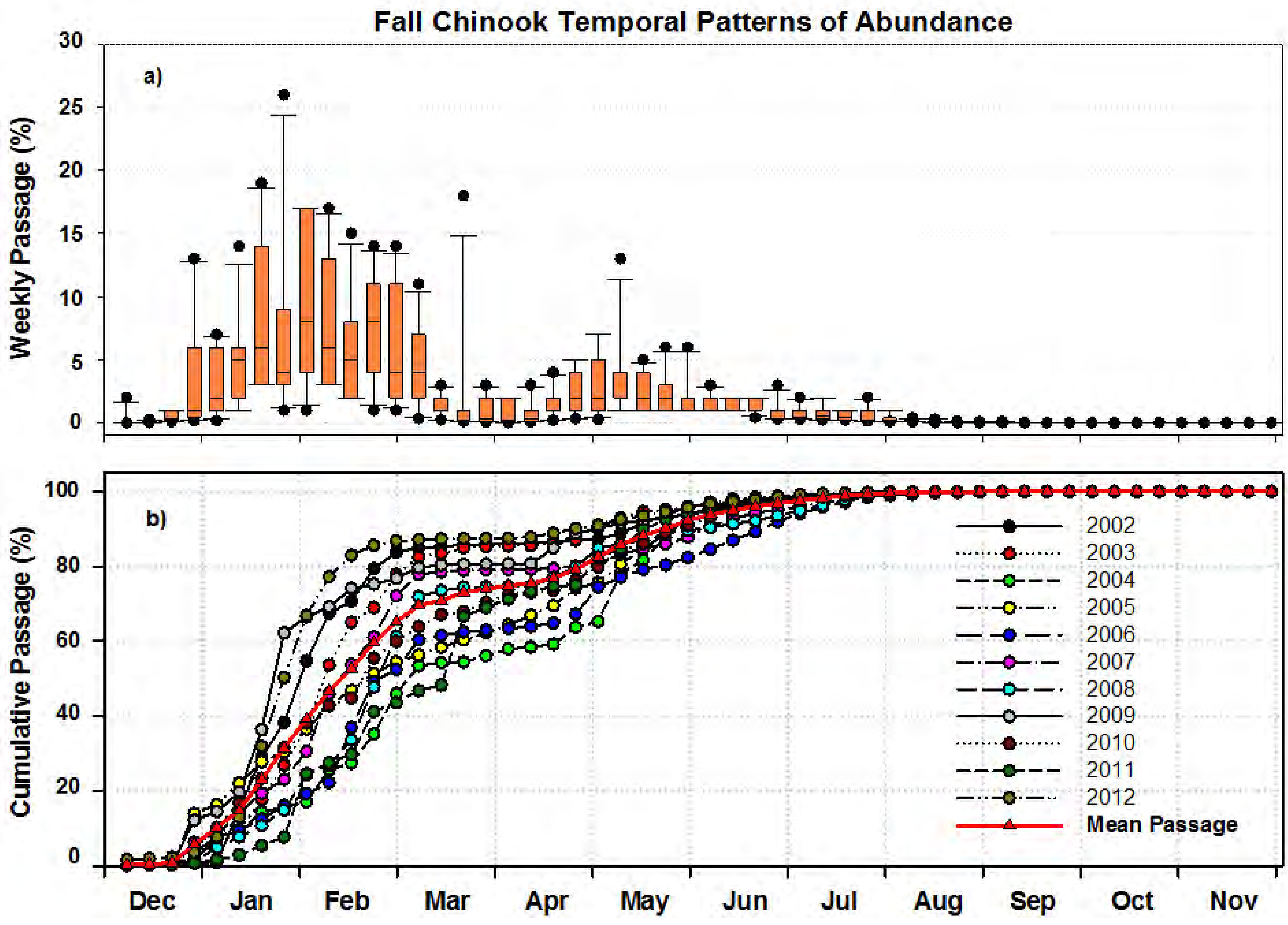

Figure 11. RBDD rotary trap fall Chinook (a) boxplots of weekly passage estimates relative to annual total passage estimates and (b) cumulative weekly passage with 11-year mean passage trend line for the period December 2002 through September 2013.

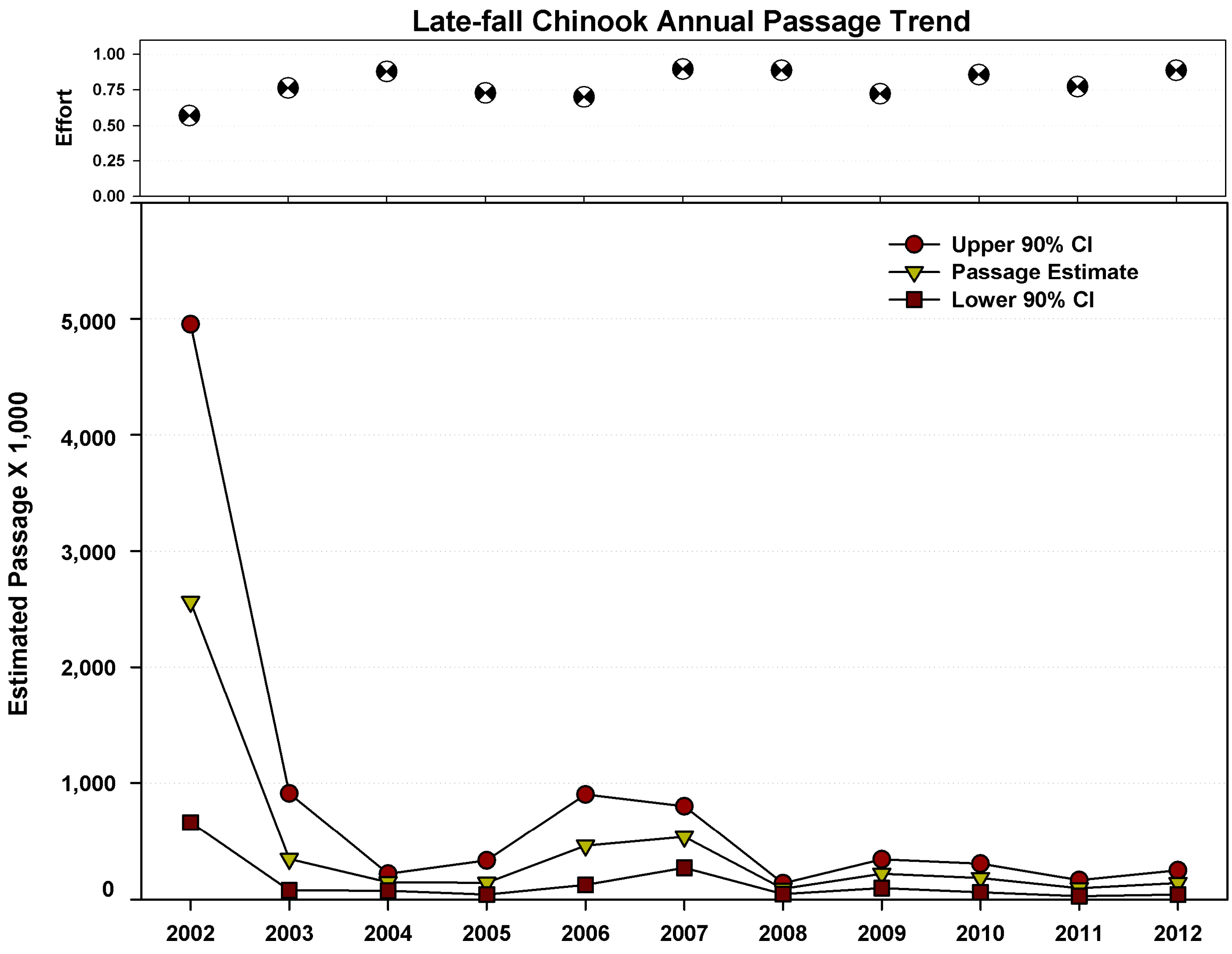

Figure 12. RBDD rotary trap late-fall Chinook annual sample effort and passage estimates with 90% confidence intervals (CI) for the period April 2002 through March 2013.

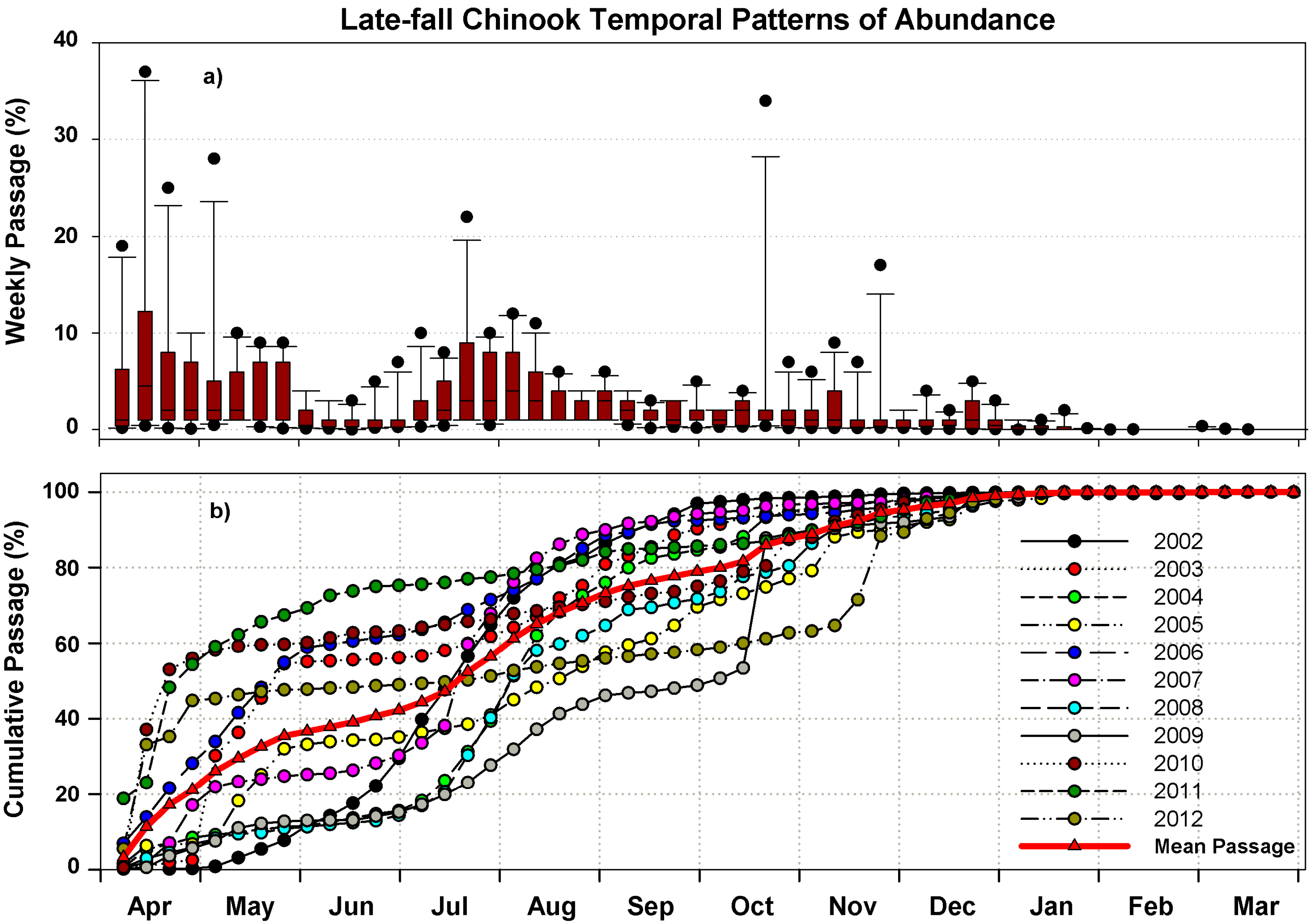

Figure 13. RBDD rotary trap late-fall Chinook (a) boxplots of weekly passage estimates relative to annual total passage estimates and (b) cumulative weekly passage with 11-year mean passage trend line for the period April 2002 through March 2013.

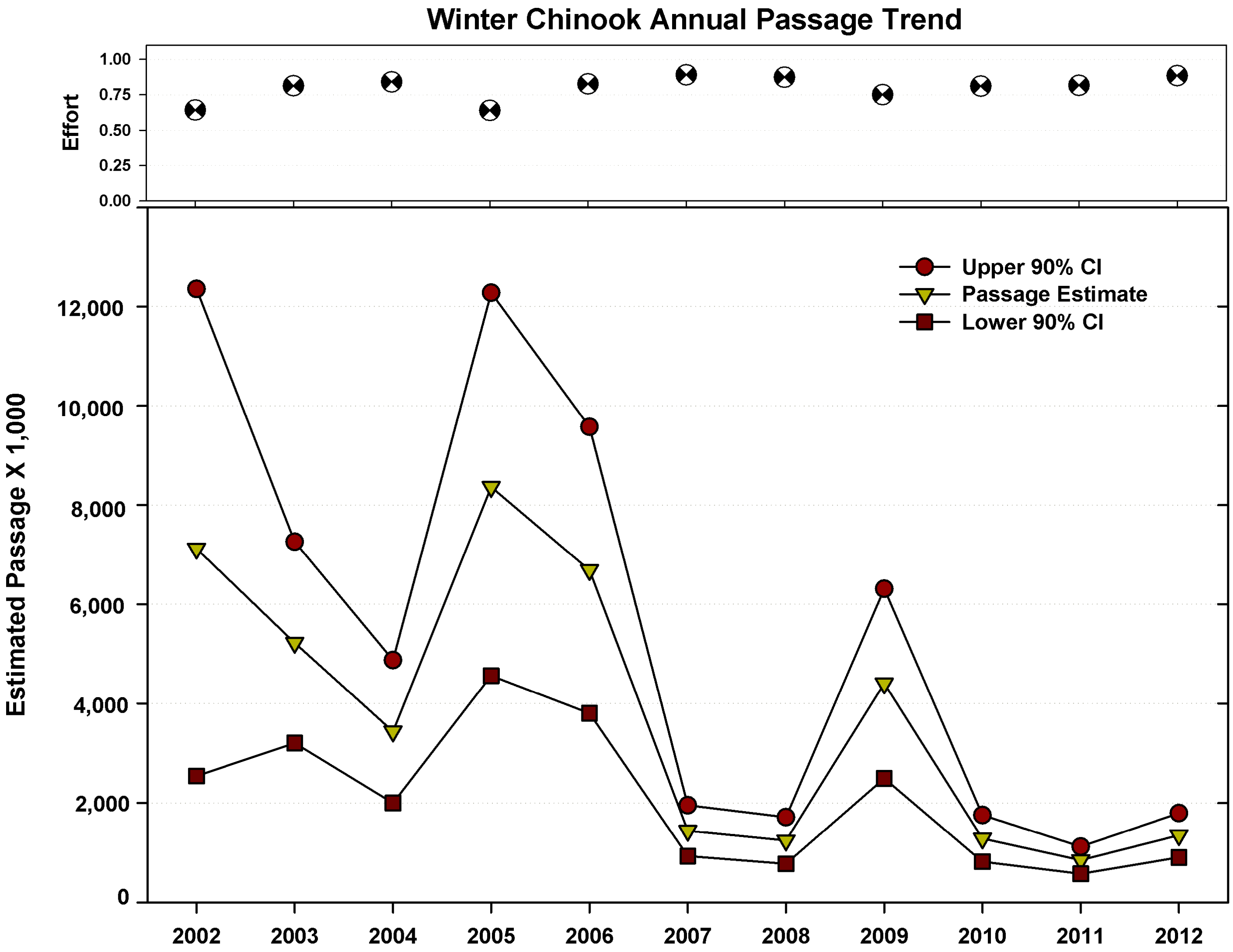

Figure 14. RBDD rotary trap winter Chinook annual sample effort and passage estimates with 90% confidence intervals (CI) for the period July 2002 through June 2013.

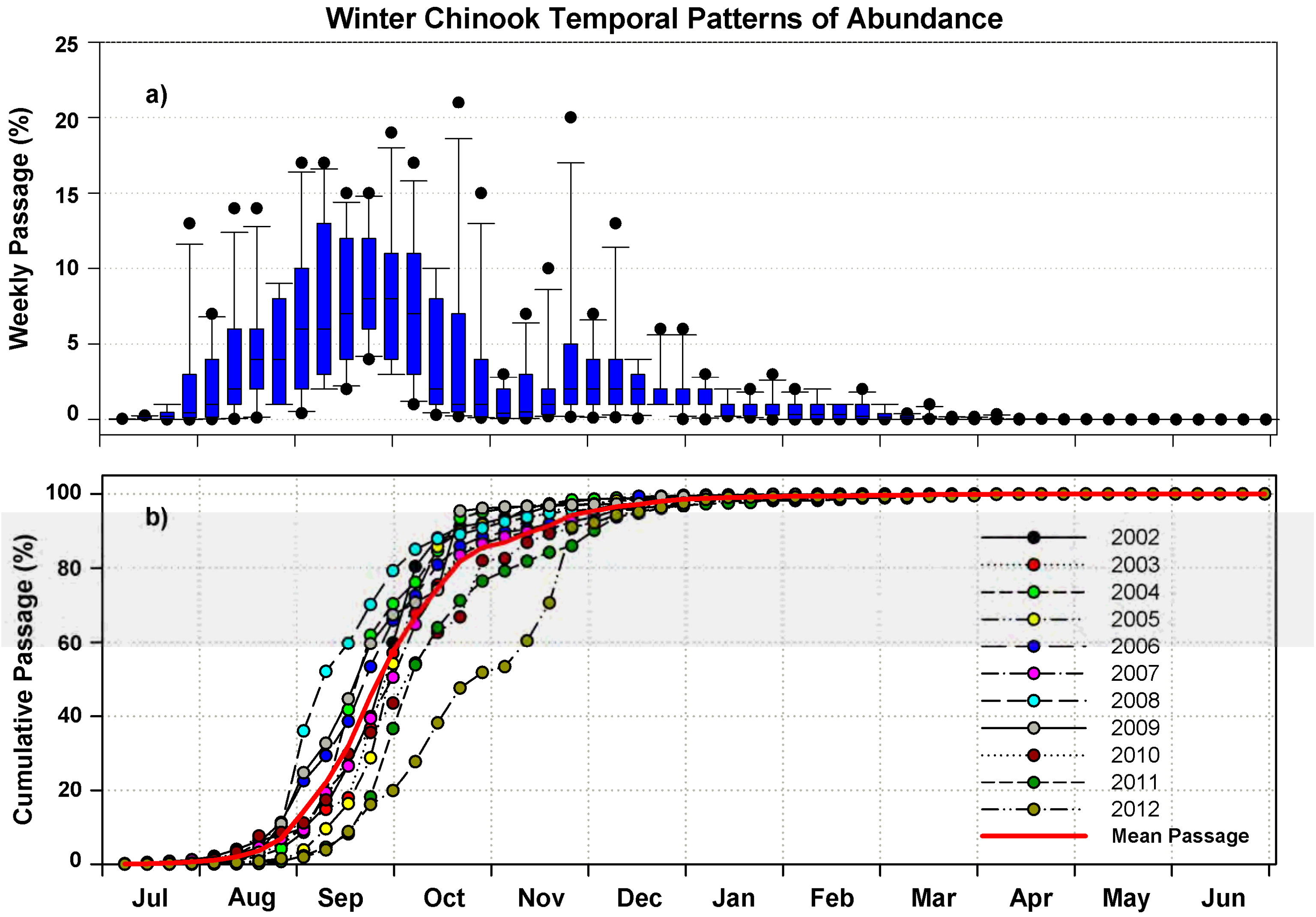

Figure 15. RBDD rotary trap winter Chinook (a) boxplots of weekly passage estimates relative to annual total passage estimates and (b) cumulative weekly passage with 11-year mean passage trend line for the period July 2002 through June 2013.

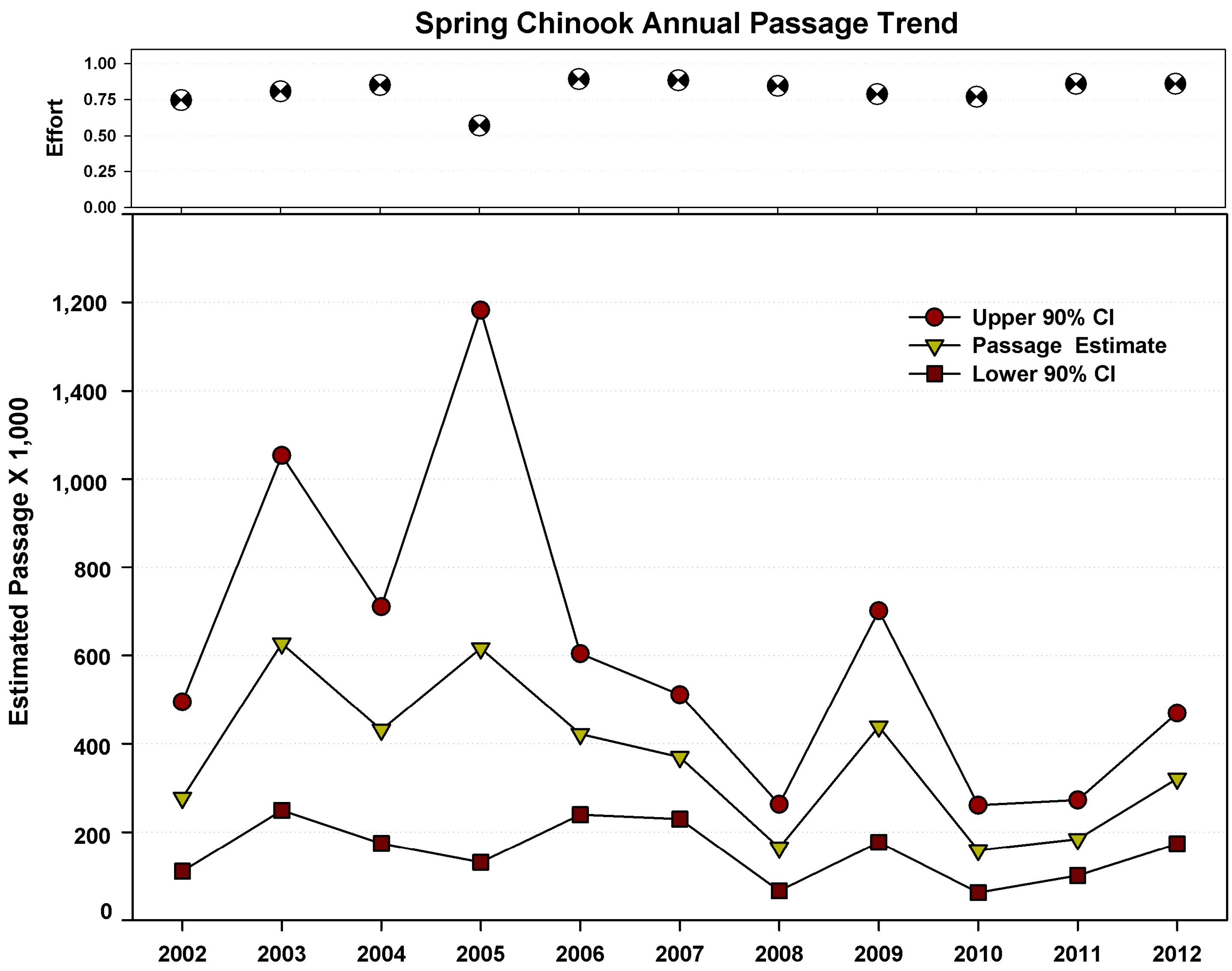

Figure 16. RBDD rotary trap spring Chinook annual sample effort and passage estimates with 90% confidence intervals (CI) for the period October 2002 through September 2013.

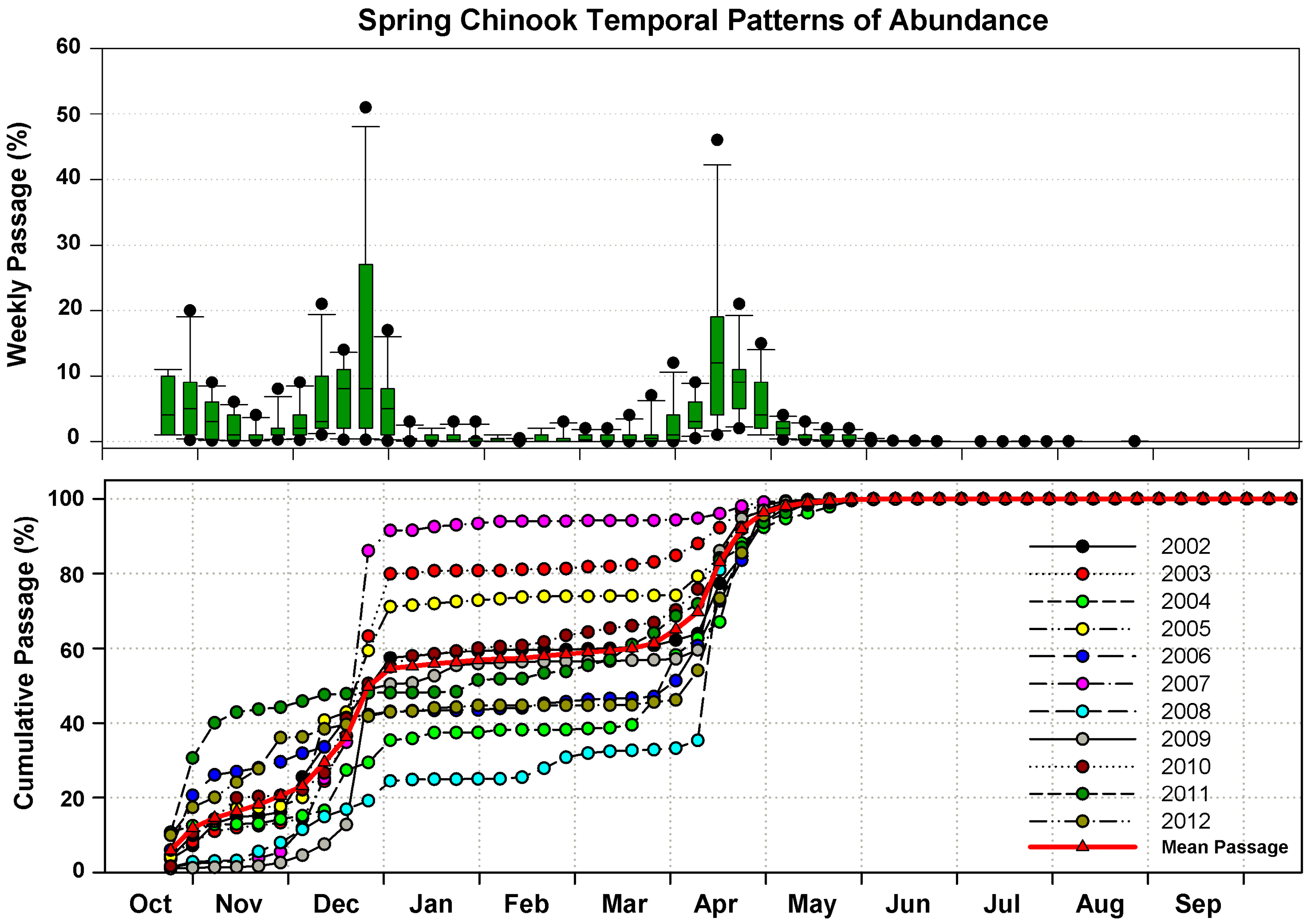

Figure 17. RBDD rotary trap spring Chinook (a) boxplots of weekly passage estimates relative to annual total passage estimates and (b) cumulative weekly passage with 11-year mean passage trend line for the period October 2002 through September 2013.

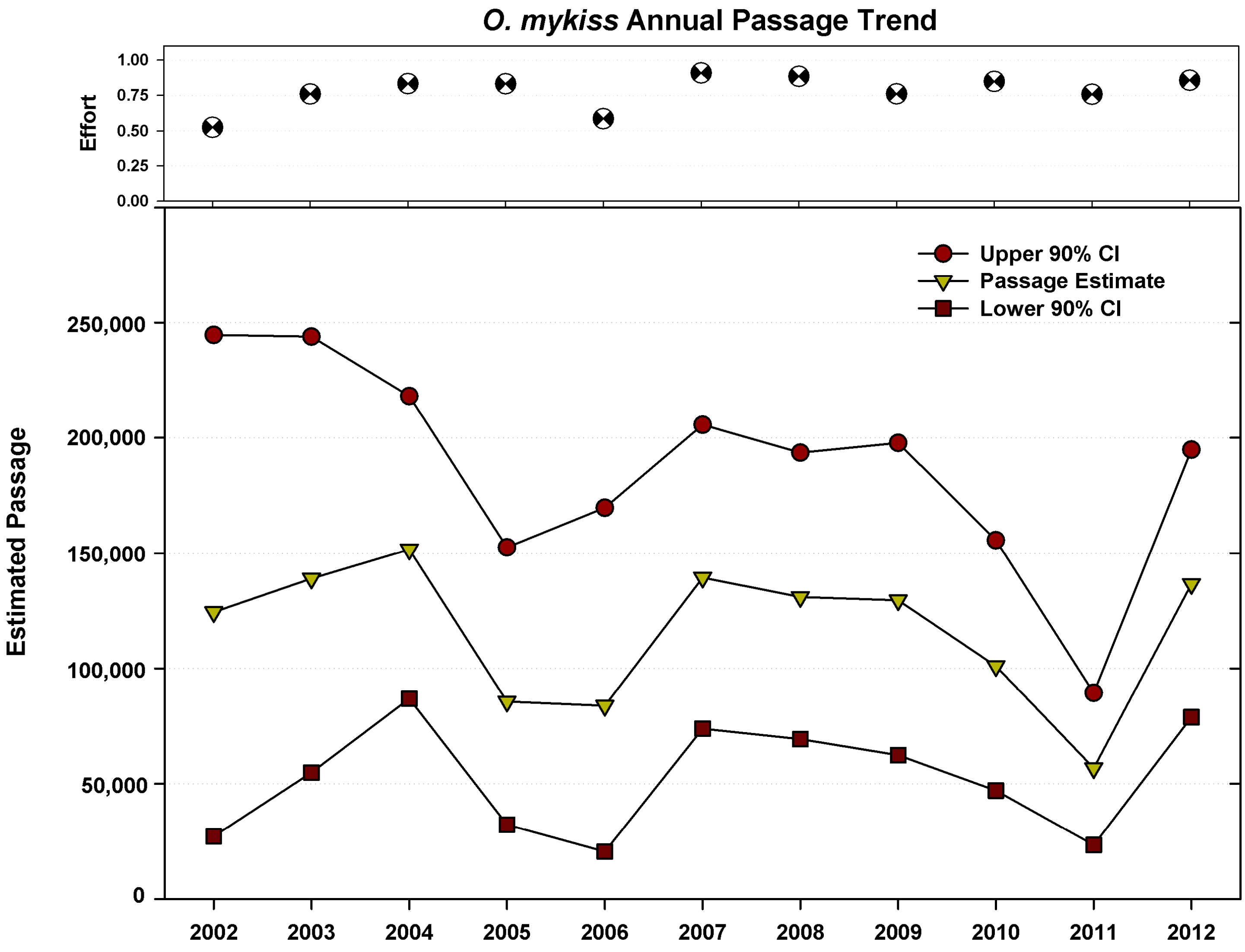

Figure 18. RBDD rotary trap *O. mykiss* annual sample effort and passage estimates with 90% confidence intervals (CI) for the period April 2002 through December 2012.

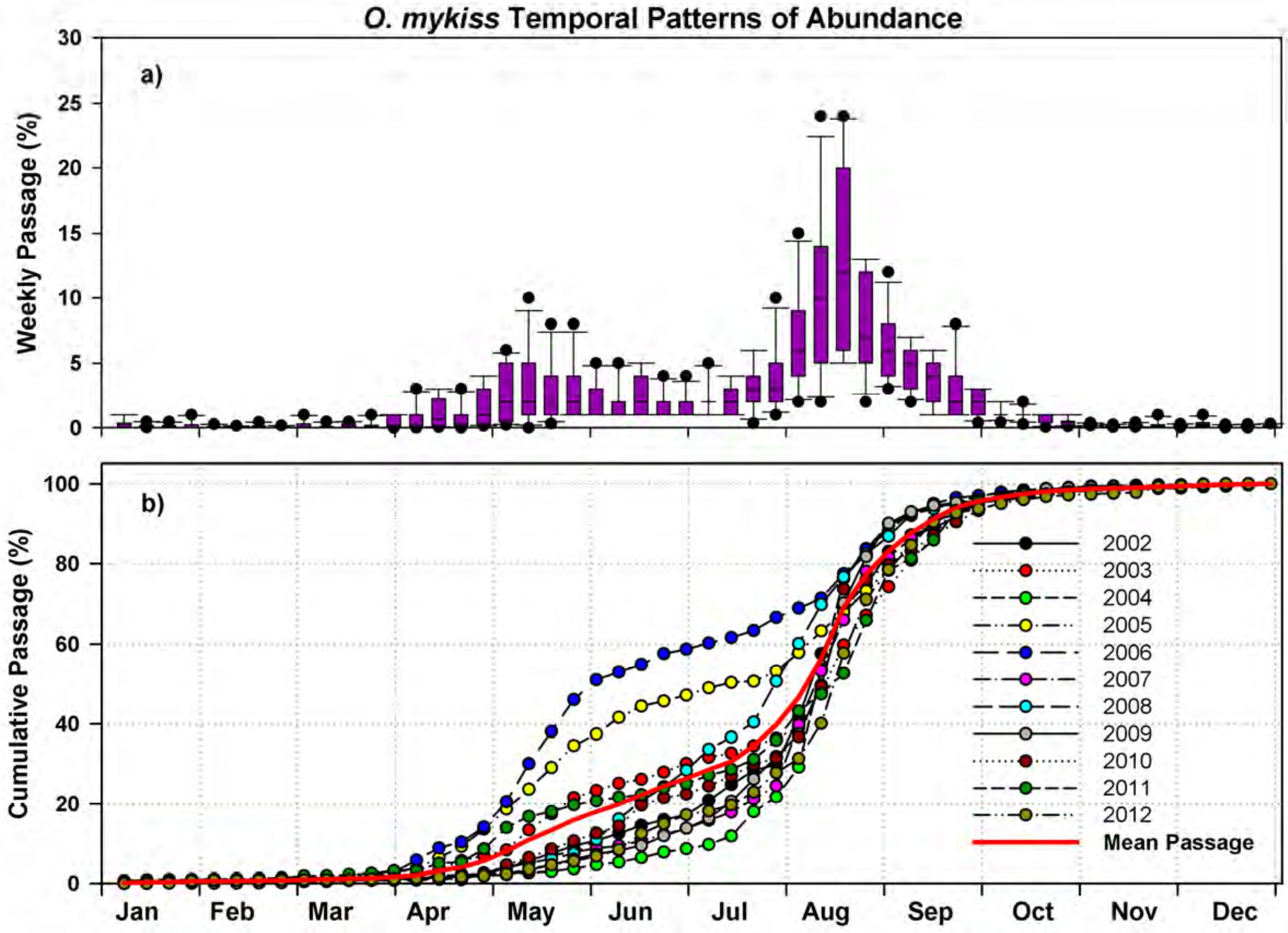

Figure 19. RBDD rotary trap *O. mykiss* (a) boxplots of weekly passage estimates relative to annual total passage estimates and (b) cumulative weekly passage with 11-year mean passage trend line for the period April 2002 through December 2012.

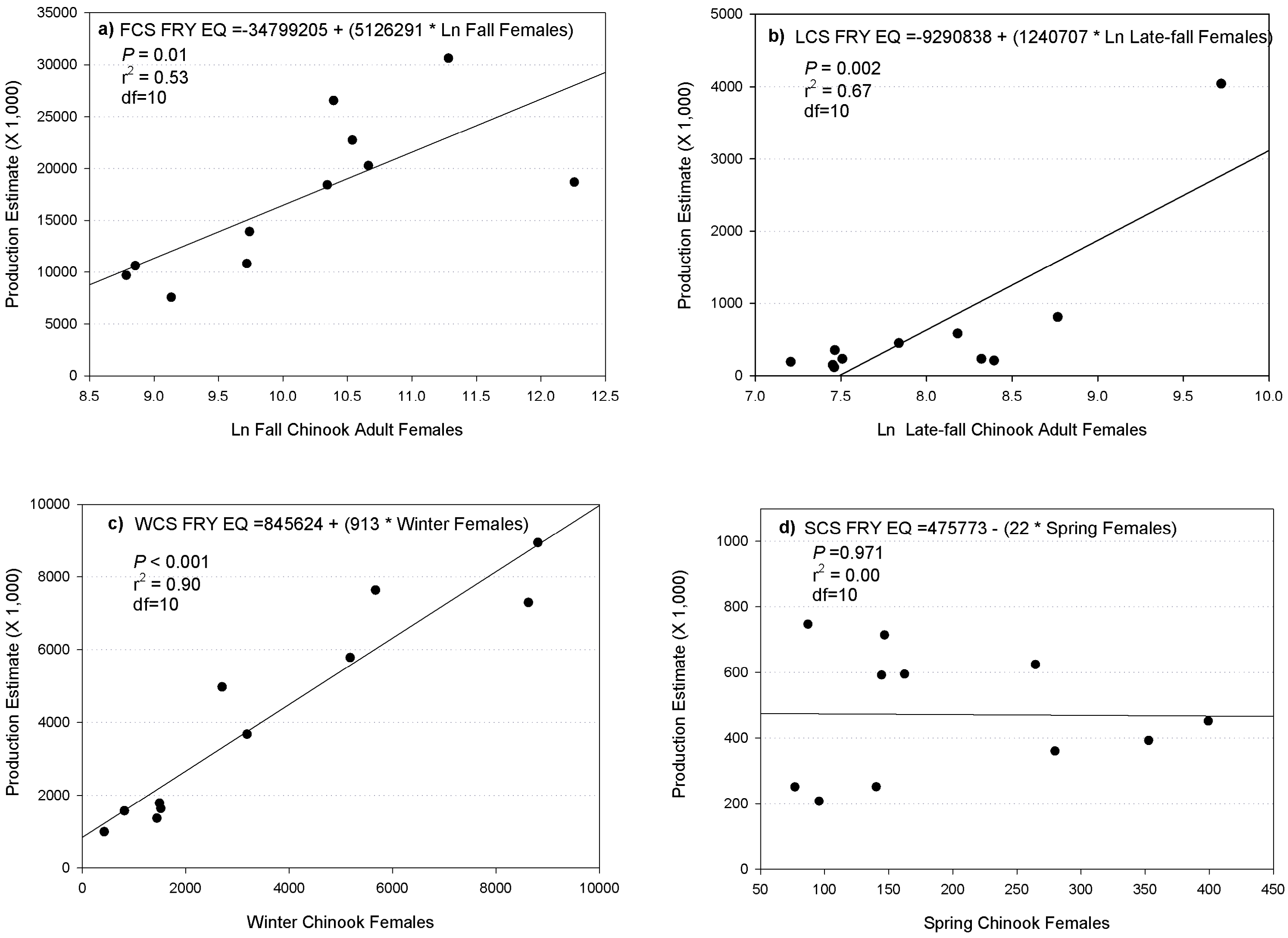

Figure 20. Relationships between a) fall, b) late-fall, c) winter, and d) spring Chinook fry-equivalent production estimates and estimated number of female adult Chinook salmon upstream of RBDD between 2002 and 2012. Note: fall and late-fall adult females were natural log transformed due to extraordinary escapement values estimated for the year 2002.

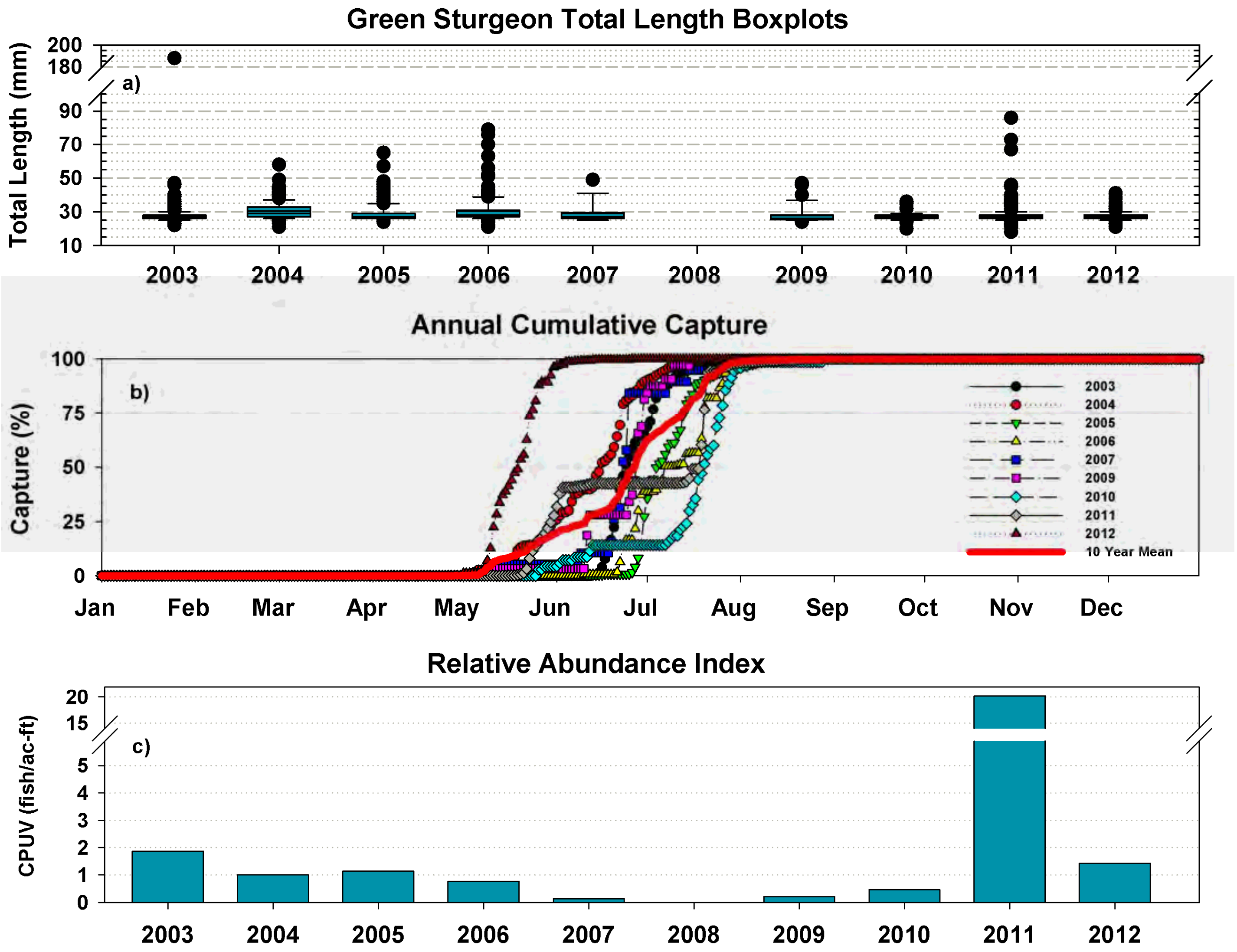

Figure 21. Green sturgeon a) annual total length capture boxplots, b) annual cumulative capture trends with 10-year mean trend line, and c) relative abundance indices. All fish captured by rotary trap at RBDD (RM 243) on the Upper Sacramento River, CA between 2003 and 2012. Data from 2002 excluded from analysis due to limited effort and USBR Crown Flow study resulting in incomparable sampling regimes and results.

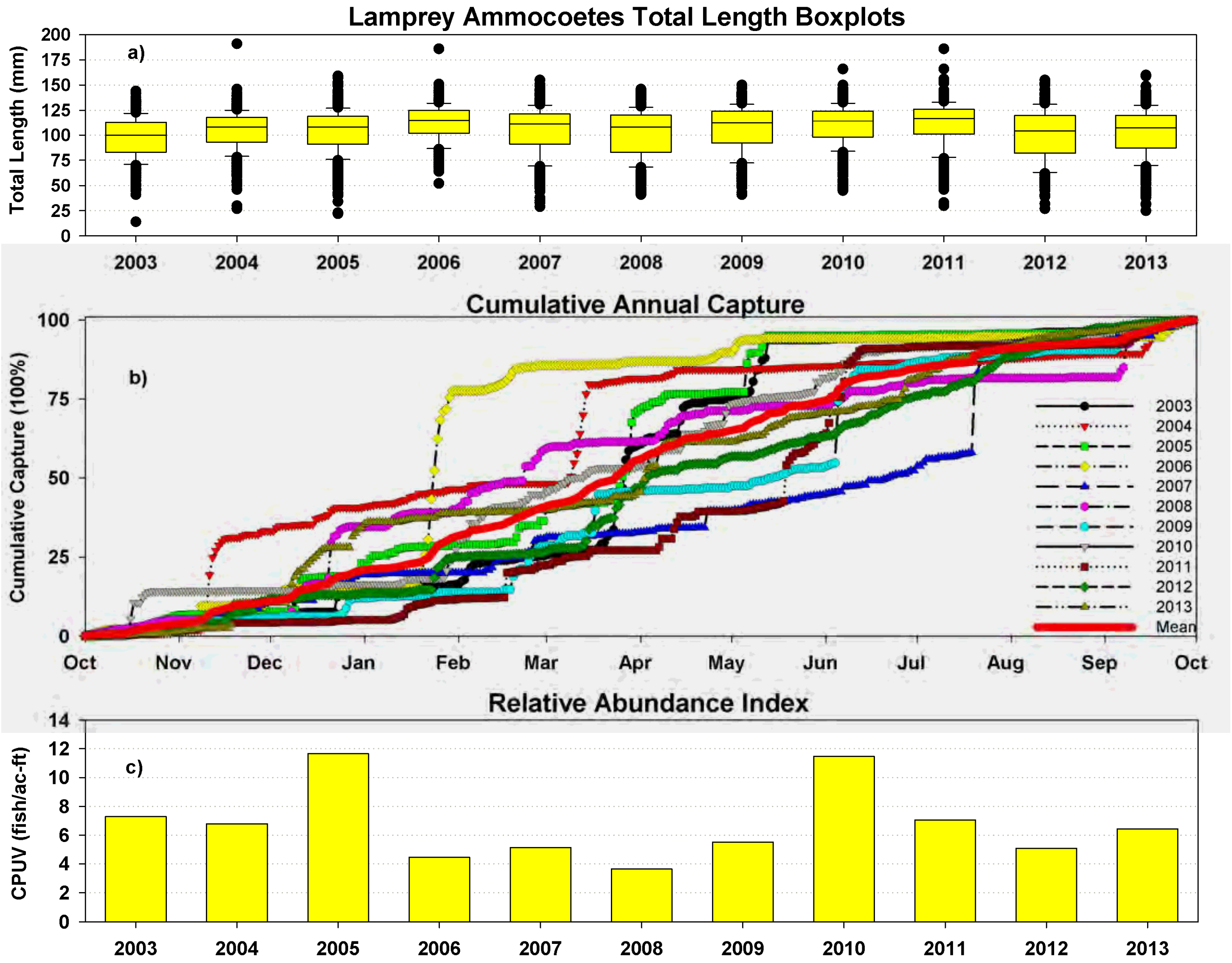

Figure 22. Unidentified lamprey ammocoetes a) total length distribution box plots, b) cumulative annual capture trends, and c) relative abundance indices from rotary trap samples collected between October 1, 2002 and September 30, 2013 by water year from the Sacramento River, CA at the RBDD (RM 243).

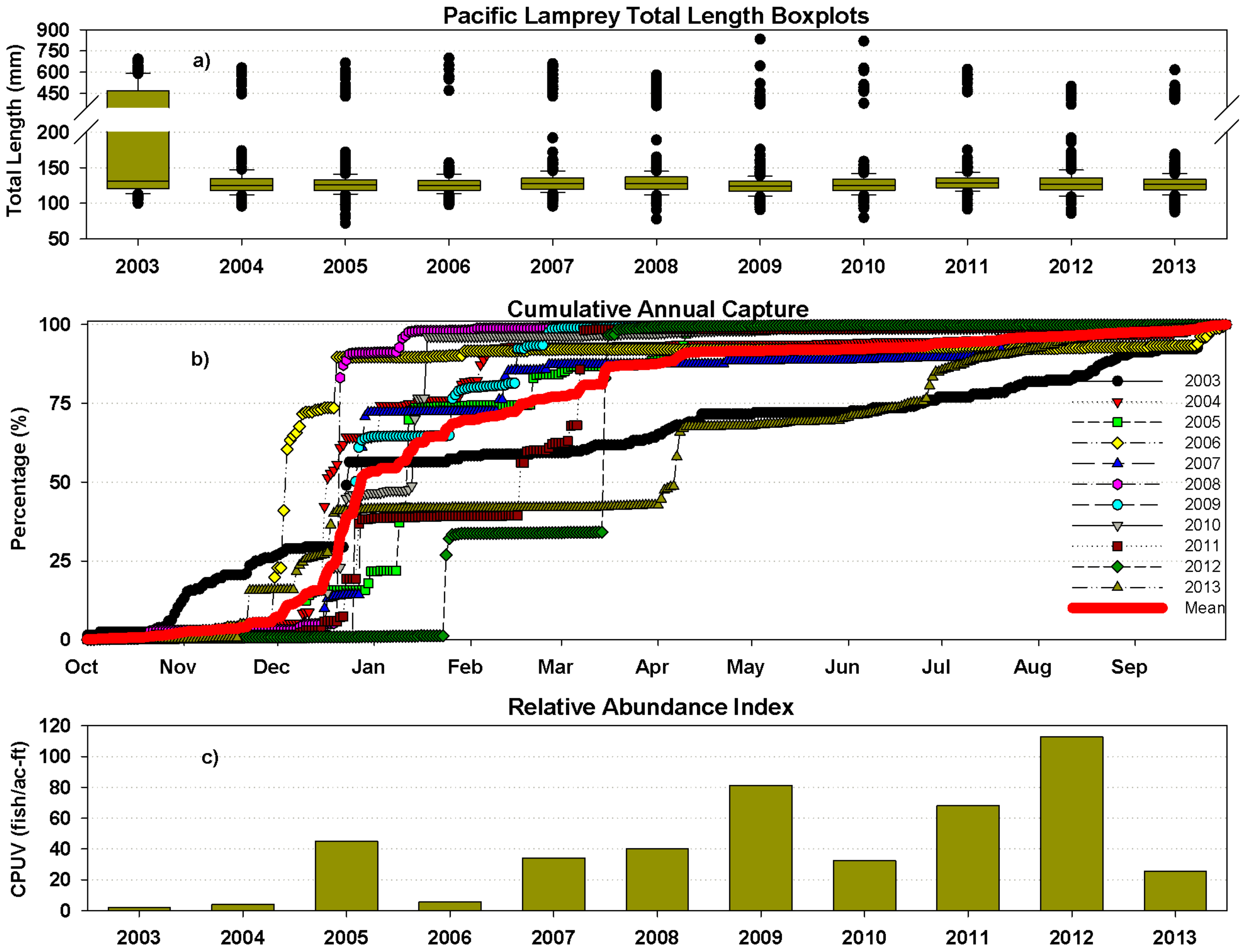

Figure 23. Pacific Lamprey (macropthalmia and adults) a) total length distribution box plots, b) cumulative annual capture trends, and c) relative abundance indices from rotary trap samples collected between October 1, 2002 and September 30, 2013 by water year from the Sacramento River, CA at the RBDD (RM 243).

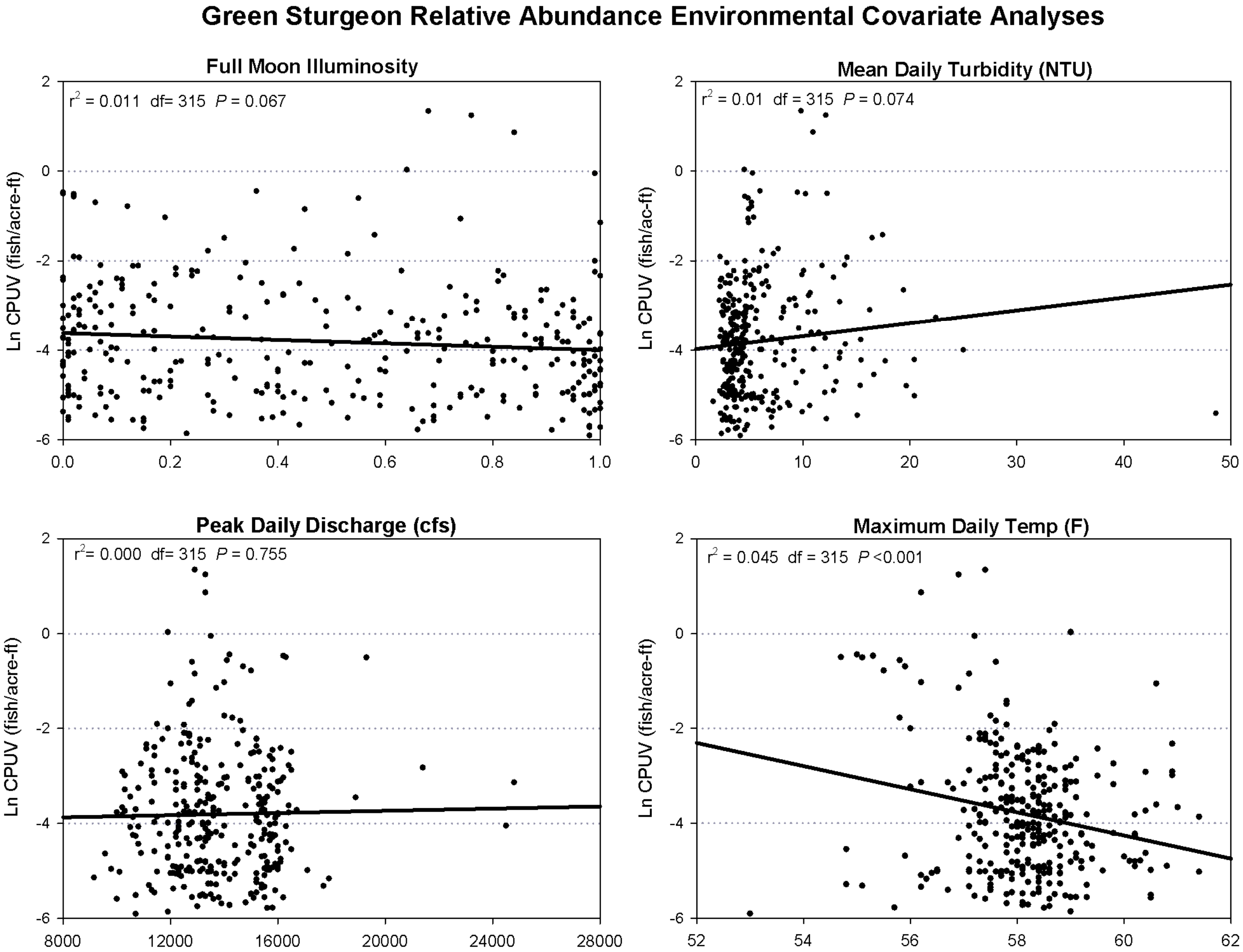

Figure 24. Regression analysis results of natural log (Ln) Green Sturgeon catch per unit volume (CPUV) and a) full moon illuminosity, b) mean daily turbidity, c) peak daily discharge and d) maximum daily temperatures at RBDD. All fish captured by rotary trap at RBDD (RM 243) on the Upper Sacramento River, CA between 2003 and 2012. Data from 2002 excluded from analysis due to limited effort and USBR Crown Flow study resulting in incomparable sampling regimes and results.

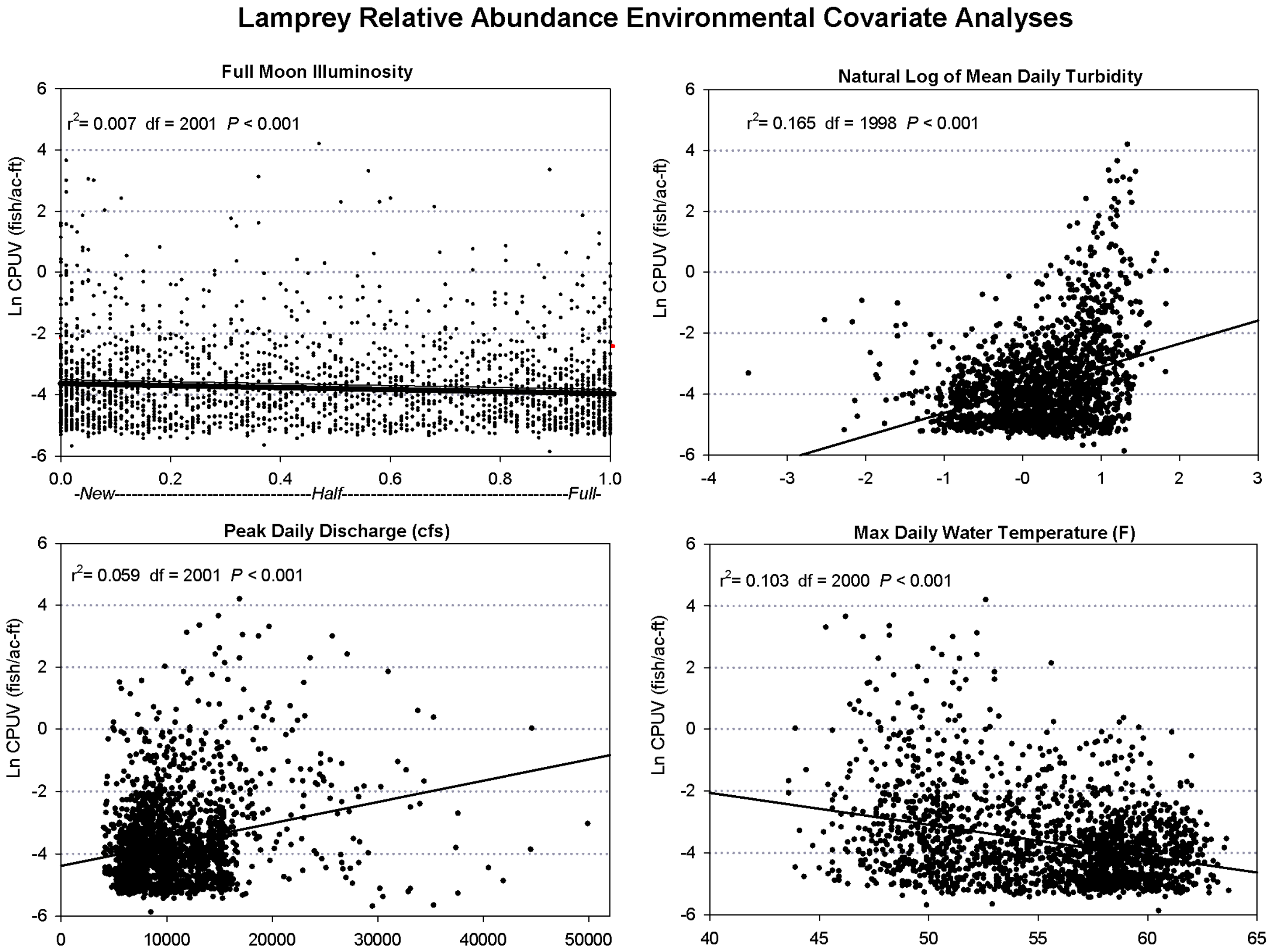

Figure 25. Regression analysis results of natural log (Ln) Lamprey *spp.* catch per unit volume (CPUV) and a) full moon illuminosity, b) Ln mean daily turbidity, c) peak daily discharge and d) maximum daily temperatures at RBDD. All fish captured by rotary trap at RBDD (RM 243) on the Upper Sacramento River, CA between water year 2003 and 2013.

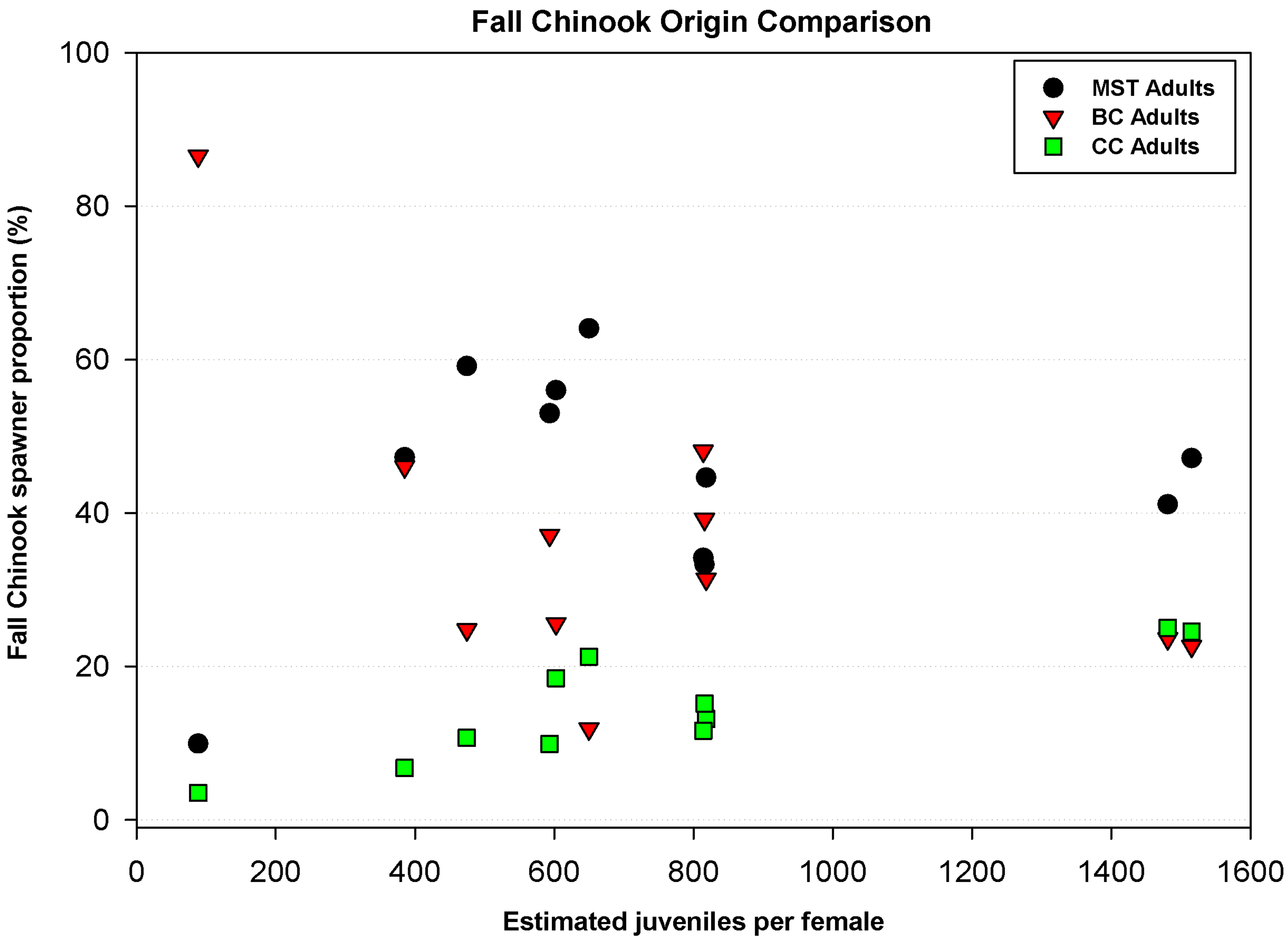

Figure 26. Comparison of estimated juveniles produced per estimated number of females in relation to distribution of fall Chinook spawners in the mainstem Sacramento River (MST), Battle Creek (BC), and Clear Creek (CC) between years 2002 and 2012.

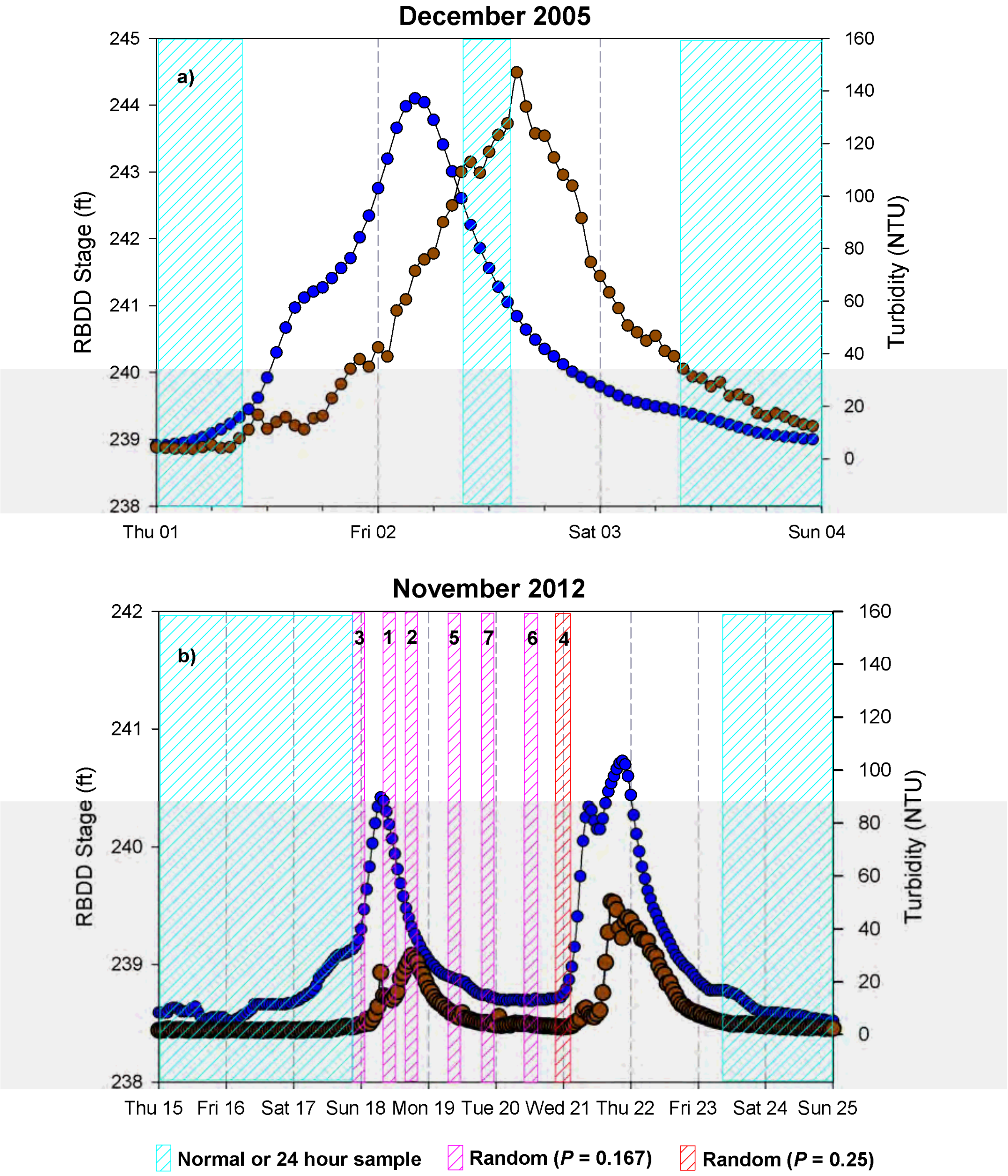

Figure 27. Timing comparison of RBDD stage (i.e., discharge level) and turbidity measurements along with sample collection times for storm events on a) December 1-4, 2005 and b) November 15-25, 2012. Numerals within sample period boxes in figure b indicate rank of standardized Chinook passage totals from greatest (1) to least (7).

APPENDIX 1

Appendix 1: List of Tables

Fall Chinook

Table A1. Summary of RBDD rotary trap annual effort, fall Chinook fry (<46 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period December 2002 through September 2013.

Brood Year	Effort	Estimated Fry Passage	Low 90% CI	Up 90% CI
2002	0.76	14,687,984	348,386	42,027,818
2003	0.81	23,612,094	6,953,966	44,283,689
2004	0.85	7,946,496	3,449,094	12,447,378
2005	0.56	11,740,225	2,452,034	24,687,255
2006	0.90	10,152,406	3,458,524	17,567,355
2007	0.88	9,594,099	4,834,813	14,353,810
2008	0.79	6,684,332	3,335,617	10,033,164
2009	0.84	6,900,302	2,190,210	11,662,489
2010	0.75	6,302,961	3,432,017	9,502,694
2011	0.87	4,437,956	2,380,436	6,498,878
2012	0.85	21,375,192	14,332,396	28,700,826

Table A2. Summary of RBDD rotary trap annual effort, fall Chinook pre-smolt/smolt (>45 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period December 2002 through September 2013.

Brood Year	Effort	Estimated Smolt Passage	Low 90% CI	Up 90% CI
2002	0.76	2,350,433	505,837	5,318,021
2003	0.81	4,124,773	1,879,521	6,393,281
2004	0.85	6,161,742	1,626,946	12,527,167
2005	0.56	6,470,030	1,041,939	14,426,210
2006	0.90	5,955,245	3,056,683	8,855,302
2007	0.88	2,537,504	1,291,848	3,821,912
2008	0.79	2,431,215	1,034,851	3,827,754
2009	0.84	1,632,074	868,002	2,396,298
2010	0.75	2,539,519	1,288,830	3,850,851
2011	0.87	1,833,305	1,029,403	2,637,509
2012	0.85	3,054,227	1,692,494	4,416,322

Late-Fall Chinook

Table A3. Summary of RBDD rotary trap annual effort, late-fall Chinook fry (<46 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period April 2002 through March 2013.

Brood Year	Effort	Estimated Fry Passage	Low 90% CI	Up 90% CI
2002	0.57	442,393	84,832	901,368
2003	0.76	196,271	4,562	683,458
2004	0.88	24,382	8,802	40,591
2005	0.73	50,274	5,723	175,598
2006	0.70	284,999	41,006	634,496
2007	0.90	144,688	54,397	235,201
2008	0.89	10,489	4,347	17,813
2009	0.72	29,568	13,126	46,360
2010	0.86	113,667	26,705	200,935
2011	0.77	69,686	18,487	120,996
2012	0.89	67,479	9,925	136,431

Table A4. Summary of RBDD rotary trap annual effort, late-fall Chinook pre-smolt/smolt (>45 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period April 2002 through March 2013.

Brood Year	Effort	Estimated Smolt Passage	Low 90% CI	Up 90% CI
2002	0.57	2,117,122	569,453	4,093,545
2003	0.76	149,976	72,089	230,841
2004	0.88	122,779	64,498	181,783
2005	0.73	93,407	35,067	160,738
2006	0.70	175,269	82,005	273,572
2007	0.90	390,932	213,642	568,595
2008	0.89	81,506	41,983	121,166
2009	0.72	190,256	83,201	297,652
2010	0.86	69,771	33,929	106,575
2011	0.77	27,354	9,535	45,914
2012	0.89	73,055	32,567	113,633

Winter Chinook

Table A5. Summary of RBDD rotary trap annual effort, winter Chinook fry (<46 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period July 2002 through June 2013.

Brood Year	Effort	Estimated Fry Passage	Low 90% CI	Up 90% CI
2002	0.64	6,381,286	2,156,758	11,217,962
2003	0.81	4,420,296	2,743,637	6,096,955
2004	0.84	3,087,102	1,812,619	4,361,584
2005	0.64	7,533,380	4,225,130	10,841,630
2006	0.83	5,813,140	3,307,323	8,318,957
2007	0.89	1,158,791	744,804	1,572,817
2008	0.87	1,063,919	662,381	1,465,748
2009	0.75	3,587,134	2,076,422	5,098,125
2010	0.81	875,049	603,549	1,146,644
2011	0.82	638,056	441,983	834,289
2012	0.89	722,048	545,751	898,345

Table A6. Summary of RBDD rotary trap annual effort, winter Chinook pre-smolt/smolt (>45 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period July 2002 through June 2013.

Brood Year	Effort	Estimated Smolt Passage	Low 90% CI	Up 90% CI
2002	0.64	737,755	373,538	1,149,079
2003	0.81	800,719	453,256	1,169,559
2004	0.84	347,581	179,502	519,265
2005	0.64	829,302	324,860	1,442,763
2006	0.83	873,940	487,244	1,264,701
2007	0.89	281,773	180,254	387,123
2008	0.87	181,071	110,592	252,089
2009	0.75	815,188	410,512	1,222,586
2010	0.81	410,341	210,252	613,810
2011	0.82	210,920	130,861	291,312
2012	0.89	627,771	354,764	900,897

Spring Chinook

Table A7. Summary of RBDD rotary trap annual effort, spring Chinook fry (<46 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period October 2002 through September 2013.

Brood Year	Effort	Estimated Fry Passage	Low 90% CI	Up 90% CI
2002	0.75	159,084	67,900	255,023
2003	0.81	502,386	189,371	857,899
2004	0.85	155,053	59,655	250,451
2005	0.57	427,719	111,396	925,898
2006	0.89	174,186	114,642	233,907
2007	0.89	336,714	212,765	460,712
2008	0.85	40,213	26,016	54,448
2009	0.79	219,627	91,683	347,845
2010	0.77	89,213	39,829	138,597
2011	0.86	88,355	63,469	113,274
2012	0.86	134,028	82,843	185,271

Table A8. Summary of RBDD rotary trap annual effort, spring Chinook pre-smolt/smolt (>45 mm FL) passage estimates and lower and upper 90% confidence intervals (CI), by brood year for the period October 2002 through September 2013.

Brood Year	Effort	Estimated Smolt Passage	Low 90% CI	Up 90% CI
2002	0.75	118,393	43,022	239,870
2003	0.81	124,529	59,434	197,777
2004	0.85	275,898	113,564	460,990
2005	0.57	187,828	19,676	460,441
2006	0.89	247,250	123,621	371,968
2007	0.89	32,787	15,894	51,271
2008	0.85	124,460	40,130	208,954
2009	0.79	218,778	83,930	354,607
2010	0.77	69,753	21,938	123,577
2011	0.86	95,935	37,782	159,702
2012	0.86	186,869	89,566	284,936

Table A9. River Lamprey, *Lampetra ayresi*, annual capture, catch per unit volume (CPUV) and total length summaries for River Lamprey captured by RBDD rotary traps between water year (WY) 2003 and 2013.

WY	Catch	CPUV Fish/ac-ft	Min TL (mm)	Max TL (mm)	Mean (mm)	Median (mm)
2003	0	0.00	-	-	-	-
2004	1	0.01	102	102	102	-
2005	0	0.00	-	-	-	-
2006	0	0.00	-	-	-	-
2007	0	0.00	-	-	-	-
2008	0	0.00	-	-	-	-
2009	0	0.00	-	-	-	-
2010	1	0.01	110	110	110	-
2011	26	0.23	99	151	121	121
2012	4	0.02	128	168	144	140
2013	0	0.00	-	-	-	-
Mean	2.9	0.02	109.8	132.8	119.3	130.5
SD	7.8	0.07	13.0	31.8	18.2	13.4
CV	266.5%	279.2%	11.9%	24.0%	15.3%	10.3%

Table A10. Pacific Brook Lamprey, *Lampetra pacifica,* annual capture, catch per unit volume (CPUV) and total length summaries for Pacific Brook Lamprey captured by RBDD rotary traps between water year (WY) 2003 and 2013.

WY	Catch	CPUV Fish/ac-ft	Min TL (mm)	Max TL (mm)	Mean (mm)	Median (mm)
2003	6	0.06	98	132	116	114.5
2004	1	0.01	159	159	159	-
2005	0	0.00	-	-	-	-
2006	0	0.00	-	-	-	-
2007	0	0.00	-	-	-	-
2008	0	0.00	-	-	-	-
2009	0	0.00	-	-	-	-
2010	1	0.02	120	120	120	120
2011	1	0.01	147	147	147	147
2012	6	0.04	112	156	138	142
2013	21	0.12	110	148	124	122
Mean	3.3	0.02	124.3	143.7	134.0	129.1
SD	6.3	0.04	23.6	14.9	16.9	14.4
CV	192.8%	159.7%	19.0%	10.4%	12.6%	11.2%

APPENDIX 2

Appendix 2: List of Figures

Appendix 2: List of Figures continued

Figure **Page**

Appendix 2: List of Figures continued

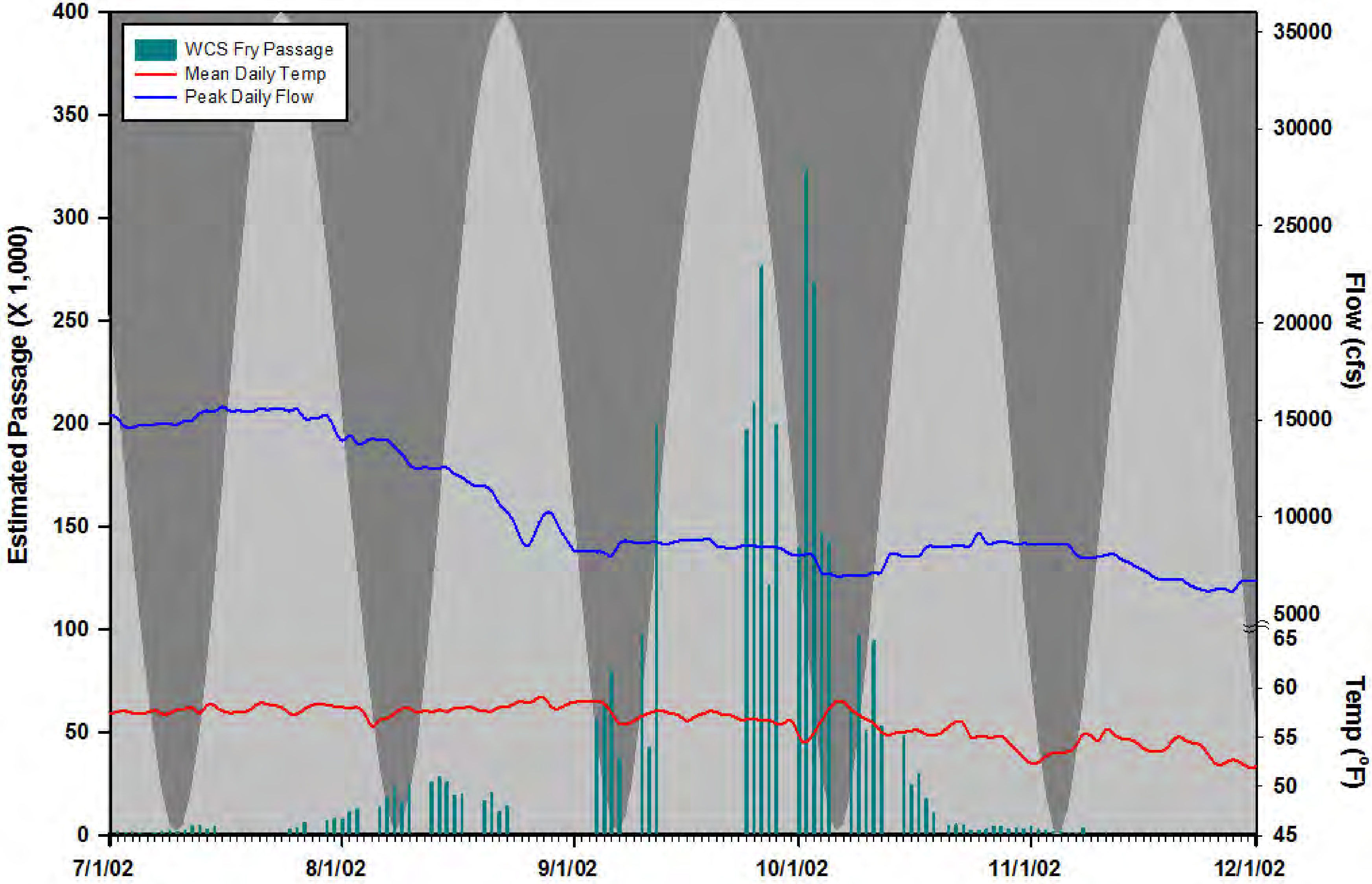

Figure A1. Brood Year 2002 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

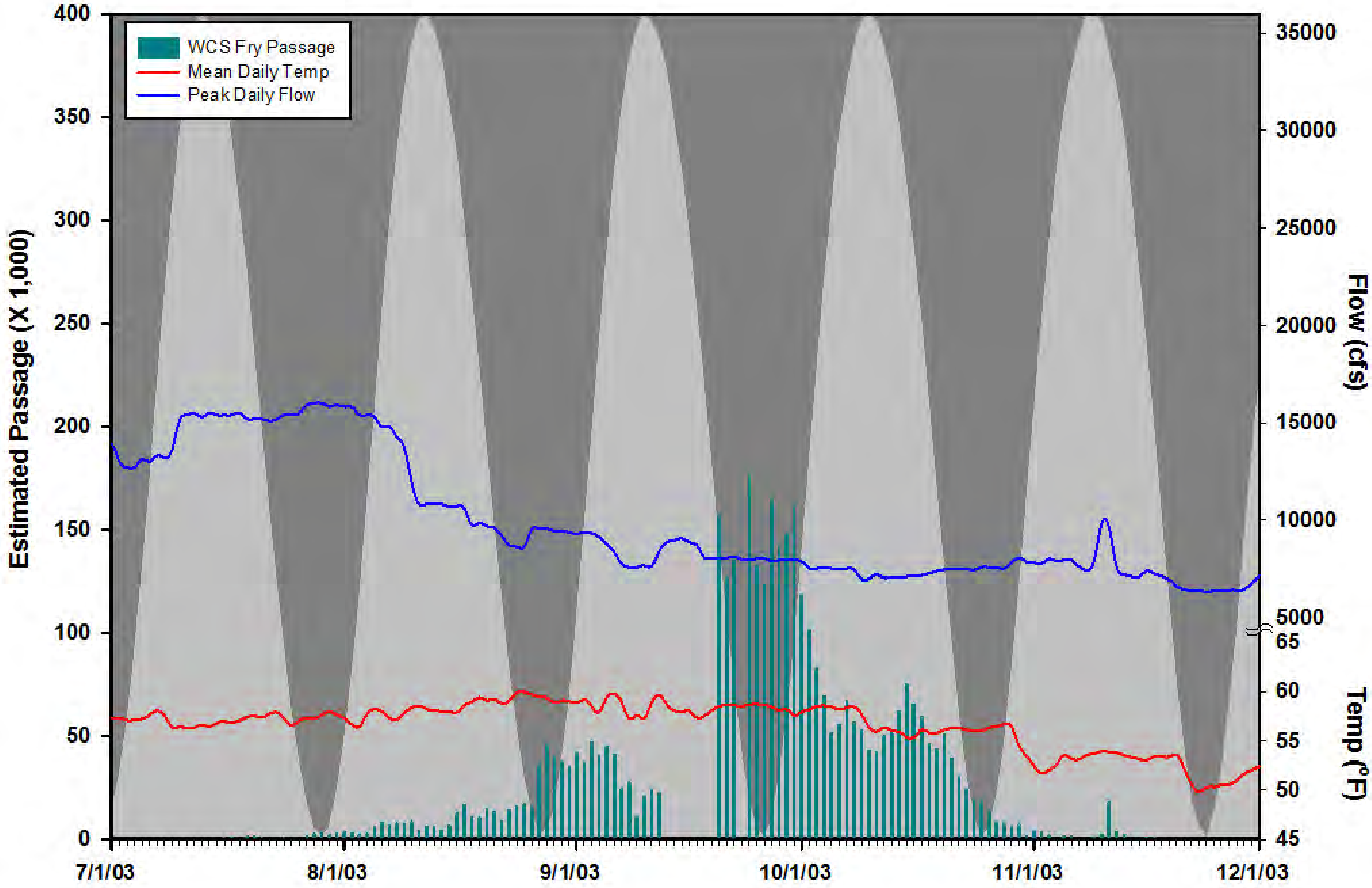

Figure A2. Brood Year 2003 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

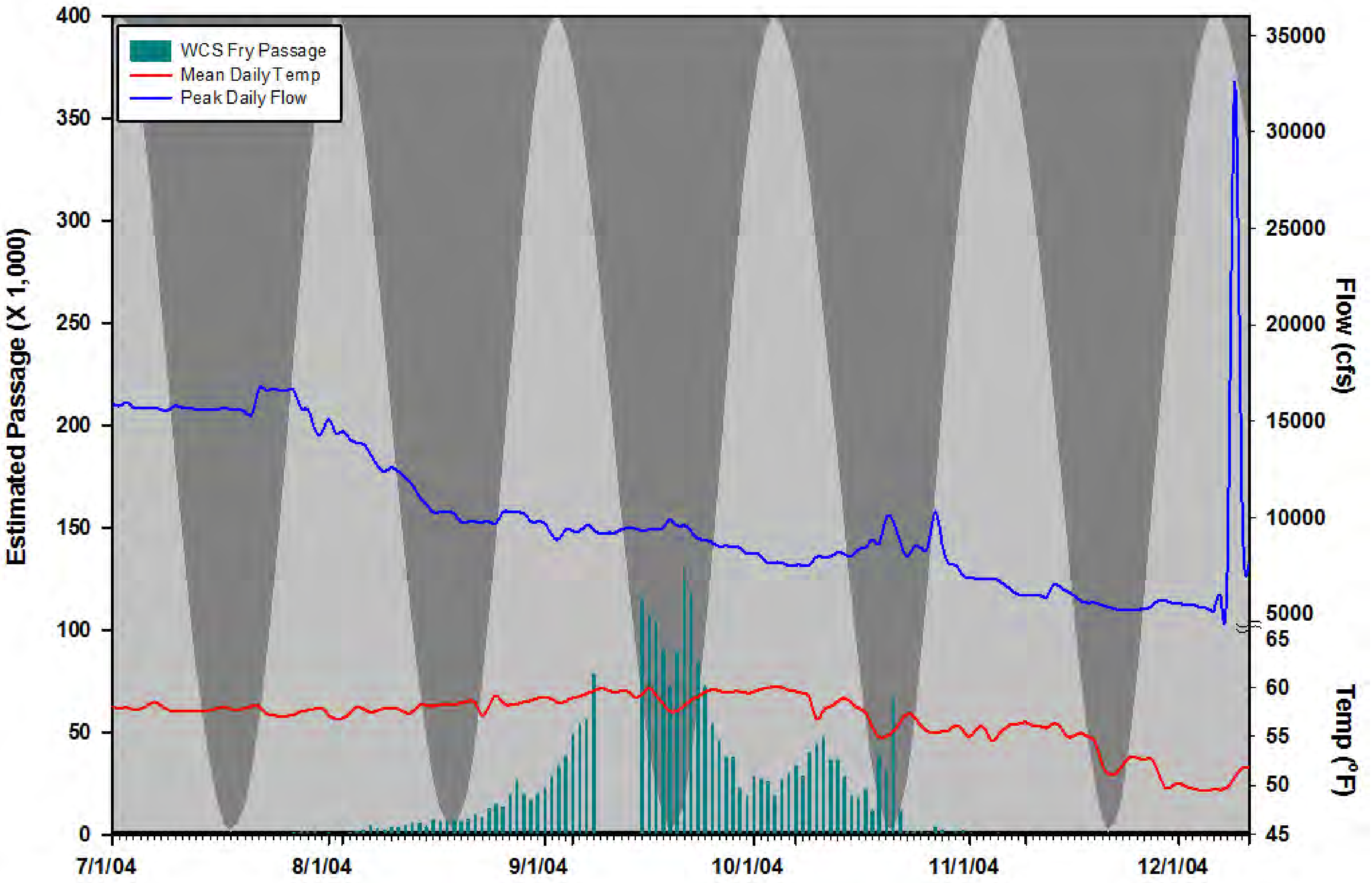

Figure A3. Brood Year 2004 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

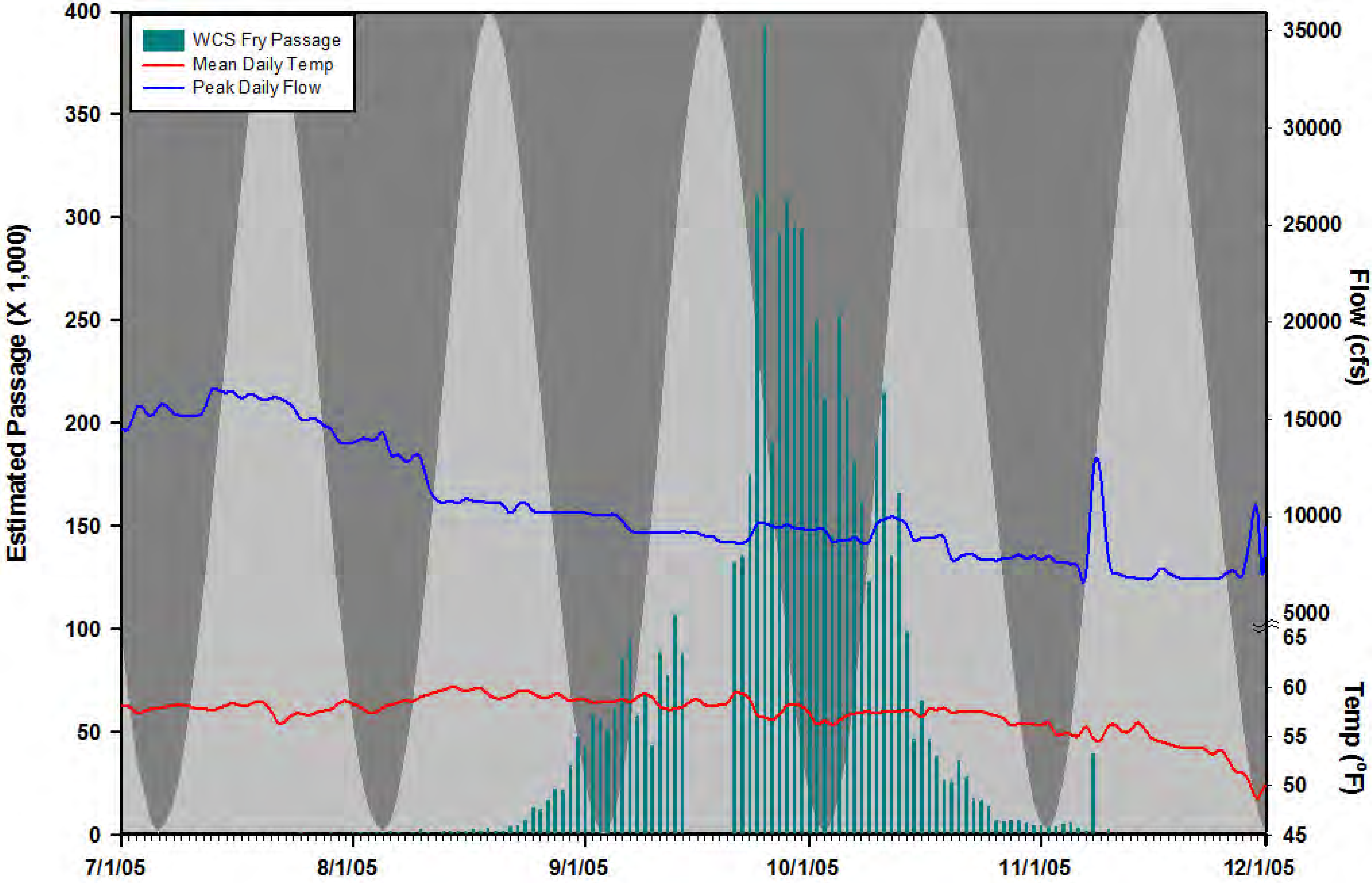

Figure A4. Brood Year 2005 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

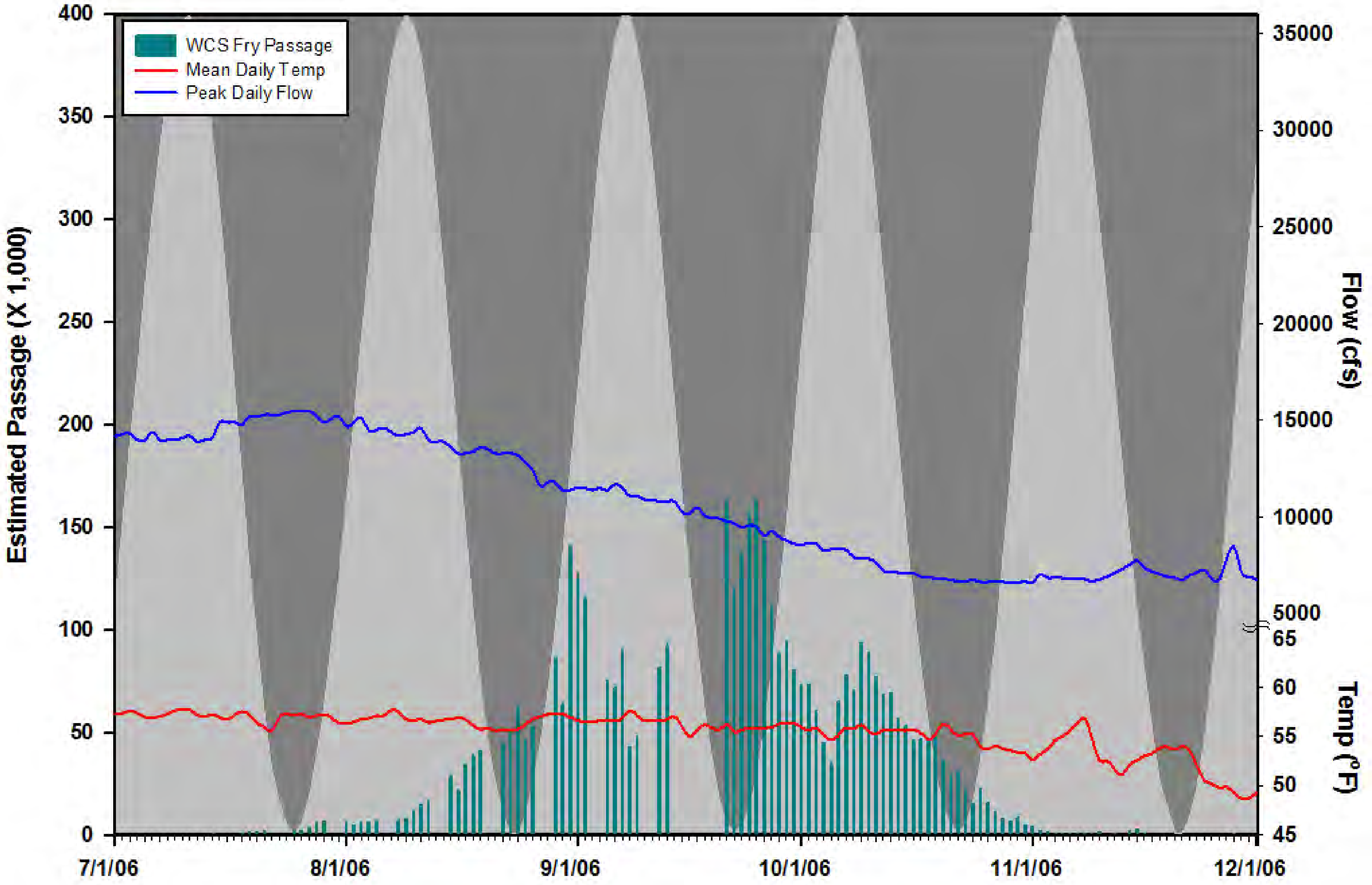

Figure A5. Brood Year 2006 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

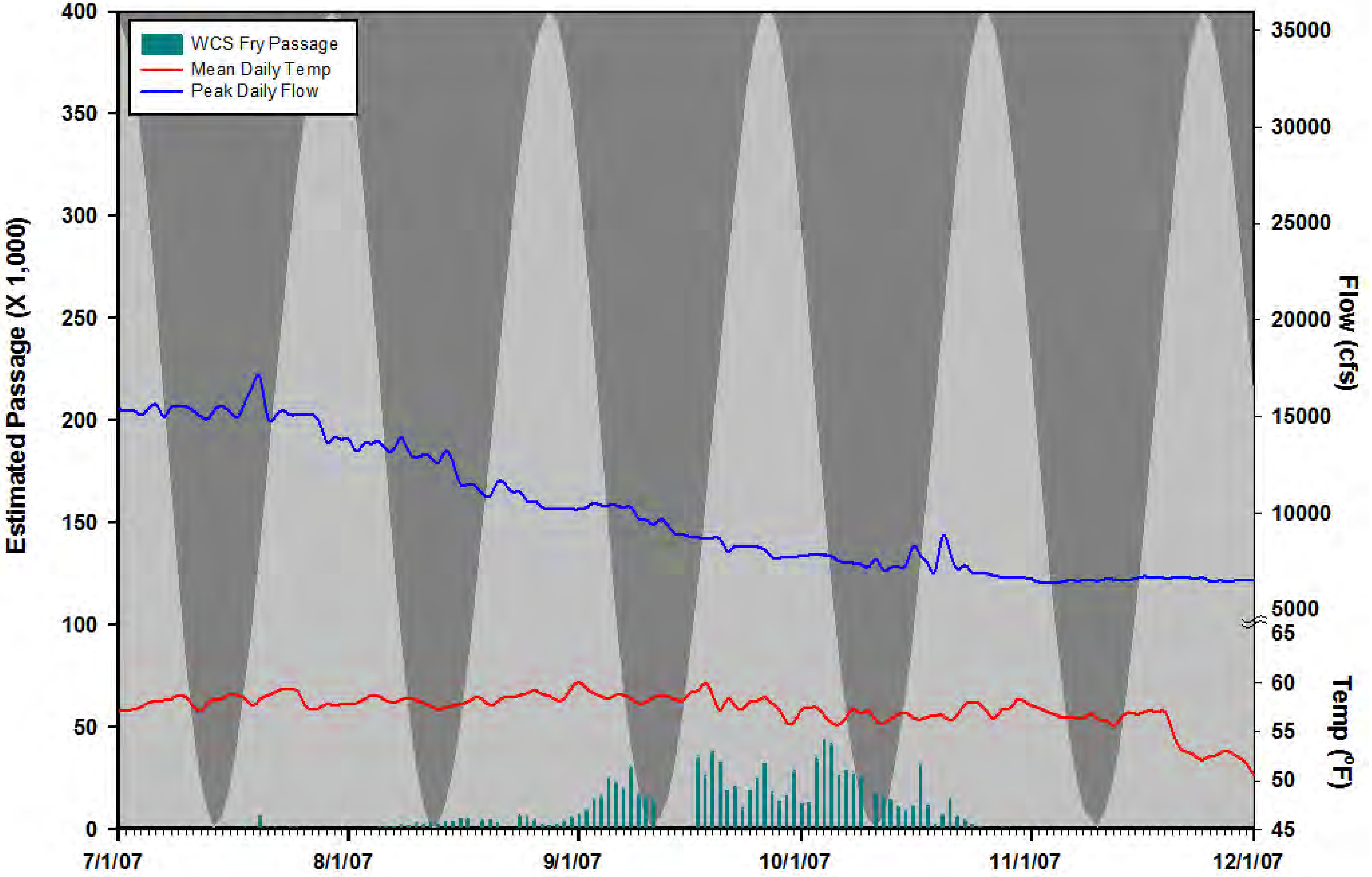

Figure A6. Brood Year 2007 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

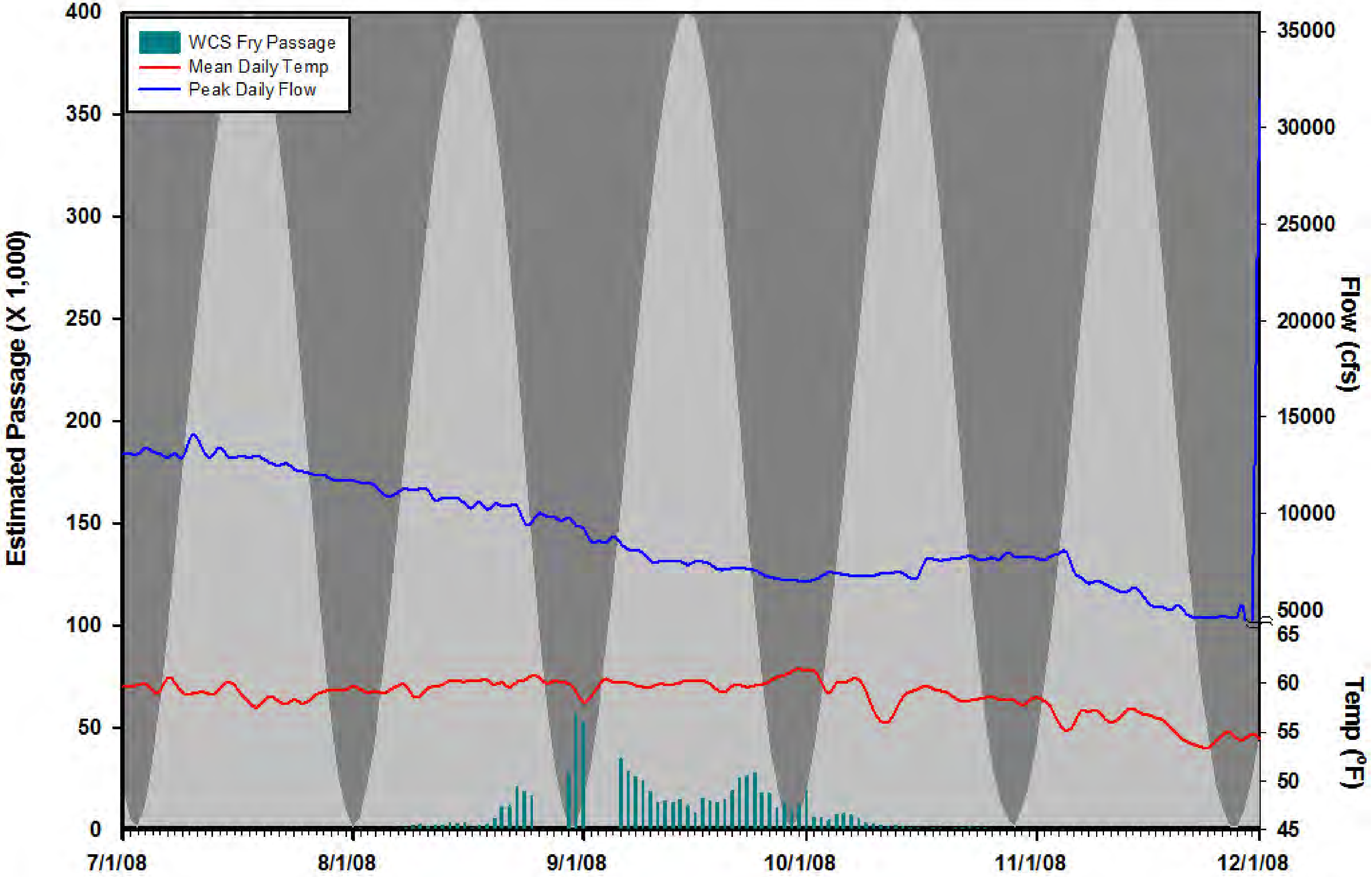

Figure A7. Brood Year 2008 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

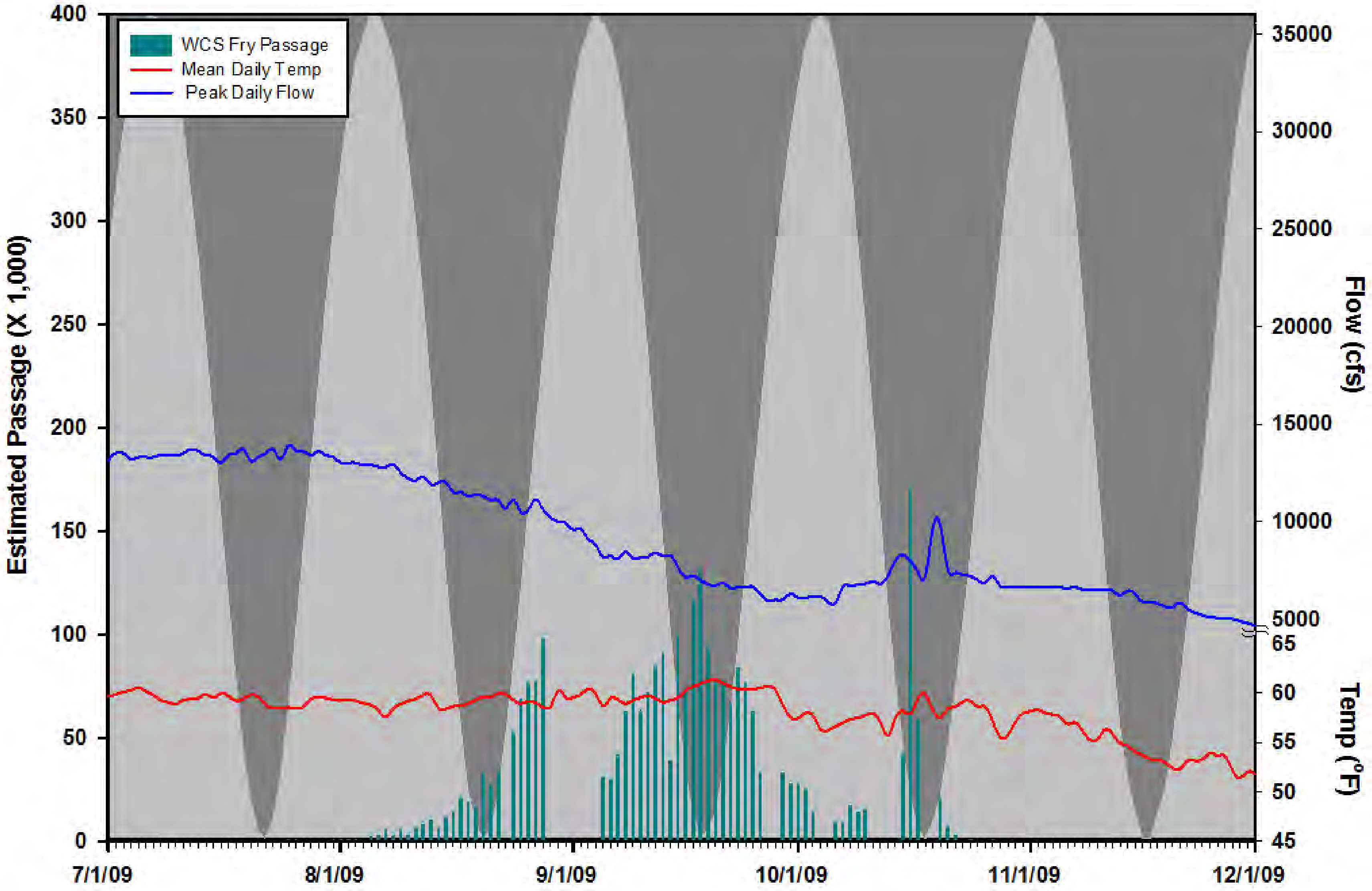

Figure A8. Brood Year 2009 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

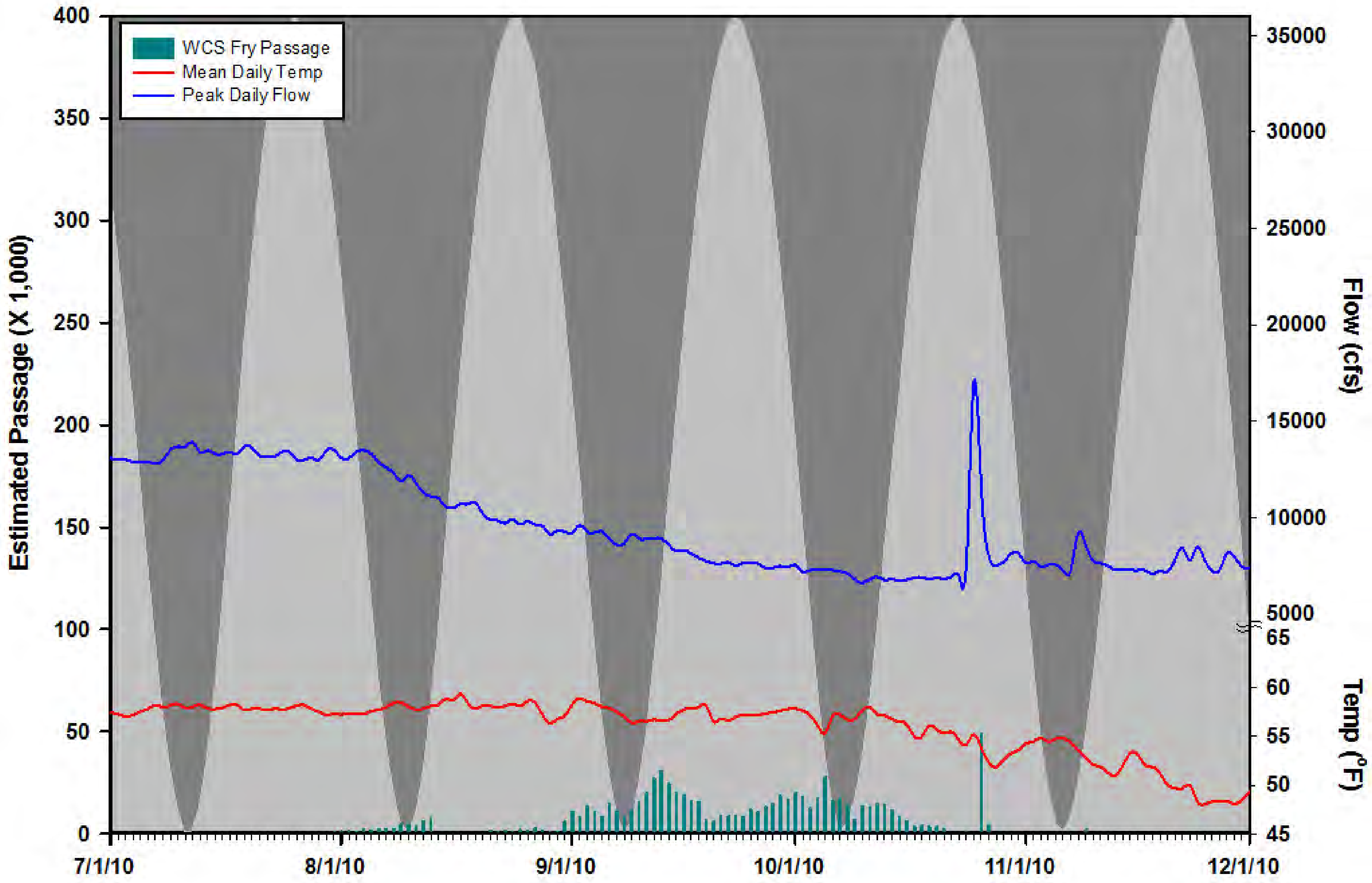

Figure A9. Brood Year 2010 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

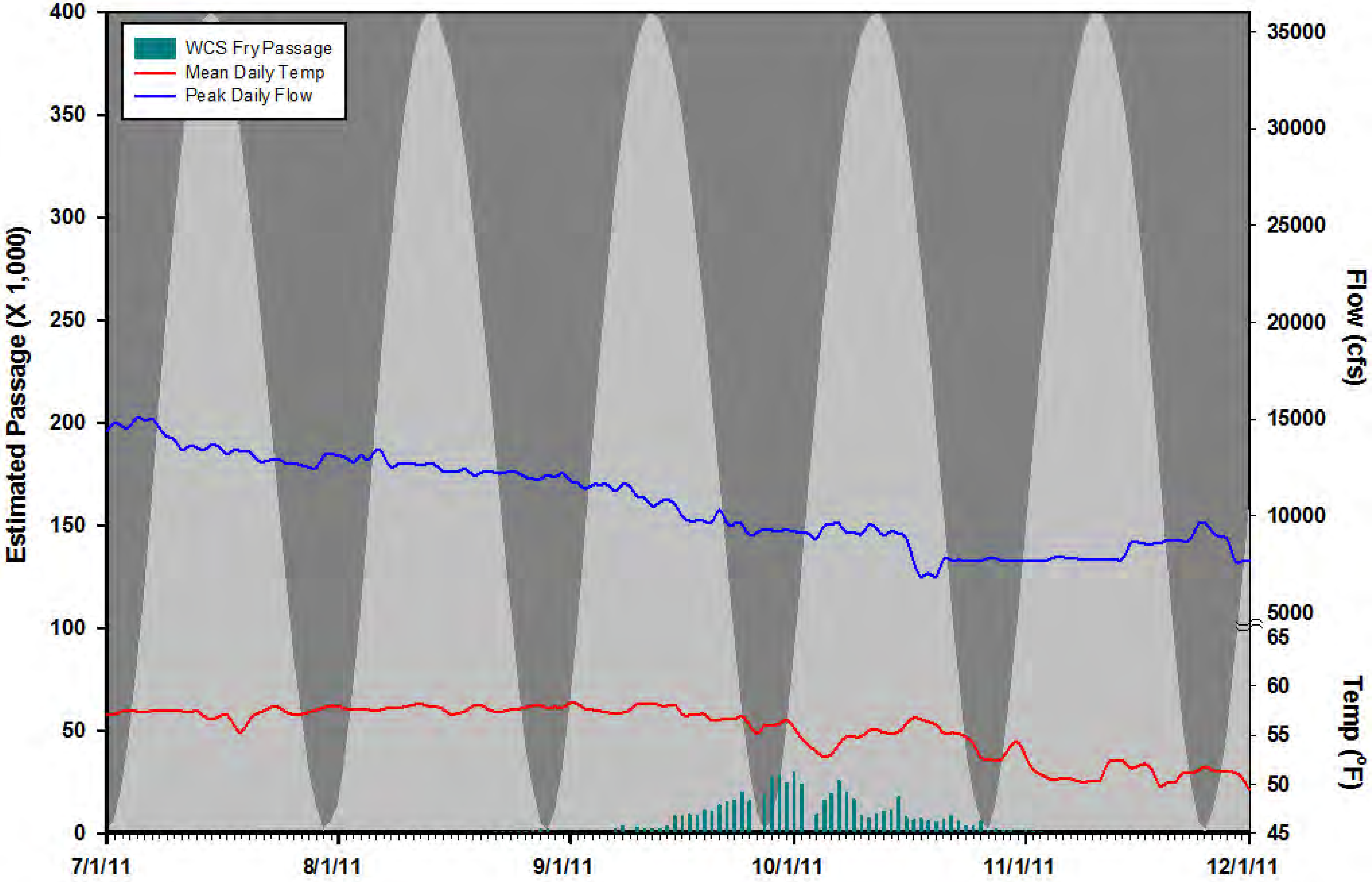

Figure A10. Brood Year 2011 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

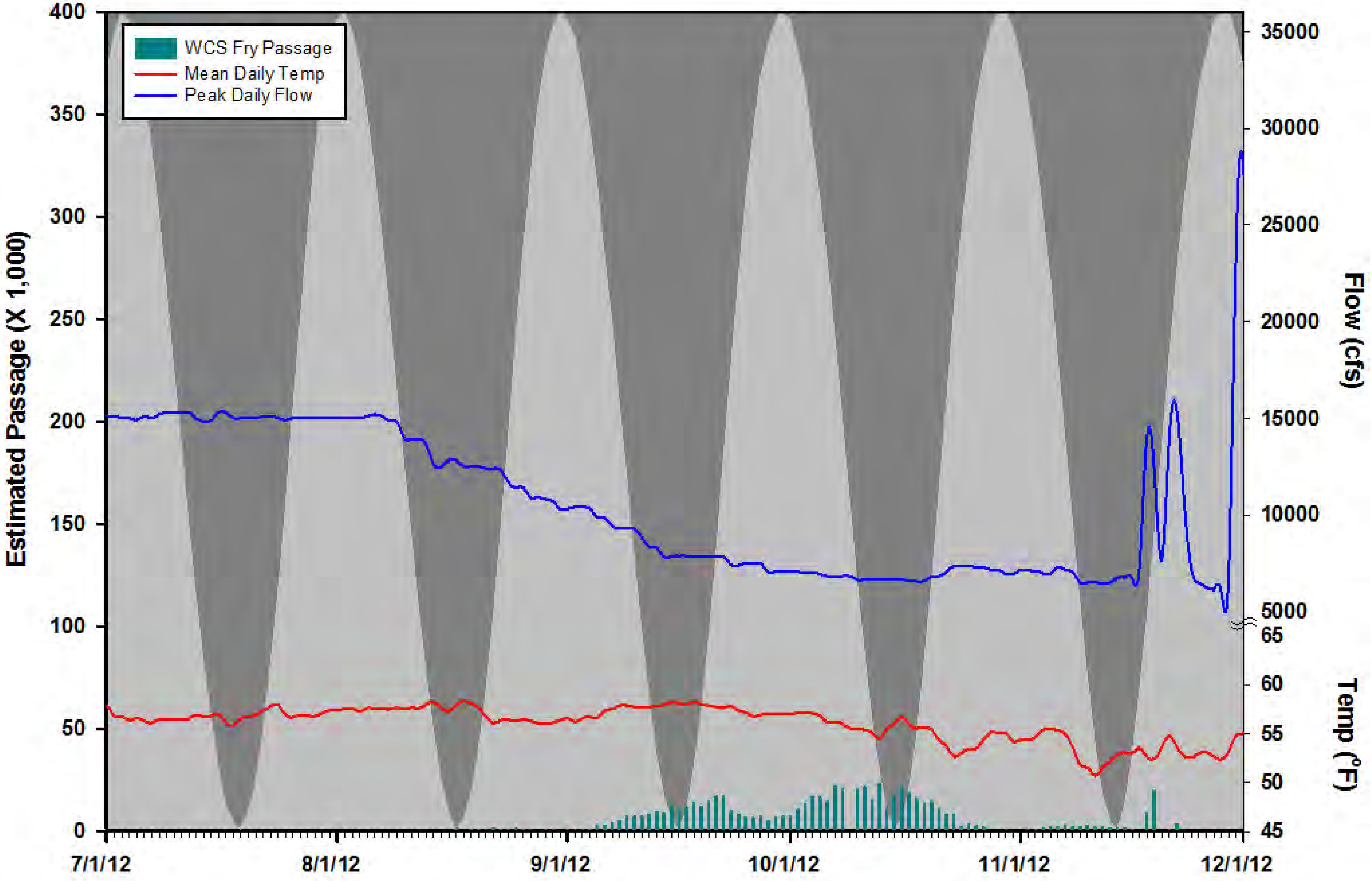

Figure A11. Brood Year 2012 winter Chinook fry passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

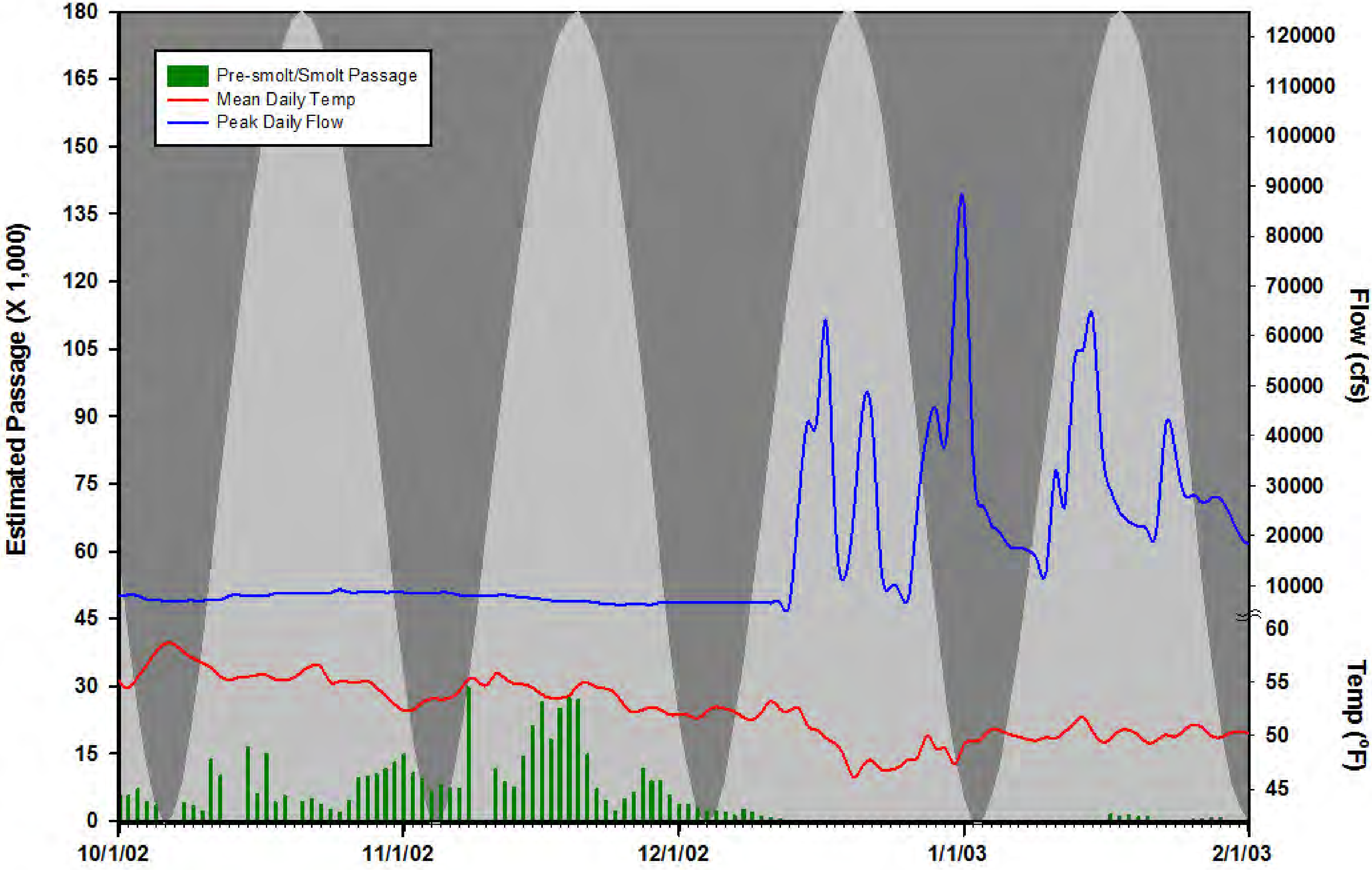

Figure A12. Brood Year 2002 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

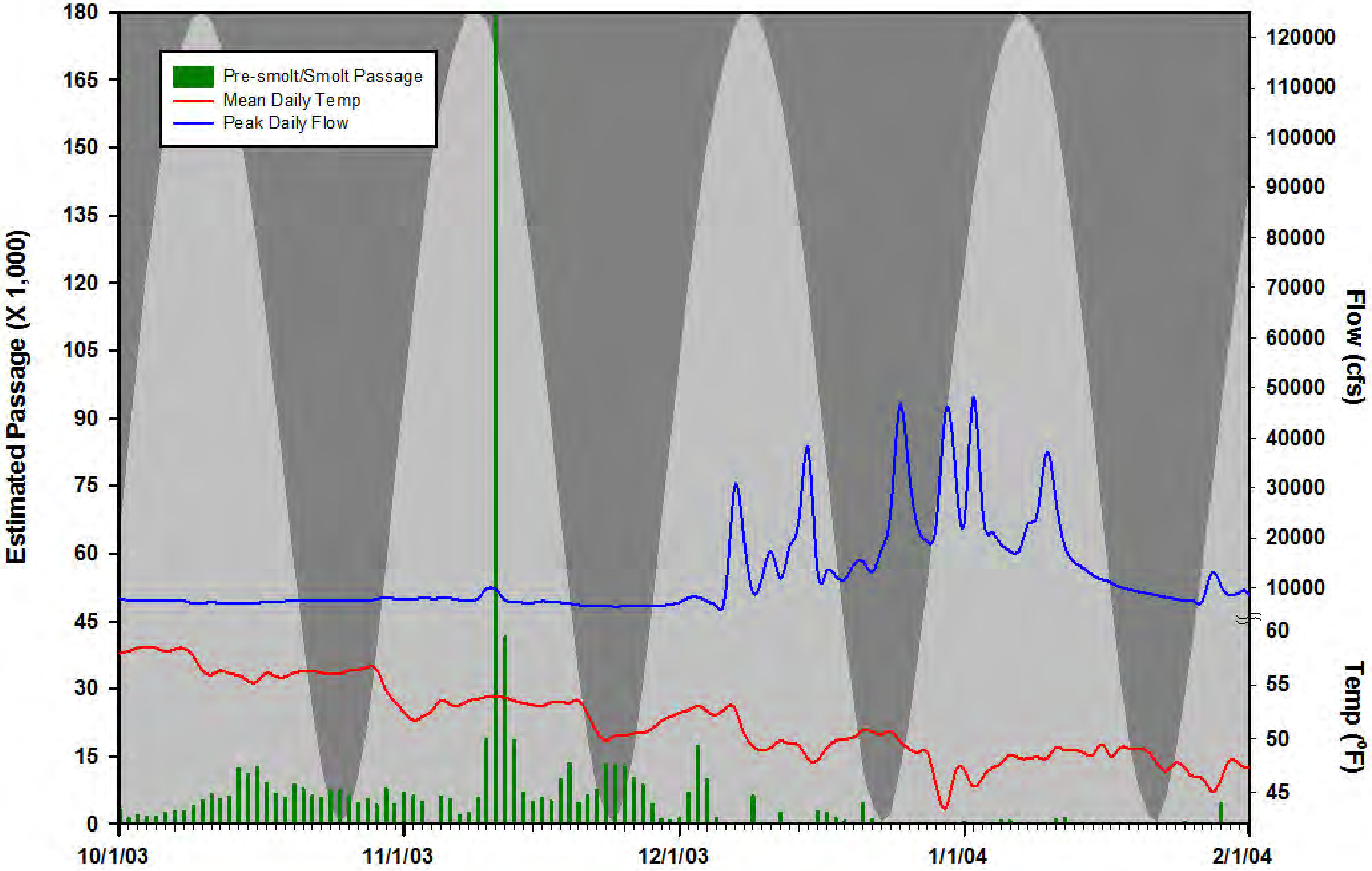

Figure A13. Brood Year 2003 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

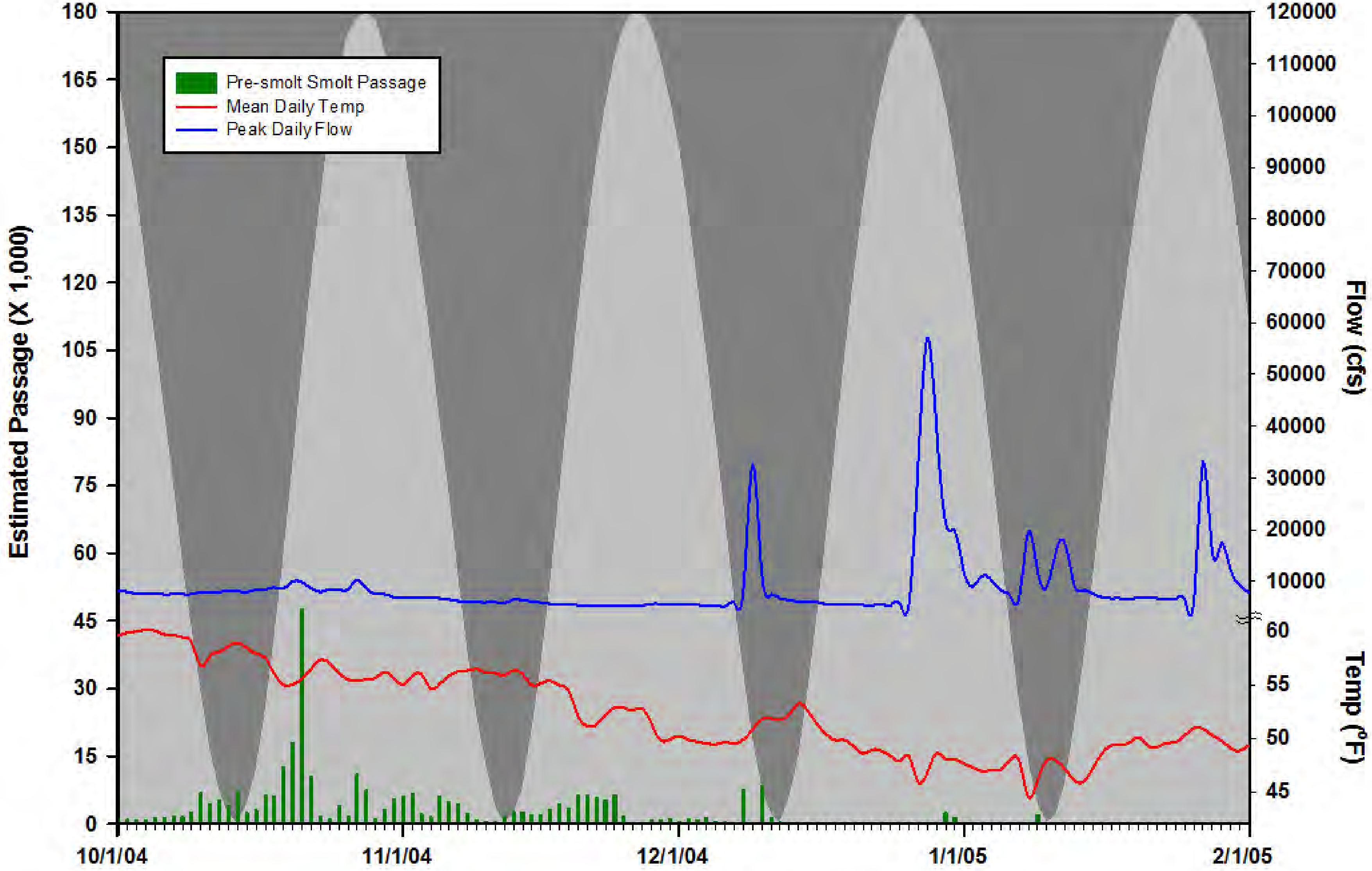

Figure A14. Brood Year 2004 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

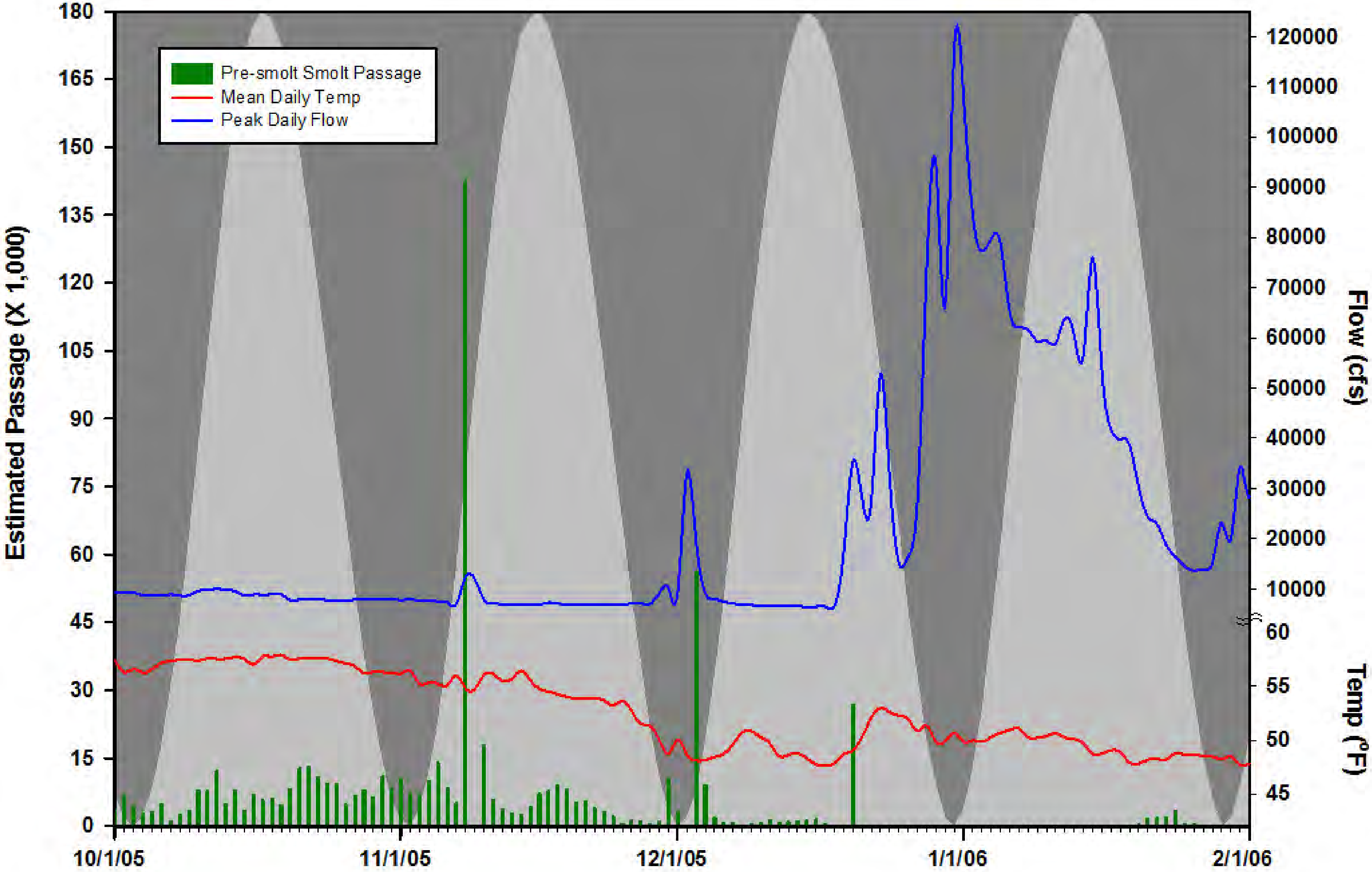

Figure A15. Brood Year 2005 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

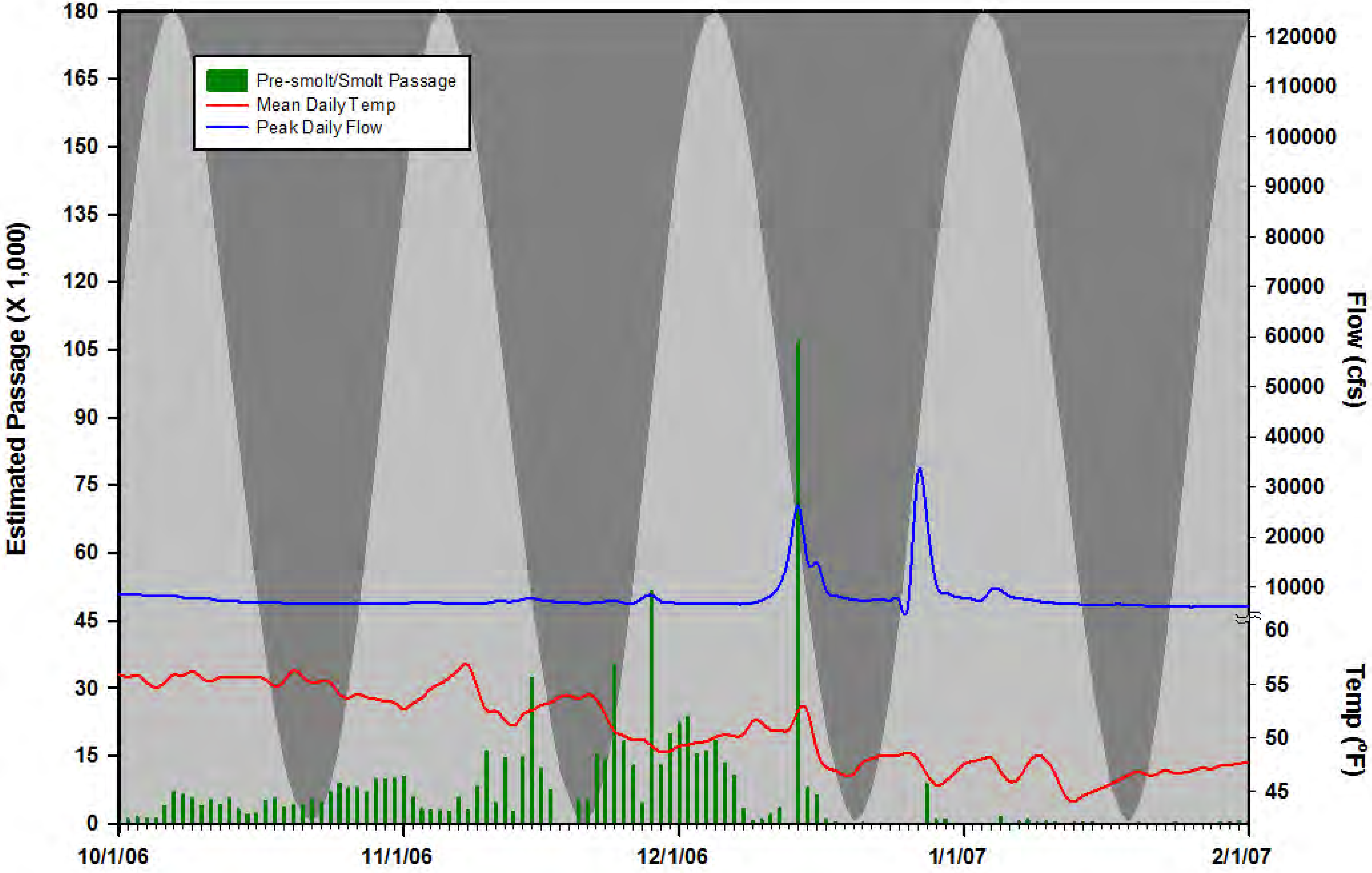

Figure A16. Brood Year 2006 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

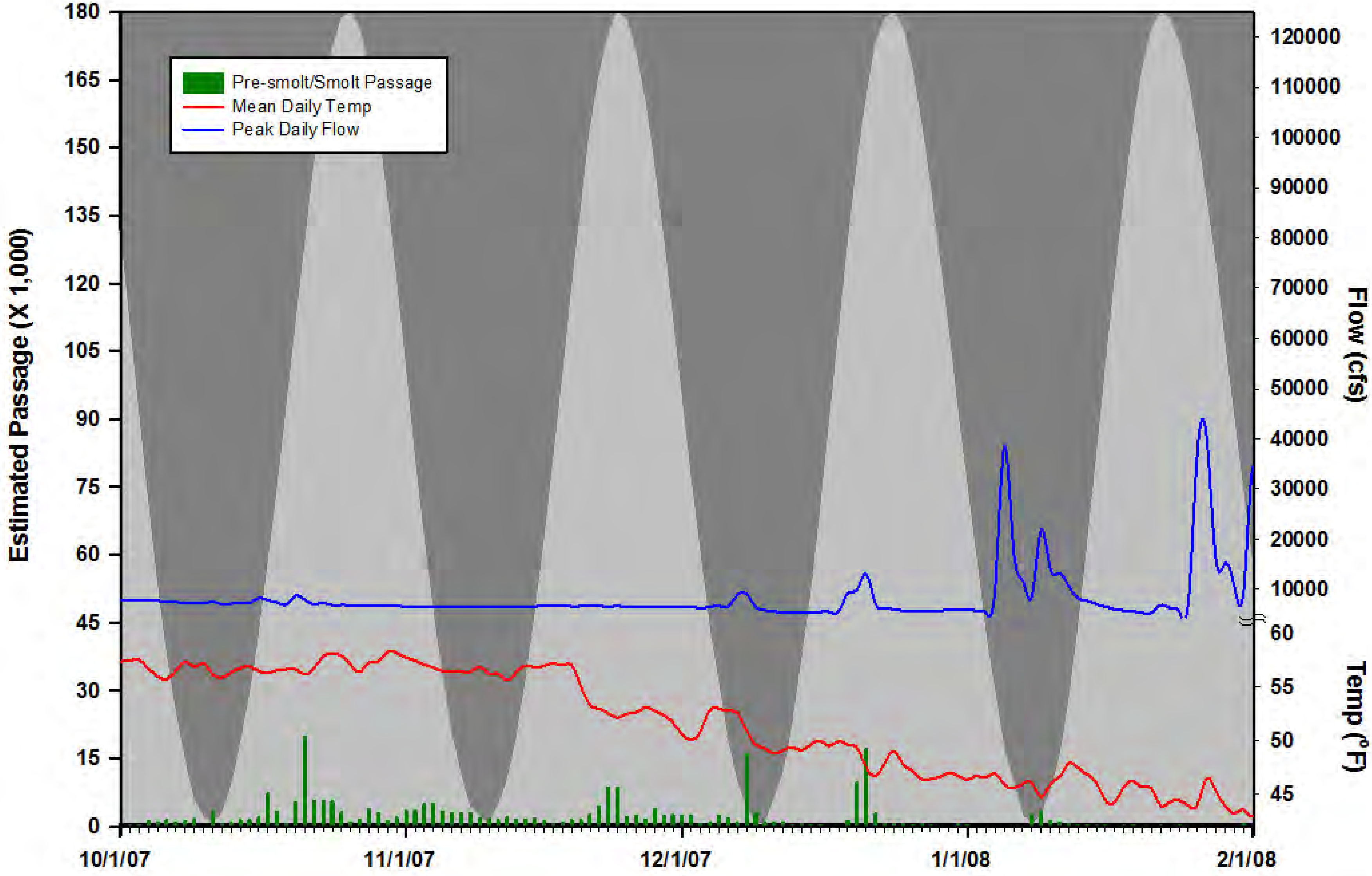

Figure A17. Brood Year 2007 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

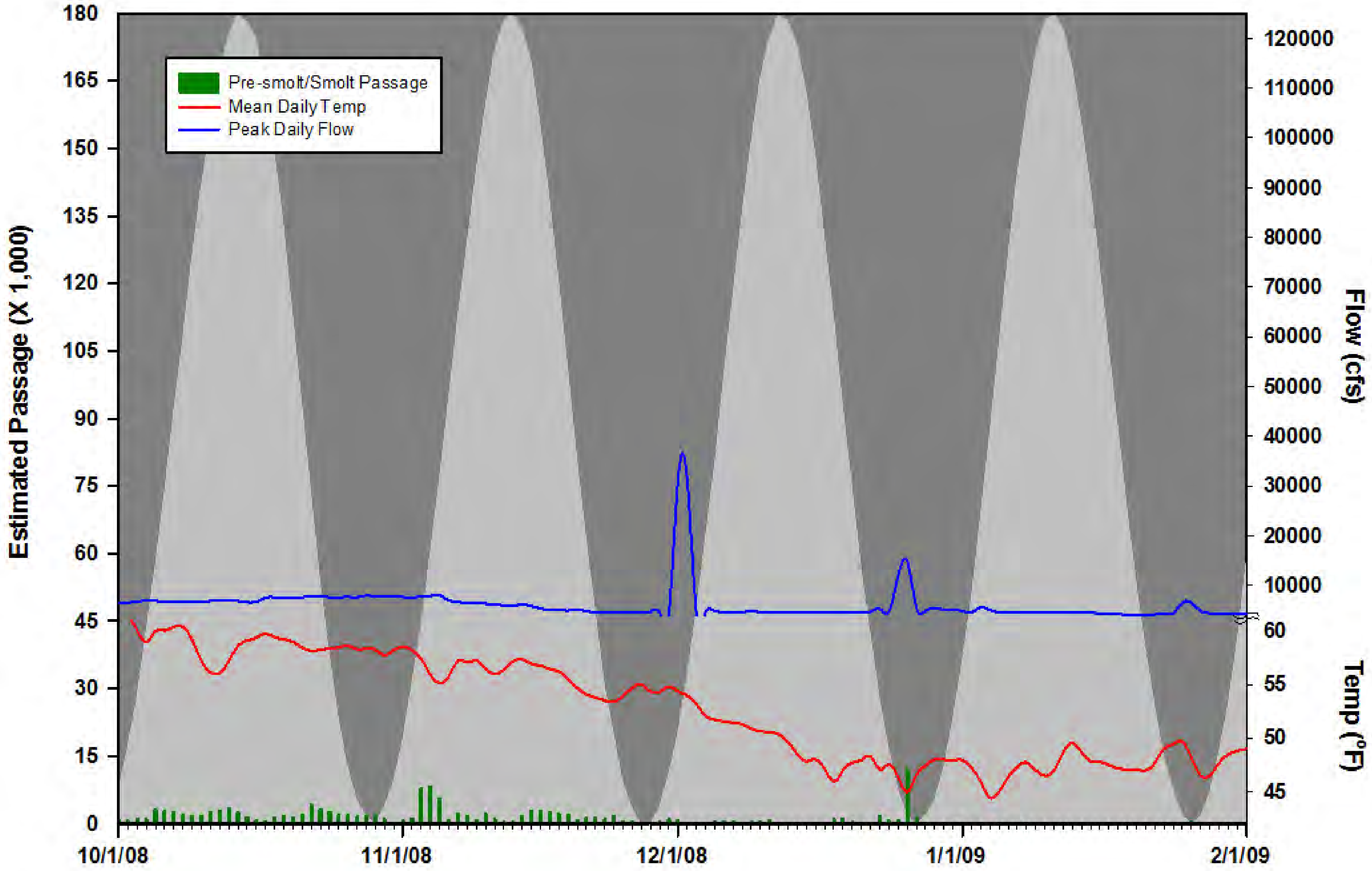

Figure A18. Brood Year 2008 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

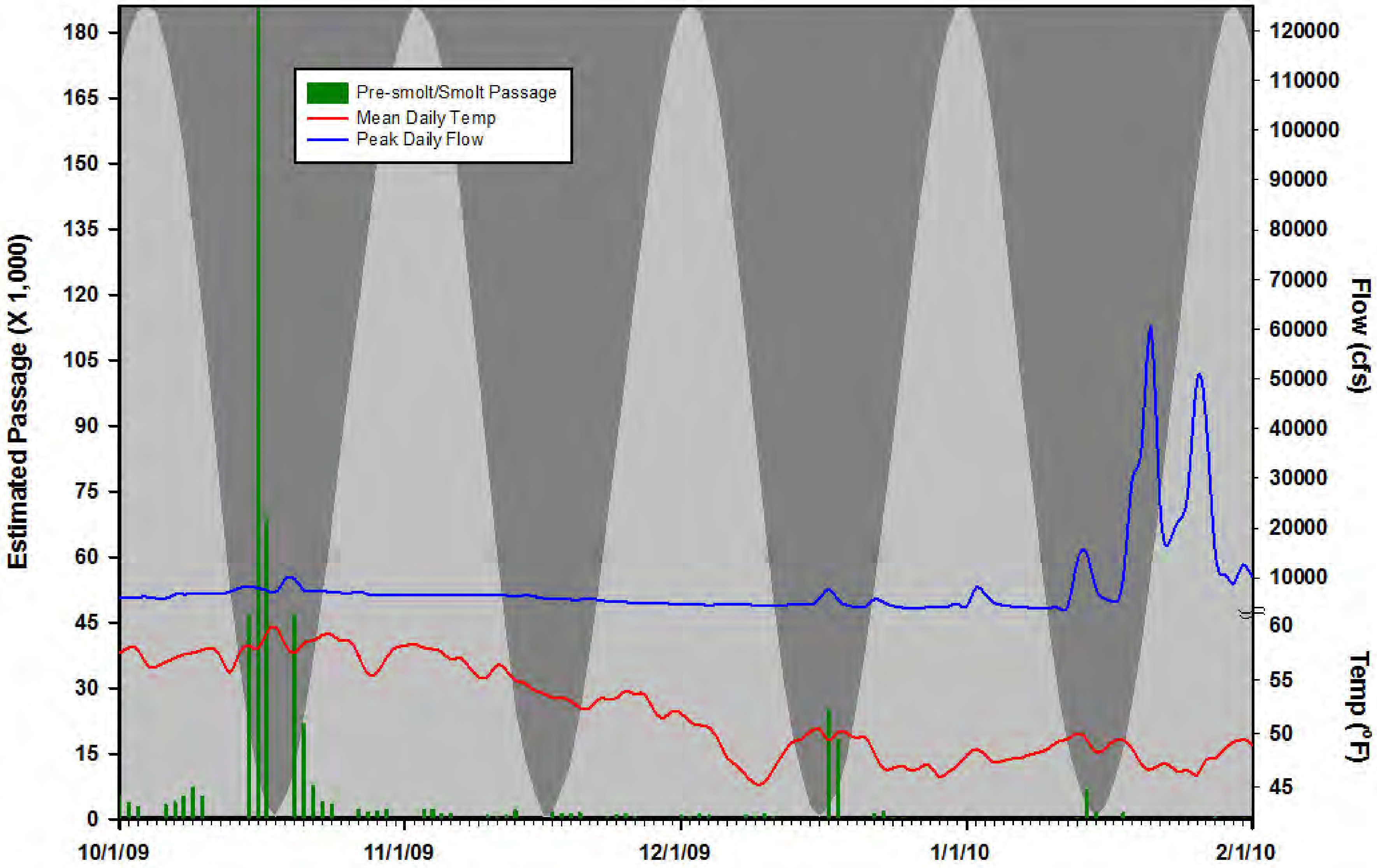

Figure A19. Brood Year 2009 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

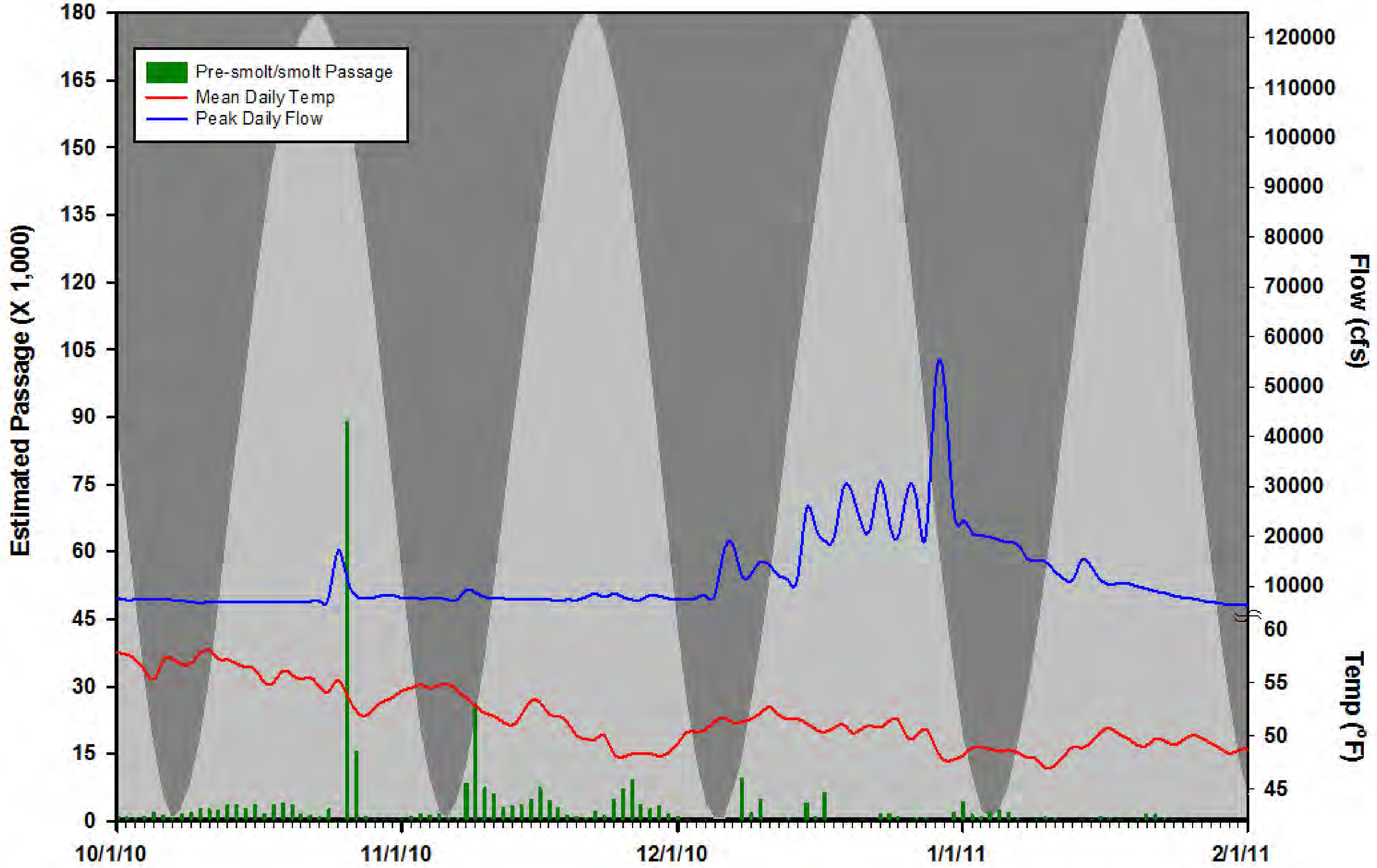

Figure A20. Brood Year 2010 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

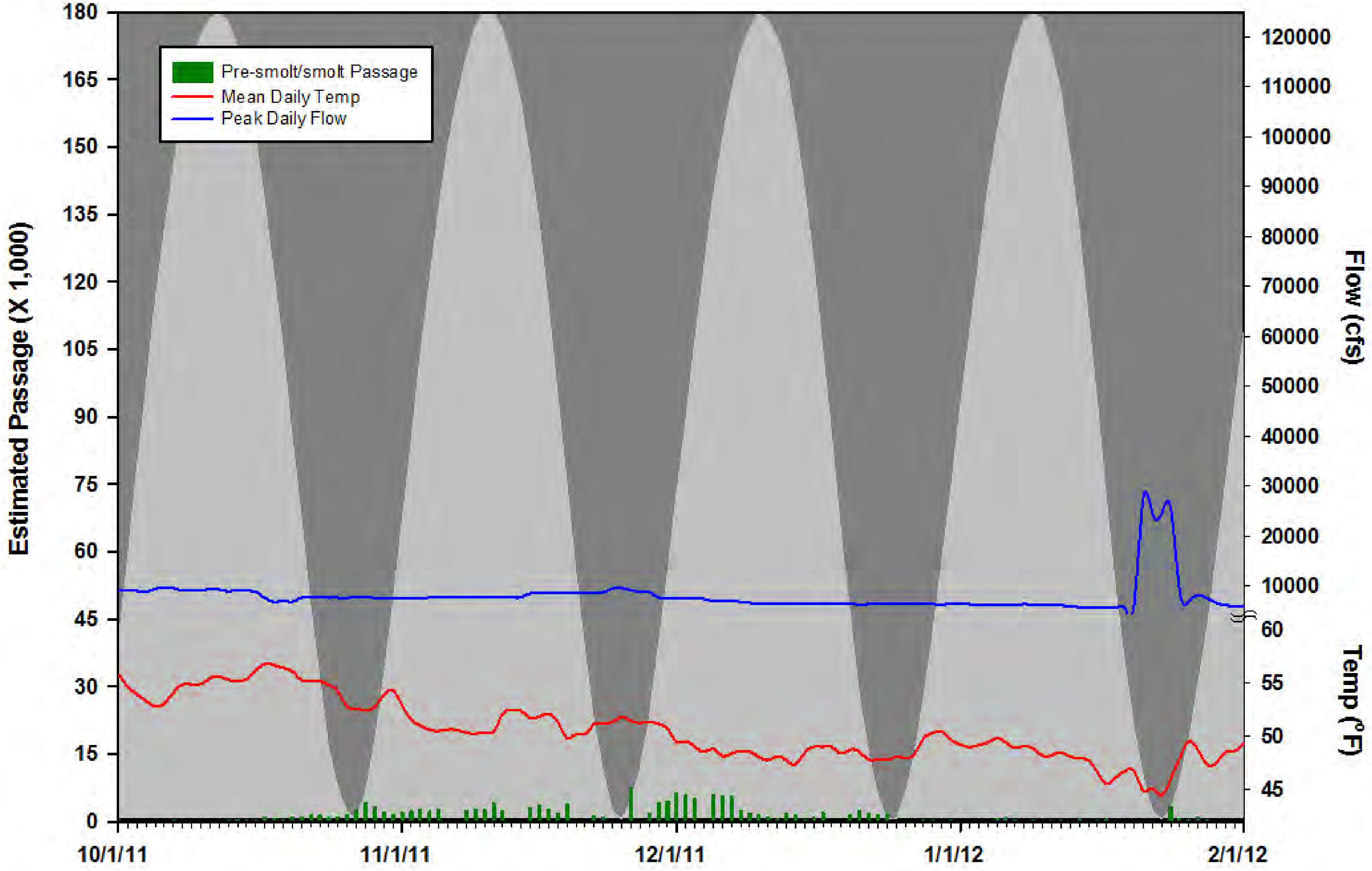

Figure A21. Brood Year 2011 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

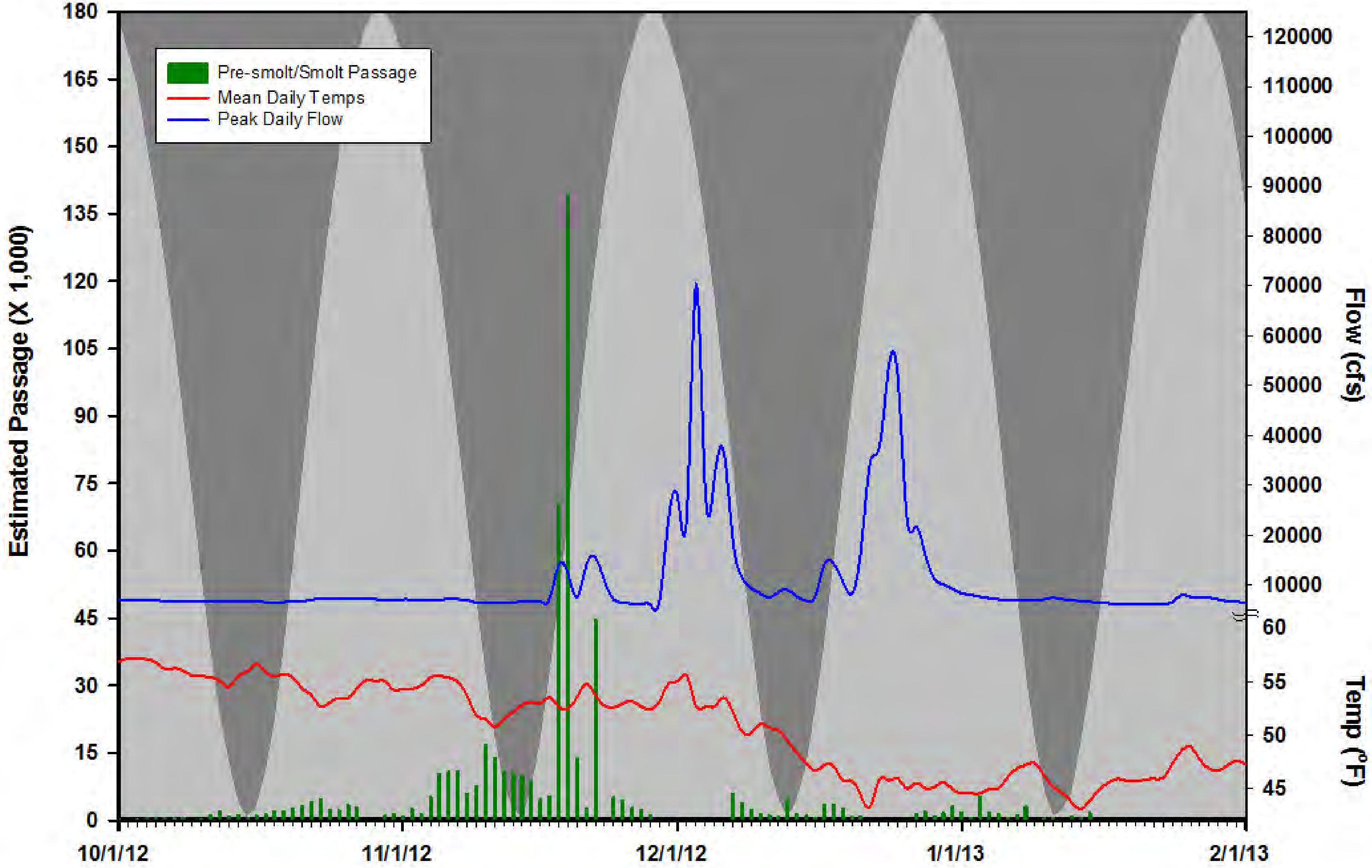

Figure A22. Brood Year 2012 winter Chinook pre-smolt/smolt passage with moon illuminosity indicated by back ground shading (peak of light gray equals full moon), mean daily water temperatures (red), and peak daily flows (blue) at Red Bluff Diversion Dam.

INTERAGENCY ECOLOGICAL PROGRAM, MANAGEMENT, ANALYSIS, AND SYNTHESIS TEAM

An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish

Technical Report 90
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Interagency Ecological Program
for the
San Francisco Bay/Delta Estuary

A Cooperative Program of:

California Department of Water Resources
California Department of Fish and Wildlife
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers
State Water Resource Control Board
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Environmental Protection Agency
National Marine Fisheries Service

Fall Midwater Trawl survey crew deploying net, circa 2005. Photo from CDFW.

Cover photo by Steven Culberson, USFWS

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Abbreviations

CCF	Clifton Court Forebay
CVP	Central Valley Project
Delta	Sacramento-San Joaquin River Delta
DRERIP	Delta Regional Ecosystem Restoration Implementation Program
DSC	Delta Stewardship Council
EMP	Environmental Monitoring Program
FLaSH	Fall Low Salinity Habitat
FMWT	Fall Midwater Trawl Survey
IEP	Interagency Ecological Program
LSZ	low salinity zone
MAST	Management, Analysis, and Synthesis Team
NRC	National Research Council
OMR	Old and Middle River
POD	Pelagic organism decline
SFE	San Francisco Estuary
SKT	Spring Kodiak Trawl Survey

SFPF	Skinner Fish Protection Facility
SRWTP	Sacramento Regional Water Treatment Plant
SSC	suspended sediment concentration
SWP	State Water Project
TFCF	Tracy Fish Collection Facility
TNS	Summer Tow Net Survey

An updated conceptual model of Delta Smelt biology: our evolving understanding of an estuarine fish

By Management, Analysis, and Synthesis Team

Executive Summary

The main purpose of this report is to provide an up-to-date assessment and conceptual model of factors affecting Delta Smelt (*Hypomesus transpacificus*) throughout its primarily annual life cycle and to demonstrate how this conceptual model can be used for scientific and management purposes. The Delta Smelt is a small estuarine fish that only occurs in the San Francisco Estuary. Once abundant, it is now rare and has been protected under the federal and California Endangered Species Acts since 1993. The Delta Smelt listing was related to a step decline in the early 1980s; however, population abundance decreased even further with the onset of the "pelagic organism decline" (POD) around 2002. A substantial, albeit short-lived, increase in abundance of all life stages in 2011 showed that the Delta Smelt population can still rebound when conditions are favorable for spawning, growth, and survival. In this report, we update previous conceptual models for Delta Smelt to reflect new data and information since the release of the last synthesis report about the POD by the Interagency Ecological Program for the San Francisco Estuary (IEP) in 2010. Specific objectives include:

1. Provide decision makers with a practical tool for evaluating difficult trade-offs associated with management and policy decisions.
2. Provide scientists with a framework from which they can formulate and evaluate hypotheses using qualitative or quantitative models.
3. Provide the general public with a new way of learning about Delta Smelt and their habitat.

Our updated conceptual model describes the habitat conditions and ecosystem drivers affecting each Delta Smelt life stage, across seasons and how the seasonal effects contribute to the annual success of the species. The conceptual model consists of two nested and linked levels of increasing specificity. The *general life cycle conceptual model* for four Delta Smelt life stages (adults, eggs and larvae, juveniles, and subadults) includes stationary ecosystem components and dynamic environmental drivers, habitat attributes, and Delta Smelt responses. The more detailed *life stage transition conceptual models* for each of the four Delta Smelt life stages describe relationships between environmental drivers, key habitat attributes, and the responses of Delta Smelt to habitat attributes as they transition from one life stage to the next.

Our analyses and conceptual model show that good larval recruitment is essential for setting the stage for a strong year class; however, increased growth and survival through subsequent life stages are also needed to achieve and sustain higher population abundance. We used our conceptual model to generate 16 hypotheses about the factors that may have contributed to the 2011 increase in Delta Smelt relative abundance. We then evaluated these hypotheses by comparing habitat conditions and Delta Smelt responses in the wet year 2011 to those in the

prior wet year 2006 and in the drier years 2005 and 2010. Larval recruitment was similarly high in both wet years and lower in the drier antecedent years, but juvenile and adult abundance increased only in 2011. In 2005 and 2006, the population was limited by very poor survival from the larval to the juvenile life stage. We found that in 2011, Delta Smelt may have benefitted from a combination of favorable habitat conditions throughout the year, including:

1. Adults and larvae benefitted from prolonged cool spring water temperatures, high 2011 winter and spring outflows which reduced entrainment risk and possibly improved other habitat conditions, and possibly enhanced food availability in late spring.

2. Juveniles benefitted from cool water temperatures in late spring and early summer as well as from improved food availability and low levels of harmful *Microcystis*.

3. Subadults also benefitted from improved food availability and from favorable habitat conditions in the large, low salinity zone (salinity 1-6) located more toward Suisun Bay in 2005-2006 and 2010.

Our comparisons of other habitat attributes either produced inconclusive results or were limited by a lack of suitable data or other necessary information. This was especially true for predation risk and toxicity, and other contaminant effects. Clearly more monitoring and studies are needed on these two topics, but we also found many other data and information gaps. Overall, we did not entirely reject any of our hypotheses. Together with the large amount of published information used to construct our conceptual model, this gives us some confidence that the majority of the elements and linkages of our conceptual model are relevant and (qualitatively) correct. However, the mechanisms they describe are likely variable in the degree to which they drive population outcomes, depending on the conditions in any given year and prior Delta Smelt abundance levels. In addition, the scientific merit of some linkages for which data are sparse (e.g., predation and contaminants effects) is impossible to evaluate without additional information.

Importantly, while this report identifies many data and information gaps that must be filled before some hypotheses can be objectively evaluated, the report includes a very large amount of pertinent data and information that is currently available. The San Francisco Estuary is clearly an intensely monitored and studied ecosystem and Delta Smelt may well be one of the most thoroughly studied endangered fish species in the world. The most critical data for this report came from four long-term Interagency Ecological Program fish monitoring surveys. These surveys provide sound, high-quality data about the annual distribution and relative abundance of Delta Smelt for time periods ranging from one to more than five decades. These four surveys, other monitoring surveys, and numerous research studies provide data about many habitat attributes and ecosystem drivers.

The report ends with key conclusions, a discussion of our hypothesis testing approach, and recommendations for future work and adaptive management applications. The final report Chapter contains many concrete examples of studies, modeling approaches, and management applications that are directly derived from the conceptual model. These examples are not meant to be exhaustive lists. Rather, they are primarily intended to illustrate science and management applications of our conceptual model.

We strongly recommend that analysis, synthesis and modeling efforts, such as this report, be a high priority for the management and science organizations that oversee monitoring and research in the estuary. Without these types of integrative efforts, ongoing and proposed adaptive management processes must conduct such efforts in an *ad hoc* manner, often driven by unrealistic schedules that are unlikely to be fulfilled. Such adaptive management processes in the estuary include the ongoing adaptive management of fall outflow for Delta Smelt, the new "Collaborative Science and Adaptive Management Program," the California Delta Stewardship Council's Delta Plan, and the multi-agency Bay Delta Conservation Plan. On a more basic level, such synthesis efforts identify data gaps that serve to focus research and management efforts on scientifically relevant topics rather than the "crisis of the day."

The 2011 increase in the Delta Smelt abundance index demonstrated that the species still has the ability to rebound to higher abundance levels. Delta Smelt has often been called an indicator – or canary in the coalmine – for overall ecosystem conditions in the estuary. The 2011 increase suggests that the system has not yet irreversibly shifted into an altered state that will no longer support native species. Given the profound habitat alterations in the San Francisco Estuary, continued study of the environmental drivers and habitat attributes and the subsequent responses of the Delta Smelt population seem critical to the wise management of the species. Some possible topics for future synthesis groups include:

1. Reviews and updates to existing conceptual and mathematical models.
2. Further development of mathematical models of Delta Smelt population abundance drawn specifically from the conceptual models described in this report; applications and extensions of recently published models to help make management decisions and guide new modeling efforts; additional modeling efforts and future research projects to improve resolution and understanding of the particular factors identified as critical to reproduction, recruitment, survival, and growth.
3. Review and refinement of new models such as the emerging comprehensive state-space population model (K. Newman, U.S. Fish and Wildlife Service, personal communication); development of additional models or modules of models specifically aimed at estimating effects of inadequately monitored or difficult to measure and evaluate habitat attributes such as predation risk and toxicity; development of new "nested" and/or "linked" mathematical modeling approaches that can accommodate multiple drivers and their interactive effects across temporal and spatial scales.
4. Interdisciplinary collaboration among scientists, managers, and stakeholders to develop and model management scenarios and strategies based on principles of integrative ecosystem and landscape-based management rather than relatively crude distinctions among categorical "water year types."

Continued growth of California's human population, climate change, new species invasions, and other changes will increase management challenges. Science and management have to go hand in hand to constantly identify, implement, evaluate, and refine the best management options for this ever-changing system. We hope that the conceptual model and information in this report will be useful for achieving these goals.

Chapter 1: Introduction

The San Francisco Estuary

Estuarine ecosystems are among the most complex ecosystems on earth (Wilson 1998). They are constantly changing ecosystems that respond to dynamic “drivers” of change (Healey et al. 2008, Baxter et al. 2010). Natural drivers include the geological and geographic setting, climatic and oceanic variability, dynamic hydrological and nutrient regimes, weather and disturbance regimes, biogeochemical processes, species assemblages, and many other biotic and abiotic features. Estuaries also respond to a broad range of human activities. Some of these “human drivers” have negative impacts on ecosystems. These negative human drivers are often called “stressors.” Human stressors on estuarine ecosystems include water and land use, pollutant discharges, species introductions, and fishing (Townend 2004, Lotze et al. 2006, Cloern and Jassby 2012). The interplay of natural and human drivers and their effects on the San Francisco Estuary and in particular on the Delta Smelt (*Hypomesus transpacificus*), an endemic fish species, is the subject of this report.

The San Francisco Estuary (SFE; Fig. 1) is comprised of an upstream region consisting of channels and islands associated with the confluence of the Sacramento and San Joaquin Rivers known as the “Delta” and a series of downstream bays and marshes that are separated from the Pacific Ocean by the “Golden Gate,” the sea passage between the San Francisco and Marin peninsulas. Because of California’s Mediterranean climate, the SFE experiences large interannual and seasonal flow variations, which are modulated by tides and human management of the rivers within the Delta watershed (Moyle et al. 2010). These hydrological variations lead to a dynamic estuarine salinity gradient. In the winter and spring fresh water often extends into San Pablo Bay, while in the summer and fall brackish water can intrude into the western Delta. These seasonal differences are exacerbated by pronounced interannual differences in precipitation in the watershed. Extremely dry years with little precipitation and very wet years with widespread flooding do not occur in predictable patterns (Dettinger 2011).

The SFE has undergone dramatic morphological, hydrological, chemical, and biological alterations since the onset of the California Gold Rush in the middle of the 19th century (Nichols et al. 1986, Arthur et al. 1996, Baxter et al. 2010, Brooks et al. 2012, NRC 2012, Whipple et al. 2012, Cloern and Jassby 2012). These alterations include five human activities that have changed ecological functions and habitats in many riverine and estuarine systems with increasingly dense human populations: diking, draining, dredging, diverting, and discharging. Specifically, diking and draining have reduced the vast wetlands that once covered and surrounded the SFE to small remnants. There has been an 80-fold decrease in the ratio of wetland to open water area in the Delta, from a historical ratio of 14:1 to a current ratio of 1:6 (Whipple et al. 2012, Herbold et al. 2014). Diking and dredging have led to a substantial reconfiguration of the bays, sloughs, and channels, while large-scale water diversions, and discharge of contaminants have altered water quantity and quality. Small water diversions occur throughout the freshwater portion of the estuary, but the largest water diversions are at the pumping facilities of the federal Central Valley Project (CVP) and the State Water Project (SWP) that export water from the southwestern Delta to agricultural and urban areas to the south (Fig. 2). In addition, a wide variety of non-native plants and animals have been introduced and have become established in the SFE (Cohen and Carlton 1998, Light et al. 2005, Winder et al. 2011).

Figure 1. Map of the San Francisco estuary. The inset shows various values of X2, the distance in kilometers from the Golden Gate to the near bottom salinity 2 isohaline.

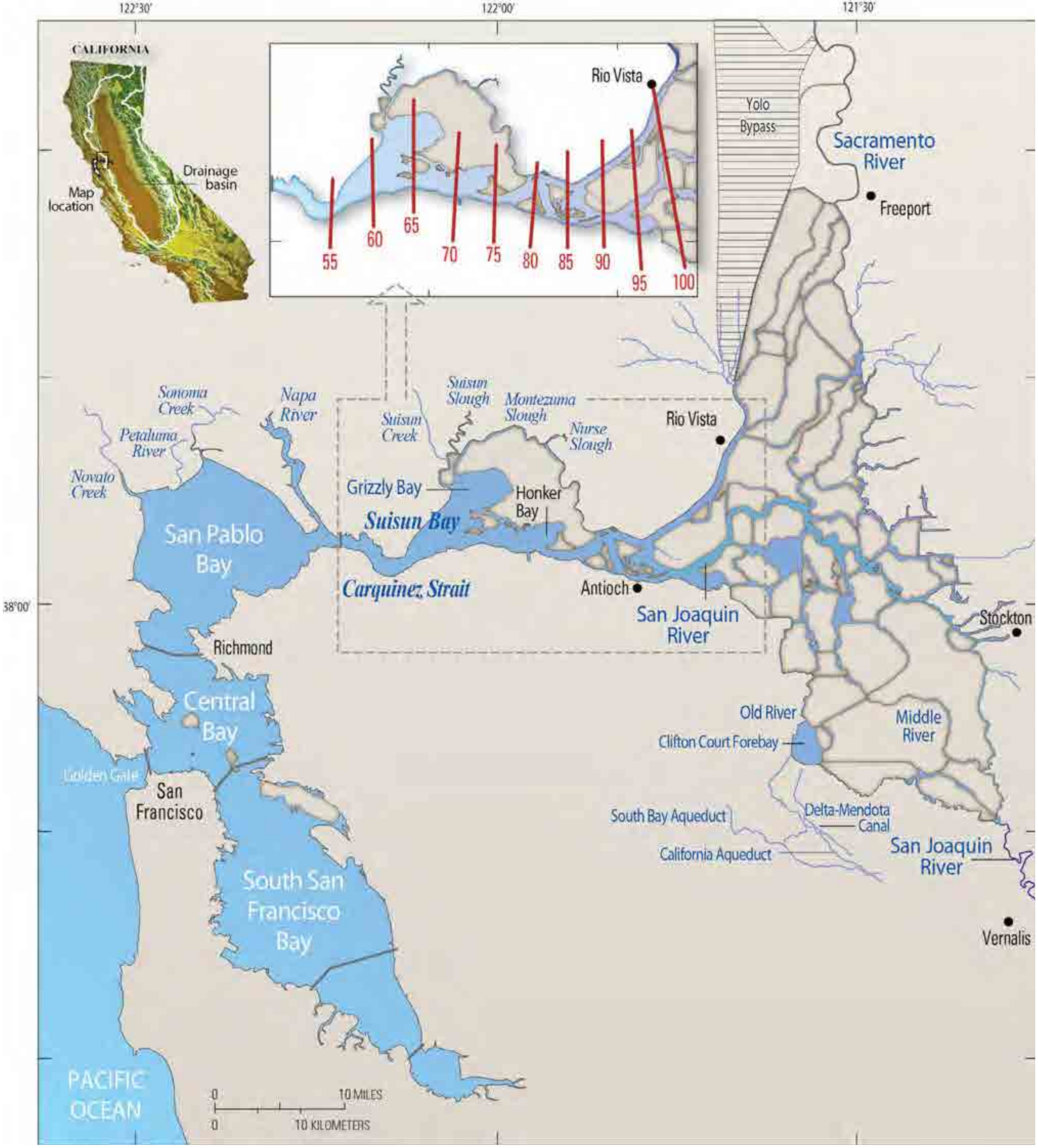
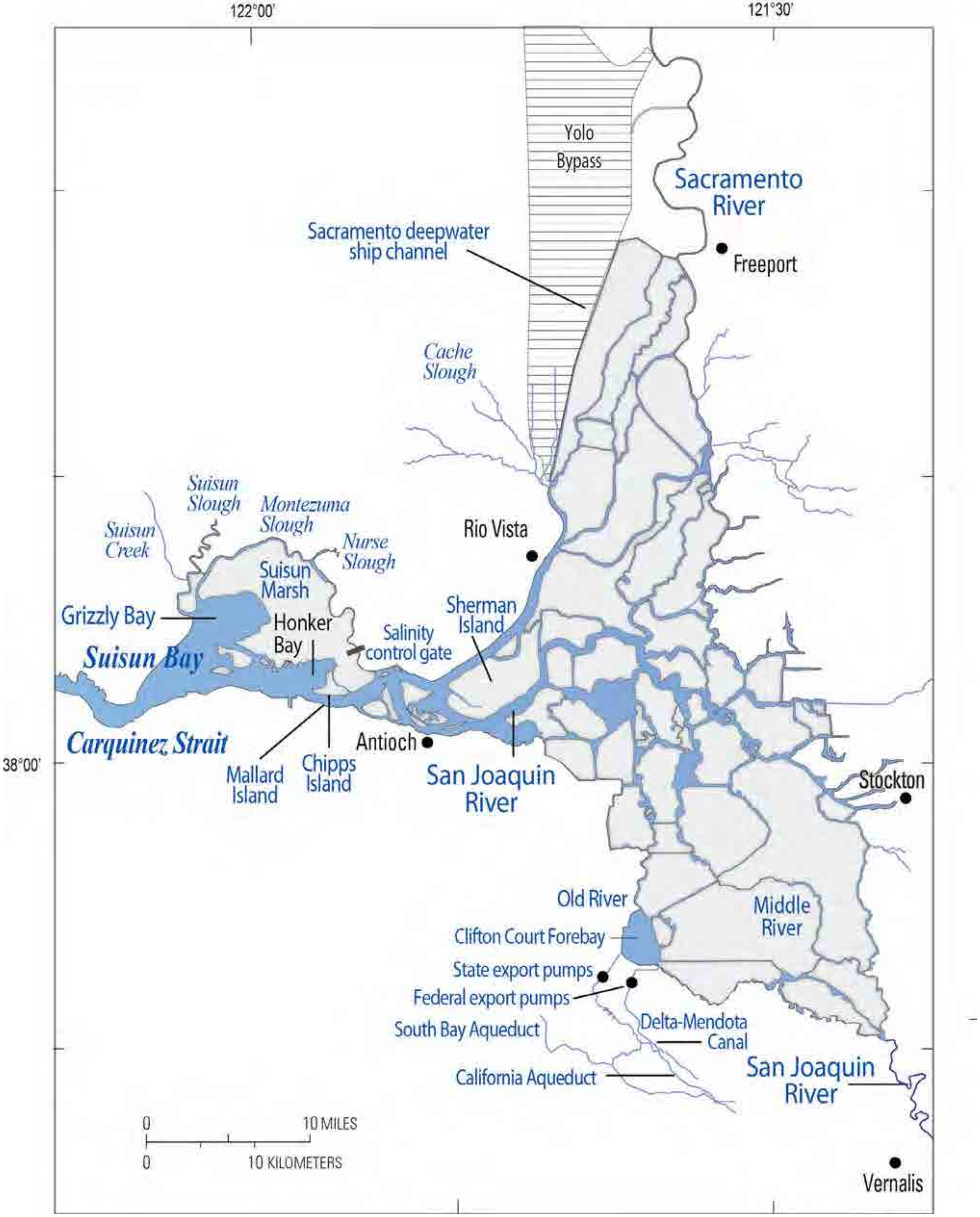


Figure 2. Map of the upper San Francisco estuary. The upper estuary includes the Suisun Bay region and the Sacramento-San Joaquin Delta, which are west and east of Chipps Island respectively. The area from approximately Chipps Island to the west end of Sherman Island is referred to as the "confluence."



Many of the more recent ecological changes in the SFE have been documented by long-term monitoring surveys. Most of these surveys are conducted under the auspices of the Interagency Ecological Program (IEP), an interagency science consortium with three State and six federal member agencies (http://www.water.ca.gov/iep/). Together with monitoring conducted by others, these monitoring surveys provide one of the longest and most comprehensive environmental and biological data records in a U.S. coastal ecosystem. With each additional year of monitoring, this data record serves as an increasingly valuable tool for observing gradual changes or abrupt shifts in ecological conditions and for identifying their underlying causes (Cloern and Jassby 2012).

The modern SFE continues to be a dynamic and complex ecosystem that supports many important ecosystem services (Millennium Ecosystem Assessment 2005), including the provision of fresh water, agricultural crops, commercial and recreational fisheries, and other recreational opportunities. However, it no longer provides adequate habitat for many of its native species as evidenced by severe declines in several of its native fish populations (e.g., Bennett and Moyle 1996, Brown and Moyle 2005, Sommer et al. 2007).

Pelagic fish declines

Among the native fishes of the upper SFE (Fig. 2), the endemic Delta Smelt is of high management concern because of a decline of its annual abundance indices (see Chapter 3 for details of fish surveys and indices), particularly longer term indices for juveniles and subadults, to persistent low levels (Fig. 3). This decline led to its listing under the federal Endangered Species Act in 1993. The Delta Smelt is a slender-bodied pelagic fish with a maximum size of about 120 mm standard length (length from snout to end of vertebral column) and a maximum age of two years. It is the most estuary-dependent of the native fish species in the SFE (Moyle et al. 1992, Bennett 2005). The continued existence of the species is dependent upon its ability to successfully grow, develop, and survive in the SFE.

Delta Smelt is not the only fish species currently in decline in the Delta. Abundance indices of Longfin Smelt (*Spirinchus thaleichthys*), age-0 Striped Bass (*Morone saxatilis*), and Threadfin Shad (*Dorosoma petenense*) declined simultaneously with those of Delta Smelt in about 2002. This simultaneous decline has become known as the pelagic organism decline (POD) (Sommer et al. 2007, Baxter et al. 2008, 2010) (Fig. 4). Given the very different life histories of these four pelagic species, it is unlikely that a single environmental variable could account for the POD declines. In general, researchers have suggested that the POD declines were likely multi-causal (Sommer et al. 2007, Baxter et al. 2008, 2010, Mac Nally et al. 2010, Cloern and Jassby 2012, NRC 2012). Several researchers have suggested that the SFE has undergone an ecological regime shift (Moyle and Bennett 2008, Baxter et al. 2010, Glibert et al. 2011, Cloern and Jassby 2012). In the present system, an invasive aquatic macrophyte (*Egeria densa*) dominates the littoral zone of many areas of the Delta and provides favorable habitat for many invasive fishes (e.g., Largemouth Bass *Micropterus salmoides*; Brown and Michniuk 2007); invasive clams (*Potamocorbula amurensis* and *Corbicula fluminea*) consume a large portion of the available pelagic phytoplankton (Alpine and Cloern 1992, Lopez et al. 2006, Lucas et al. 2002, Lucas and Thompson 2012); agricultural, industrial, and urban discharges transport large quantities of nutrients and a plethora of contaminants into many regions of the estuary; and current management of water for agricultural, industrial and urban purposes is focused on optimizing the reliability of water exports by the CVP and SWP.

Figure 3. Delta Smelt abundance index for life stages of Delta Smelt including the larvae-juveniles (20 mm Survey), juveniles (Summer Townet Survey), subadults (Fall Midwater Trawl), and adults (Spring Kodiak Trawl). The initiation of each individual survey is indicated by the initial bar with subsequent missing bars indicating when an index could not be calculated. See Chapter 3 for details of sampling programs, including geographic coverage, and Appendix B for details of calculationg abundance indices.

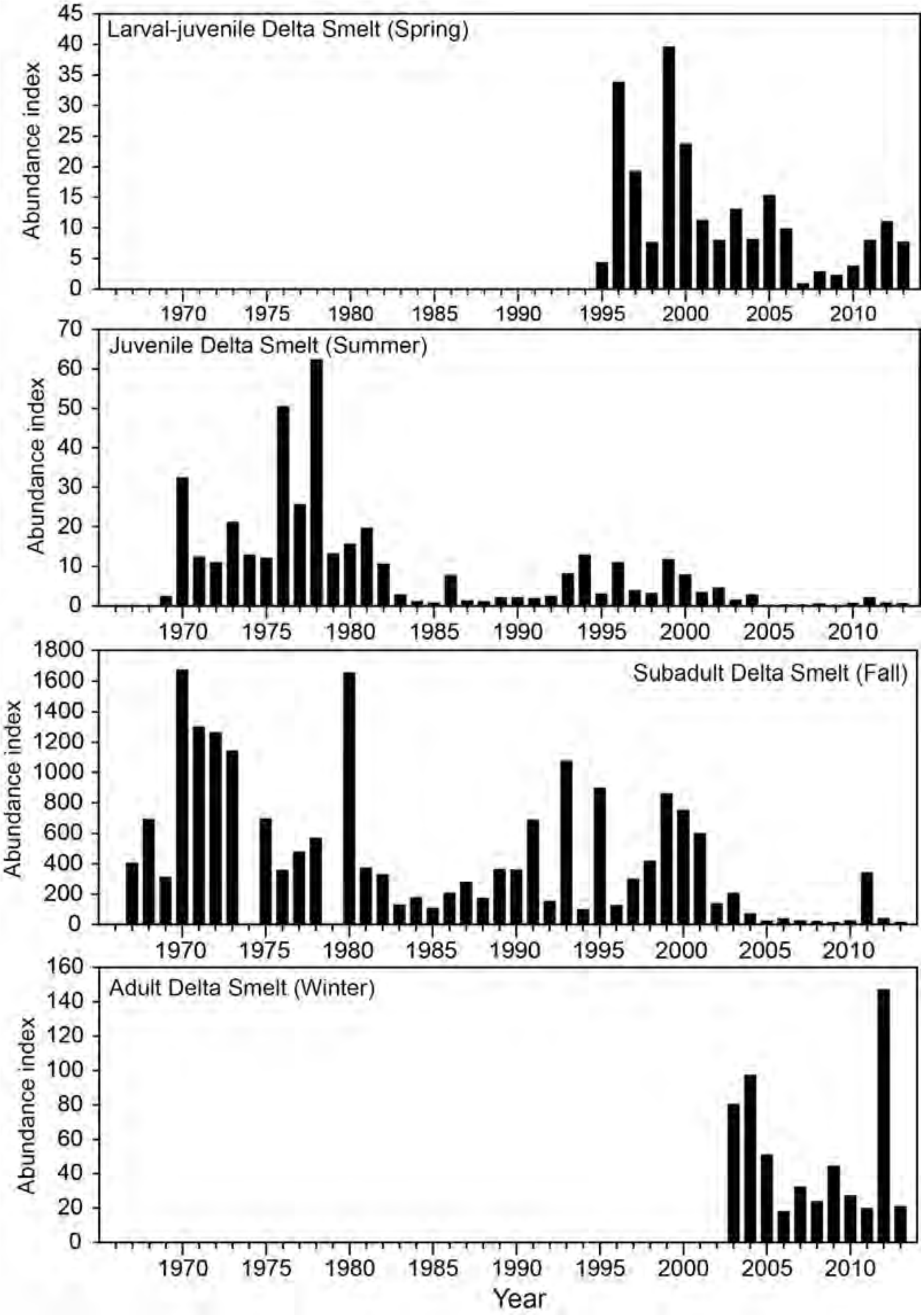
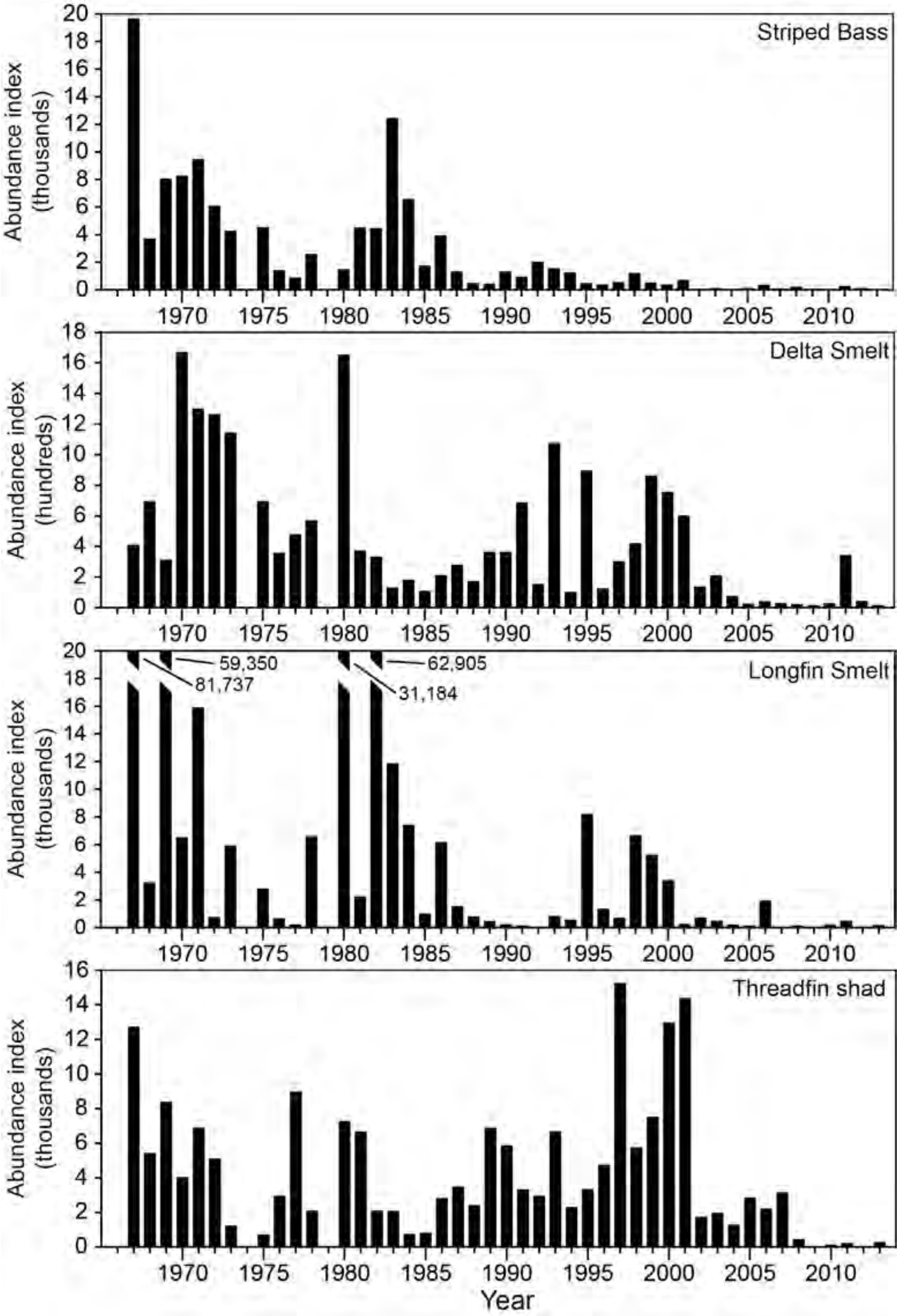


Figure 4. Abundance indices from Fall Midwater Trawl for Delta Smelt, Longfin Smelt, age-0 Striped Bass, and Threadfin Shad. Missing bars indicate when an index could not be calculated. See Chapter 3 for details of sampling programs, including geographic coverage, and Appendix B for details of calculationg abundance indices.



Changes in Delta Smelt distribution and abundance

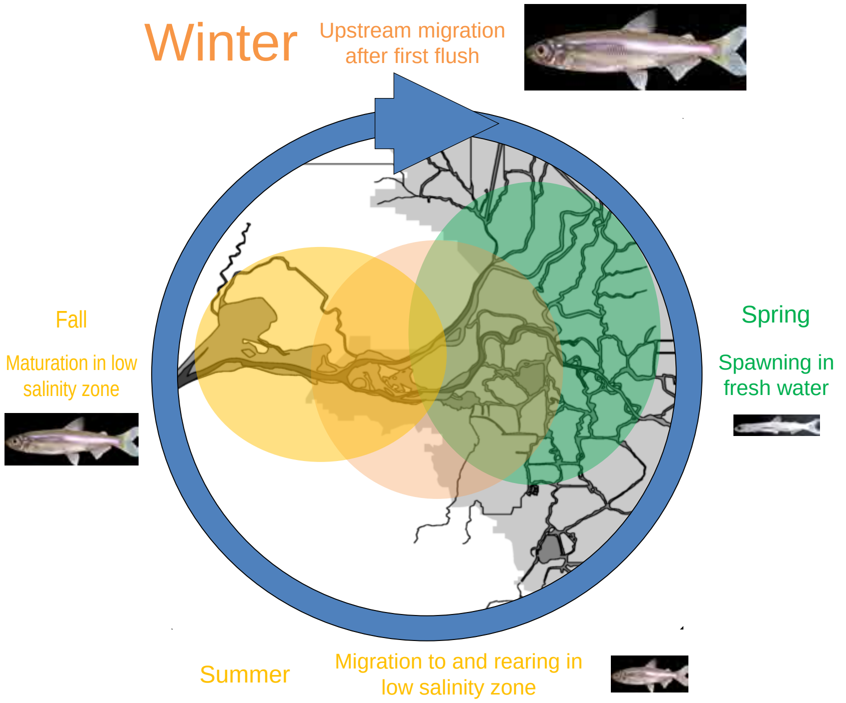
Long-term monitoring surveys conducted by the IEP have documented substantial changes in the distribution and abundance of Delta Smelt in its small native geographic range which extends from the upstream boundaries of tidal influence in the northern, eastern and southern Delta region of the estuary to Suisun and San Pablo Bays in the north-western region of the estuary. The geographic range of Delta Smelt also includes some of the larger tidal sloughs and tributaries adjacent to Suisun and San Pablo Bays, including some Suisun Marsh sloughs and the lower Napa River (Bennett 2005, Hobbs et al. 2007, Sommer et al. 2011, Merz et al. 2011, Sommer and Mejia 2013, Murphy and Hamilton 2013). Delta Smelt are generally considered a pelagic species. While they are commonly found in shallow shoal areas such as Honker and Grizzly Bays in the Suisun Bay region of the estuary and larger marsh sloughs such as Suisun and Montezuma Sloughs in Suisun Marsh and the lower reaches of Cache and Lindsey Sloughs in the northern Delta, they are less commonly encountered in near-shore areas and only rarely in smaller marsh sloughs (Bennett 2005, Merz et al. 2011, Sommer and Mejia 2013).

The Delta Smelt has been characterized as a “semi-anadromous” fish species that spawns in fresh water and rears in fresh to brackish water (Fig. 5; Dege and Brown 2004, Bennett 2005, Sommer et al. 2011, Merz et al. 2011). While Delta Smelt have been documented throughout their geographic range during most months of the year (Sommer et al. 2011, Merz et al. 2011, Murphy and Hamilton 2013), their distribution varies seasonally in response to dynamic abiotic and biotic habitat attributes such as salinity, temperature, turbidity, and presumably food supplies (Bennett et al. 2005, Sommer et al. 2013, Brown et al. 2014). In years with high freshwater discharge in winter and spring, spawning and rearing of larval and early post-larval fish can temporarily extend seaward into San Pablo Bay, while in years with less discharge it usually occurs in the Delta, Suisun Bay and Suisun Marsh. Juveniles and adults are distributed across a broader salinity range (0 to about 18) than larval and post-larval fishes which tend to be most abundant in the low salinity zone (salinity 1-6). Dege and Brown (2004) and Sommer et al. (2011) found that the center of the Delta Smelt distribution is associated with salinities of about 2 during most months and moves with the estuarine salinity gradient as the salinity gradient responds to flow.

Historically, Delta Smelt were commonly observed throughout the fresh and low salinity portions of their geographic range (Erkkila et al. 1950, Radke 1966). Over the last two decades, their geographic distribution has become more constricted during the summer and fall. At present, Delta Smelt are less commonly found in the southern and eastern Delta during the winter and spring and are largely absent from this region in the summer and fall (Nobriga et al. 2008, Sommer et al. 2011). While Delta Smelt continue to be found in the northern Delta year-round and individual catches in this region are sometimes large, particularly during winter and spring, the majority of the population is usually observed in the region near to and west of the Sacramento-San Joaquin River confluence, especially in the summer and fall (Sweetnam 1999, Feyrer et al. 2007, Nobriga et al. 2008, Merz et al. 2011, Sommer et al. 2011, Sommer and Mejia 2013).

In addition to documenting changes in distribution, long-term IEP surveys also reveal that the annual abundance indices of Delta Smelt have greatly declined since the first long-term pelagic fish monitoring survey began in summer 1959 (Fig. 3). Both a gradual, long-term decline and step changes, most recently around 2002, have been described using a variety of qualitative and statistical approaches for subadult Delta Smelt caught in the fall (e.g., Bennett and Moyle 1996, Bennett 2005, Manly and Chotkowski 2006, Thomson et al. 2010). These declines have not been smooth or entirely unidirectional and also include a great deal of interannual variability (Fig. 3).

Figure 5. **Simplified life cycle of Delta Smelt (modified from Bennett 2005). Colors correspond to different seasons with the low salinity zone changing position with season.**



Since the beginning of the POD in 2002, the Delta Smelt abundance indices have often been at record low levels, leading to concerns about declines in effective population size (Fisch et al. 2011) and a loss of population-level resilience, meaning the ability of the population to recover to higher population abundances when conditions are suitable. For example, population sizes might become too small to produce enough eggs or larvae to outpace predation on eggs and larvae.

Delta Smelt had previously rebounded from low population abundances, most recently in the wet years of the late 1990s (Fig. 3). The lack of increase in Delta Smelt in the wet year of 2006 combined with new evidence for genetic bottlenecks and a significant decline in effective population size from 2003 to 2007 (Fisch et al. 2011) were thus a source of great concern. However, during 2011, the next wet year after 2006, the species did increase in abundance (Fig. 3). Unfortunately, the increase in Delta Smelt abundance was short-lived and did not carry over into the following year-class in 2012, a drier year. Nevertheless, the temporary increase gave some cause for renewed optimism about the resilience of the species and its potential recovery. In addition, the contrasts between habitat conditions and Delta Smelt responses in 2006 and 2011 provided an opportunity to gain new insights into the Delta Smelt habitat requirements that might help better manage this species and its habitat.

Protecting Delta Smelt

Delta Smelt are currently protected under both California and federal endangered species legislation. The protection and recovery of Delta Smelt and its estuarine habitat in the SFE will likely require the human population of California to reduce its dependence on some of the natural resources provided by the SFE. This will become even more challenging in the future because of climate change and the continued growth of California's human population. California's population has increased by approximately 38 million people compared to the population when California became a state in 1850 and has increased by about 22.5 million compared to 1959 when Delta Smelt monitoring started 55 years ago (U.S. Census Bureau data). More than three quarters of today's 38 million Californians live south of the SFE, and the majority of these Californians and millions of acres of farmland rely on fresh water diverted from the Delta for all or part of their water supply. The conflicts and trade-offs between species protection measures and actions to provide water and other natural resources to California's growing human population have resulted in repeated attempts to reconcile these seemingly irreconcilable objectives through regulatory requirements, new institutional arrangements, and management plans.

Among the regulatory requirements are the State water right decisions issued by the California State Water Resources Control Board, which grant SWP and CVP water rights permits, but also include requirements to protect fish. State regulations also include increasingly more stringent waste discharge permits. For example, the new permit recently issued to the Sacramento Regional County Wastewater Treatment Plant includes new requirements for major treatment upgrades to better protect downstream water uses and the health of the estuary. Federal regulations include water quality requirements under the Clean Water Act and Biological Opinions (BiOps) issued under the federal Endangered Species Act. Two BiOps assess the effects of the coordinated operations of the SWP and CVP on Delta Smelt, Green Sturgeon, and salmonid fish populations, and their designated critical habitat. These BiOps include "reasonable and prudent alternatives" to lessen negative impacts of SWP and CVP operations and avoid jeopardy to the species, while at the same time trying to avoid major reductions in water exports from the Delta.

Recent institutional reconciliation attempts include the multiagency, State and federal CALFED Bay-Delta Program and Authority (CALFED) and the California Delta Stewardship Council (DSC), a new State agency. From 1994 to 2010, CALFED attempted to reconcile water allocation and ecosystem restoration efforts in the estuary in a way that would allow them to "get better together" (Doremus 2009). After the demise of CALFED, the State of California created the DSC to address what the legislature termed the "co-equal goals" of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem (CA Water Code §85054, http://deltacouncil.ca.gov/).

Among the many management plans aimed at reconciling species protection and human water and land use objectives are plans by the DSC, SWRCB, and new groupings of multiple agencies and stakeholders. The DSC recently completed and is now starting to implement its comprehensive "Delta Plan" (http://deltacouncil.ca.gov/delta-plan-0) to achieve the co-equal goals, while the SWRCB is on track to complete a major update to its "Bay-Delta Plan" which may result in changes to water right permits (http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/). Three California State agencies recently completed a new California Water Action Plan that includes actions to help achieve the co-equal goals (http://resources.ca.gov/california_water_action_plan/). A multi-agency planning effort that includes State and federal agencies as well as local Public Water Agencies (water contractors) is working to complete the "Bay-Delta Conservation Plan" (BDCP, http://baydeltaconservationplan.com). The BDCP is a proposed Habitat Conservation Plan under the federal Endangered Species Act and a Natural Community Conservation Plan under the California Natural Community Conservation Planning Act. It proposes to implement habitat restoration measures, stressor reduction activities, improved water project operations criteria, and new water conveyance infrastructure. If approved by the regulatory agencies, this plan would provide long-term permits for the various projects and water operations to proceed over a 50-year time frame.

Management actions, regulatory requirements, and institutional arrangements in the SFE have undergone substantial and complex changes over the last 150 years. Hanak et al. (2011) describe a progression from an early disorganized "laissez-faire" era of California and SFE water management followed by increasingly organized and large-scale management schemes, from local water use to state-wide water projects, which led to a current "era of conflict" and the hope for a new "era of reconciliation." A complete review of these changes is outside the scope of this report and the reader is referred to Hanak et al. (2011) and other existing reports on this topic. It is important to note, however, that increasingly, these changes have been "adaptations" based on the results of monitoring, studies, and other scientific activities in the SFE. Many of these scientific activities have been conducted under the auspices of the IEP (Herrgesell 2013). It can be argued that some of the activities preceding and ultimately leading to the creation of the IEP in 1970 ushered in an era of increasingly intense and formalized "adaptive management" before the term itself was coined.

Adaptive management is a formal approach to natural resource management that closely connects science with management to devise, track, and improve management outcomes. This connection started to become an important aspect of fisheries management in the 1950s (e.g., Beverton and Holt 1957), although the term itself was not coined until 1978 when Holling (1978) and Walters and Hilborn (1978) provided a conceptual framework for adaptive resources management. This framework was later refined to distinguish between "passive" and "active" adaptive management. According to Williams (2011), "active adaptive management actively pursues the reduction of uncertainty through management interventions, whereas passive adaptive management focuses on resource objectives, with learning a useful but unintended byproduct of decision making […]. In practice this means that a key difference between passive and active adaptive management is the degree to which the objectives that guide decision making emphasize the reduction of uncertainty." In active adaptive management, management actions are designed as "experimental treatments" with clear hypotheses about outcomes that are tested through rigorous data collection and analyses. This accelerates learning, but can come at the expense of achieving resource objectives because potentially less effective management actions may be included in the experimental design. Moreover, the more intense science efforts needed for active adaptive management can be costly over the short term (Williams 2011). This may explain why passive adaptive management, while not always referred to by this name or implemented in the formal and rigorous way now advocated by the DSC's Delta Plan (DSC 2013), has been and continues to be common in the SFE, but active adaptive management – viewed by some as the only "real" adaptive management – is still rare.

Of all current management actions and requirements affecting Delta Smelt, the actions required in the 2005 and 2008 BiOps issued by the U.S. Fish and Wildlife Service (FWS) are most directly aimed at the protection of Delta Smelt. The 2008 BiOp takes a life cycle approach to protecting Delta Smelt and includes an explicit requirement for adaptive management of fall outflow. After initial steps to design a passive adaptive management program, the U.S. Bureau of Reclamation (Reclamation) decided to take a more active approach aimed at more rapidly reducing uncertainties about the underlying mechanisms and effects of fall outflow management on Delta Smelt (Reclamation 2011, 2012, Brown et al. 2014). The study component of the fall outflow adaptive management plan, also known as the "fall low salinity habitat" (FLaSH) studies, was developed with the help of a new conceptual model (FLaSH conceptual model, Brown et al. 2014) and has been implemented by the IEP starting in 2011. The FLaSH studies provided an opportunity to intensely study the increase in the Delta Smelt abundance index observed in 2011. At this initial stage of the adaptive management program and the FLaSH studies, the 2011 data were compared to data gathered in the previous wet year, 2006, during which fall outflow was lower. The intitial data analysis effort also considered antecedent conditions in 2010 and 2005, resulting in a simple comparative approach focusing on four years (Brown et al. 2014).

Report Purpose and Organization

It is clear that the recovery of Delta Smelt and other listed and unlisted native species will be a key requirement of any plan to manage the resources of the SFE. Understanding the factors driving Delta Smelt population dynamics is a major goal of resource management agencies. The main purpose of this report is to provide an up to date assessment of factors affecting Delta Smelt throughout its primarily annual life cycle. Specific goals are to provide decision makers with scientific information for evaluating difficult trade-offs associated with management and policy decisions, provide scientists with a resource for formulating and testing hypotheses and mathematical models, and provide the general public with a new way for learning about Delta Smelt and their habitat.

We address these goals through a synthesis of scientific information about Delta Smelt with an emphasis on new information since the release of the last POD synthesis report in 2010 (Baxter et al. 2010). As in previous reports, conceptual models play a key role in this report. Conceptual models are useful tools for organizing and synthesizing information, designing research and modeling studies, and for evaluating potential outcomes of management actions. Here, we revisit previously developed conceptual models for Delta Smelt, and synthesize new information about factors affecting Delta Smelt and Delta Smelt responses to those factors. This comprehensive body of information is then used to construct and populate a Delta Smelt conceptual model, within a new framework.

Numerous conceptual models have been developed to describe the relationships and linkages among environmental drivers of ecosystem change, ecosystem and habitat attributes, and Delta Smelt responses. In Chapter 2 of this report, we provide a brief introduction to conceptual models and review some of the conceptual models developed for the SFE and for Delta Smelt. In Chapter 3, we introduce a new conceptual model framework for Delta Smelt and describe our approach to updating the previously developed Delta Smelt conceptual models. We also describe the data sources and analytical approaches used in this report. In Chapter 4, we review and synthesize recent information about drivers and habitat attributes affecting Delta Smelt and Delta Smelt responses to habitat attributes. In Chapter 5, we present an updated conceptual model for Delta Smelt that include key drivers, habitat attributes, interactions between them, and Delta Smelt responses discussed in Chapter 4. In Chapter 6, we review and synthesize recent information about Delta Smelt population dynamics, life history, and population trends. In Chapter 7, we use the updated conceptual model to formulate hypotheses about Delta Smelt responses and changing habitat conditions and test them using a simple comparative approach similar to the FLaSH approach (Brown et al. 2014), but for all life stages of Delta Smelt. The purpose of Chapter 7 is to put the new conceptual model along with the comparative approach to an immediate test that is of high relevance to the management of Delta Smelt. Chapter 8 presents key results and conclusions from the preceding Chapters. In Chapter 9, we discuss next steps for future conceptual, qualitative, and quantitative modeling as well as the science and management implications of the information contained in this report.

Chapter 2: Conceptual Models

Overview

We learn and think about the world we live in through mental models of how the world looks and how it works. Our mental models guide all our conscious decisions and actions. They are never static; we constantly update them with new information gained by observing the world around us and by assessing the outcomes of our decisions and actions. In our minds, we compare the new information against our existing mental models. Observations that agree with our mental models strengthen them, observations that don't agree with our mental models force us to modify, adjust, and update them.

Conceptual models are formalized versions of mental models that are communicated to others verbally and graphically. Ecologists and environmental managers use them to communicate hypotheses about "how ecosystems work" and to explore how human actions and other drivers change ecosystems. They usually use a combination of narrative text and graphical illustrations about ecosystem components and the relationships among them. More informal narrative conceptual models verbally describe cause-effect relationships, while more formal conceptual models may express them through scientific hypotheses or mathematical equations.

Conceptual model illustrations often take the form of pictures, plots, schematic images or diagrams, matrices, or tables (Fischenich 2008). For example, the IEP Estuarine Ecology Team used elaborate matrices to illustrate and assess the likely mechanisms underlying the statistically determined relationships between SFE fishes and "X2," an indicator of estuarine salinity dynamics (Estuarine Ecology Team 1997), while Reclamation (2011, 2012) used a table format to illustrate how fall outflow interacts with other features of Delta Smelt habitat and affects Delta Smelt. Schoellhamer et al. (2012) used a series of conceptual X-Y plots to illustrate a conceptual model of sediment supply reduction and downstream propagation in the SFE. Glibert (2012) and Glibert et al. (2011) used schematic images to conceptualize changes in nutrients, flows, biogeochemical processes, and the food web of the SFE. Many schematic conceptual model diagrams use boxes to depict ecosystem components and arrows to illustrate the relationships, flows, and interactions among them. The conceptual models developed by the IEP for its POD investigations (see below) include examples of schematic conceptual model depictions with few boxes and arrows, while some of the conceptual models developed for the "Delta Regional Ecosystem Restoration Implementation Plan" (DiGennaro et al. 2012, see below) and the "effects hierarchy" of factors affecting Delta Smelt abundance developed by Miller et al. (2012) provide examples of more complex schematics with a large number of boxes and arrows.

Conceptual models have become essential tools for summarizing, synthesizing, and communicating scientific understanding of ecosystem structure and functioning. They are also key to successful planning and implementation of ecological research and mathematical modeling as well as to adaptive management, restoration and recovery of ecosystems, and environmental science education (e.g., Thom 2000, Ogden et al. 2005, Fortuin et al. 2011). Conceptual models are also essential tools for identifying management and science priorities and for the selection of key ecological attributes to be used to evaluate the performance of management actions (i.e., performance measures) and assess the present relative to a desired state of an ecosystem (i.e., indicators) (Washington State Academy of Sciences 2012).

Conceptual models have clear limitations. For example, even the most complex conceptual models are highly simplified descriptions of a small part of an ecosystem – they can never tell the “whole” story. Just like our every-day mental models, they are also never final. To remain relevant, ecological conceptual models must evolve and change with the evolution of our knowledge about ecosystems. Furthermore, conceptual models identify key ecosystem components and relationships, but they do not quantify them and unless they are coupled with mathematical models, conceptual models cannot be used to make quantitative predictions.

Conceptual models can be used to make qualitative predictions about changes in ecosystem components and their relationships. These qualitative predictions can serve as testable hypotheses that help design scientific analyses and studies. The creation or revision of the conceptual models themselves usually forces the formulation of hypotheses and their testing with available data and information, as will be demonstrated in the later Chapters of this report. Qualitative predictions and testable hypotheses are also at the heart of active adaptive management. They are needed to design experimental adaptive management actions and the studies and monitoring needed to assess the outcomes from such actions. The fall outflow adaptive management plan (Reclamation 2011, 2012) provides an example of how a conceptual model was used to make qualitative predictions and design a comprehensive set of studies, the FLaSH studies. Finally, the formulation of conceptual models is usually the essential first step for constructing quantitative models. Mathematical models are sets of mathematical expressions that quantify the components and relationships in the conceptual models and can be used to make quantitative predictions about the state of ecosystem components and linkages under specific circumstances (Jackson et al. 2000). The (few) quantitative predictions in the fall outflow adaptive management plan (Reclamation 2011, 2012) are based on such mathematical models.

Ecological conceptual models generally link ecological “drivers” with ecological effects or “outcomes.” Drivers are physical, chemical, or biological factors of human or natural origin (for example, nutrients from natural soils and applied fertilizers). Outcomes can be physical, chemical or biological responses to the drivers (for example, phytoplankton growth and biomass), but can also be social and economic impacts on human components of the ecosystem (for example, harmful algal blooms that affect recreational use or costs of water treatment for drinking water supply). Drivers and outcomes are the components of the system under consideration. They are linked by mechanistic cause-effect relationships. Conceptual models can also be nested within each other, for example, to accommodate different temporal or spatial scales, or conceptual models can be coupled so that the outcome of one conceptual model becomes a driver in the next one. Drivers are often categorized in various ways, including their causal proximity to specific outcomes, whether they are natural or anthropogenic, and whether they can be altered by human management strategies and actions. Graphically, drivers are often arranged in hierarchical tiers that reflect these categories.

For example, Gentile et al (2001) describe a basic three-tiered approach that links environmental outcomes (tier 1) to proximal anthropogenic drivers termed “stressors” (tier 2) and the natural and anthropogenic drivers that act on these stressors (tier 3). Davis et al. (2010) show how different ecological regimes in Australian lakes (outcomes, tier 1) arise from the interplay of stressors (tier 2) and hydrological changes (tier 3) acting on the original ecological regime (tier 4). Carr et al. (2007) review a widely used five-tiered “Driver–Pressure–State–Impact–Response” (DPSIR) framework that focuses on identifying human-caused environmental problems and solutions. In this framework, the ultimate drivers (D) are social processes that result in specific human activities that manifest as proximal “pressures” (P) that change the “state” (S), or condition, of the environment. This can have “impacts” (I) on human well-being that are recognized as problems. Some impacts are so severe that they require a human response (R), usually in the form of institutional solutions aimed at reducing high-priority impacts. The Puget Sound Partnership Science Panel (2012) recently used the DPSIR framework to develop a conceptual model that links management strategies (i.e., responses; e.g., reduce pollution) to anthropogenic drivers (e.g., human population growth) and pressures (e.g., pollution) that affect the state of ecosystem components (e.g., habitats and species) and impact the provisioning of ecosystem services (e.g., fishing). This model helped identify scientific knowledge gaps and decision-critical issues and questions that needed to be answered in response to management priorities.

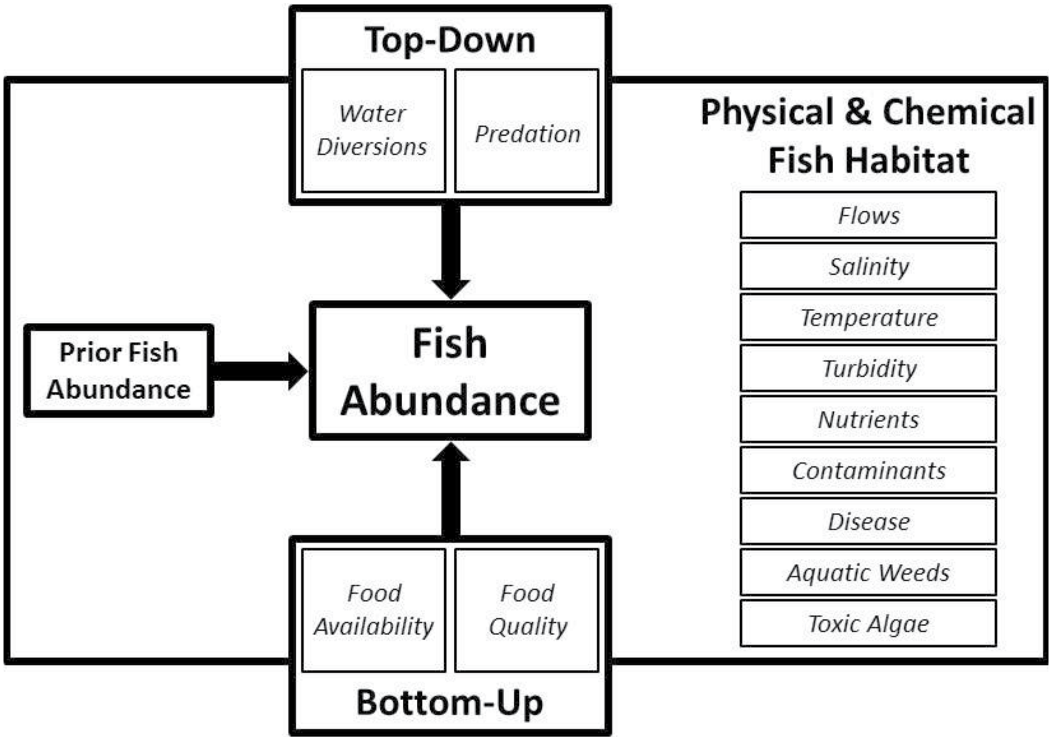
Recent Conceptual Models for the San Francisco Estuary

Over the last decade, two integrated sets of conceptual models have been developed for portions of the SFE. The first conceptual model set was developed by the Ecosystem Restoration Program (http://www.dfg.ca.gov/ERP/) to evaluate restoration actions in the Delta under the "Delta Regional Ecosystem Restoration Implementation Plan" (DRERIP; DiGennaro et al. 2012). DRERIP conceptual models were developed for ecological processes, habitats, specific species, and stressors. The DRERIP conceptual models were built around environmental drivers, their expected effects termed "outcomes," and cause-and-effect relationships between the two shown as one-way arrows termed "linkages." In the graphical depiction of the DRERIP conceptual models, different arrow widths, colors, and styles denote the importance, degree of understanding, and predictability, respectively, of the driver-linkage-outcome relationships, while symbols next to the arrows denote the direction and nature of the effect (positive, negative, or non-linear) (DiGennaro 2012, Opperman 2012). The DRERIP species conceptual models include "transition matrix" diagrams depicting how environmental drivers affect the probability of one life stage successfully transitioning to the next.

The second set of conceptual models was developed by the IEP as a comprehensive conceptual framework intended to guide investigations of the POD and to synthesize and communicate results (Sommer et al. 2007, Baxter et al. 2010). This framework includes a "basic" POD conceptual model about key drivers of change affecting pelagic fish and their habitat (Fig. 6), more narrowly focused "species-specific" conceptual models about drivers affecting the different life stages of each of the four POD fish species (e.g., Fig. 7), and a broader "ecological regime shift" conceptual model that placed the POD decline in a longer-term historical context (not shown; see Baxter et al. 2010). The basic POD conceptual model placed the four fish species in the center of interacting drivers affecting the quantity and quality of their habitat (Fig. 6), while the species-specific models identified key seasonal drivers in red, with proximal causes and effects in yellow (Fig. 7).

The National Research Council Committee on Sustainable Water and Environmental Management in the California Bay-Delta (NRC Committee) (NRC 2012) called the POD conceptual model framework "an important example of supporting science. This framework identifies and links, in the context of both ecosystem structure and functioning, the key stressors that help to explain the decline of pelagic organisms." The NRC Committee further noted that the "drivers of change" identified in the POD conceptual models "are quantifiable" and "suitable for model evaluation" and that the:

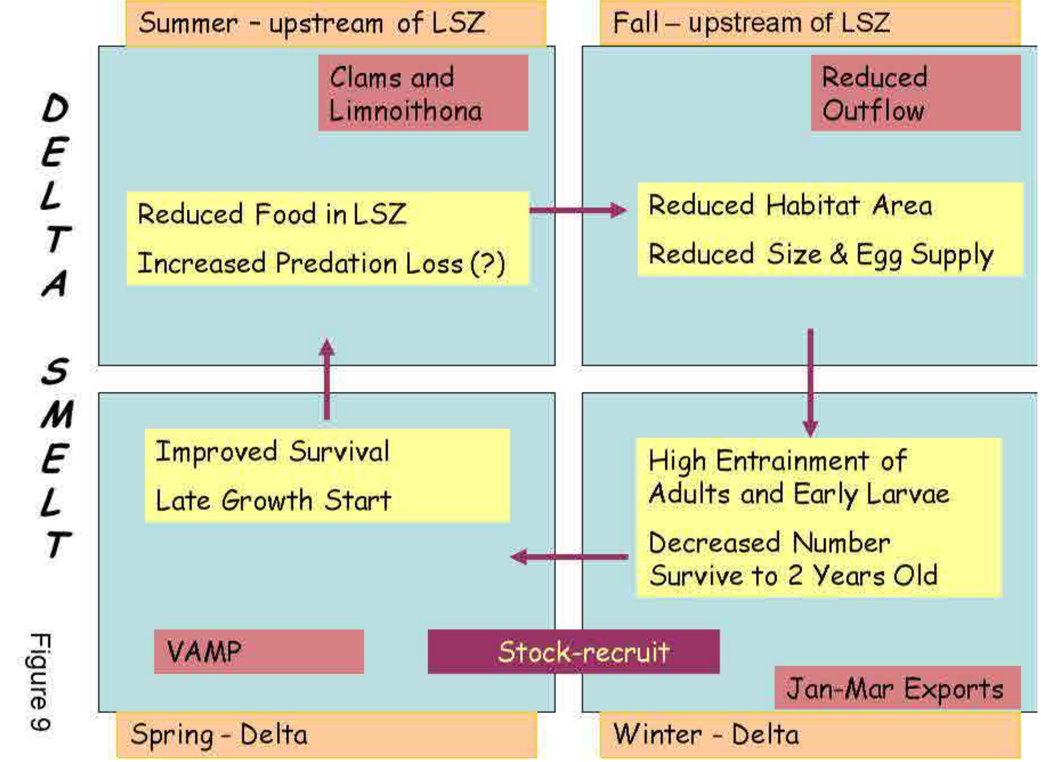
Figure 6. **The basic conceptual model for the pelagic organism decline (Baxter et al. 2010).**



> "types of stressors identified are integrative, reflecting co-occurring physical, chemical, and biotic changes. They also apply to multiple structural (food web structure, biodiversity) and functional (food transfer changes, biogeochemical cycling) changes taking place in the Delta. The framework and associated detail are both comprehensive and useful in terms of linking these drivers to changes taking place at multiple levels of the food web. This type of conceptual approach will also be useful for examining other drivers and impacts of ecological change, including observed changes in fish community structure and production; specifically, how these changes are affected and influenced by changes in physico-chemical factors (e.g., salinity, temperature, turbidity, nutrients/contaminants) and at lower trophic levels (phytoplankton, invertebrate grazers, and prey)" (NRC 2012, p. 34-35).

Since the release of the 2012 NRC report, the POD conceptual model framework has been used as the basis for additional conceptual models developed to aid planning and quantifying the ecological effects of active adaptive management of Delta outflow to improve fall low salinity habitat for Delta Smelt and to guide the associated fall low salinity habitat (FLaSH) studies (Reclamation 2011, 2012). A more complete summary of the POD and FLaSH conceptual models along with additional information about related conceptual and quantitative models in the SFE can be found in the initial FLaSH report (Brown et al. 2014, see also http://deltacouncil.ca.gov/science-program/fall-low-salinity-habitat-flash-studies-and-adaptive-management-plan-review-0).

Figure 7. Species-specific conceptual model for Delta Smelt. This is one of four species-specific conceptual models developed as part of the conceptual framework for the pelagic organism decline (Baxter et al. 2010). The low salinity zone (LSZ) is defined as salinity 1-6. The Vernalis Adaptive Management Plan (VAMP) included reductions in spring exports with possible effects on Delta Smelt.



One important new feature of the conceptual model developed for the fall outflow adaptive management plan and the FLaSH studies was the explicit consideration of interacting dynamic and relatively more stationary (geographically and temporally fixed) habitat components that was based on a conceptual model of environment-habitat-production linkages in tidal river estuaries developed by Peterson (2003). In the FLaSH conceptual model, the interactions among dynamic and stationary habitat components determine the characteristics of Delta Smelt habitat in the fall and lead to varying Delta Smelt outcomes. In essence, the dynamic flow and salinity regimes of the SFE move water, particles, and organisms across the estuary's stationary topography, which has distinct physical features that modulate the dynamic habitat components. Together, these stationary and dynamic habitat components are hypothesized to control the survival, health, growth, fecundity, and, ultimately, the reproductive success of estuarine pelagic species, such as Delta Smelt. The interplay between stationary and dynamic habitat components also helps explain the distribution and movement of Delta Smelt across its range which cannot be understood – or managed – based on geography alone.

Numerous other conceptual and quantitative models have been developed for the SFE. Kimmerer (2004) summarized many of the earlier conceptual models. More recent conceptual model examples include those by Glibert (2012) and Glibert et al. (2011) as well as the five-tiered effects hierarchy by Miller et al. (2012). Recent examples of mathematical models of habitat use and population dynamics of Delta Smelt include models based on statistical approaches (e.g., Manly and Chotkowski 2006, Feyrer et al. 2007, Nobriga et al. 2008, Feyrer et al. 2010, Thomson et al. 2010, Mac Nally et al. 2010, Miller et al. 2012). There is also a rapidly developing body of life cycle models for Delta Smelt and other SFE fish species that use statistical and numerical simulation approaches (e.g. Blumberg et al., 2010, Maunder and Deriso 2011, Massoudieh et al. 2011, Rose et al. 2011, Rose et al. 2013a,b).

Chapter 3: Approach

This report is the result of a team effort by the IEP Management, Analysis, and Synthesis Team (MAST, often referred to as “we” in this report). Appendix A briefly describes the MAST and the report development process and schedule which included a public and independent expert peer review step that led to major revisions to the draft report.

General Approach

Our general approach in this report was to develop a new conceptual model framework for Delta Smelt and to use this framework to synthesize new scientific information and update and integrate existing conceptual models including the “basic” and “species-specific” POD conceptual models, the DRERIP “transition matrix” models, the tabular FLaSH conceptual model and the hierarchical conceptual model in Miller et al. (2012) described in Chapter 2.

The development of the new conceptual model framework was guided by the conceptual model literature (see Chapter 2) and by recommendations from the independent “FLaSH Panel” of national experts convened by the Delta Science Program. The FLaSH Panel recommended to:

> “develop a schematic version of the [FLaSH] conceptual model that matches the revised, written version of the conceptual model in the draft 2012 FLaSH study report. The conceptual model in written and schematic form should continue to emphasize processes and their interactions over simple correlations, should ensure Delta Smelt vital rates remain central to thinking, and should be designed for routine use by scientists as an organizational tool and for testing hypotheses associated with the AMP [adaptive management plan]; it should be as complex as necessary to achieve these purposes. The conceptual model should also be able to encompass processes and interactions that extend before and after Fall Outflow Action periods, including areas both upstream and downstream of the LSZ” (FLaSH Panel 2012, page ii).

The conceptual modeling approach in this report is intended to provide a basis, not a substitute for the development or use of mathematical models. While mathematical models are outside of the scope of this report, we briefly discuss the promise and challenges of mathematical models for Delta Smelt, summarize some of the highlights of existing mathematical modeling efforts for Delta Smelt, and offer a brief description of two additional proposed mathematical modeling efforts — one qualitative and the other quantitative — we think are natural outgrowths of the information in this report (see Chapter 8). Development of a variety of flexible working tools to facilitate discussion of elements of the conceptual model is one intended outcome of the MAST effort. Even simple quantitative and qualitative models based on our revised conceptual model will serve to further organize thinking and characterize weaknesses in current data collection and analysis efforts.

In this Chapter, we introduce the new conceptual model framework for Delta Smelt. This framework consists of a series of nested and tiered conceptual models: a general life cycle conceptual model and more detailed life stage transition conceptual models. It was developed following recommendations by the FLaSH Panel (FLaSH Panel 2012) and extensive reviews of a draft version of this report (see http://www.water.ca.gov/iep/pod/mast.cfm and Appendix A). In Chapter 4 we review and synthesize existing information about drivers, habitat attributes, and Delta Smelt responses with a focus on new information since 2010. We use the drivers in the basic POD conceptual model as the basis for this synthesis. This information is then used to populate the nested conceptual models in the new conceptual model framework with key drivers and their linkages to Delta Smelt responses. The fully populated nested conceptual models are presented in Chapter 5. Chapter 6 focuses on Delta Smelt life history and population dynamics and trends. Chapters 4 and 6 include some new analyses of long-term monitoring data, but are largely based on a review and synthesis of the existing published literature. In Chapter 7, we compare data pertaining to ecosystem drivers (drivers), habitat attributes (drivers or outcomes) and Delta Smelt responses (outcomes) in four recent years with moderate to wet hydrology: the two most recent wet years (2006 and 2011) and the two drier years immediately before them (2005 and 2010). The intent is to assess the utility of the conceptual model for formulating and testing hypotheses that expand the comparative FLaSH approach (Brown et al. 2014) that focused on the fall to a more comprehensive year-round investigation of why Delta Smelt abundance increased in the wet year of 2011, but failed to respond to wet conditions in 2006. In each of the sections in Chapter 7 covering a specific life stage, the hypotheses inherent in the conceptual model are stated and the reasoning for including each hypothesis is explained. Although we attempted to develop independent hypotheses, this was not always possible because many drivers were related and important habitat attributes were influenced by multiple drivers and their interactions, as shown in the conceptual model diagrams and explored in Chapter 4.

Key insights from Chapters 4–7 are summarized in Chapter 8. In Chapter 8, we also discuss limitations of the analytical approaches in this report. In Chapter 9, we describe additional data and analyses needed to test hypotheses that could not be conclusively tested with the available data and our simple comparative analysis approach. We also present some ongoing or possible next steps for future years, including some recommendations for future synthesis and mathematical lifecycle modeling efforts aimed at Delta Smelt and other species and for future adaptive management, including the fall outflow adaptive management and FLaSH studies effort.

Framework for the Delta Smelt Conceptual Model

The updated Delta Smelt conceptual model framework in this report integrates and modifies features of the “basic” and “species specific” POD conceptual models (Baxter et al 2010), the FLaSH conceptual model (Brown et al. 2014), the DRERIP “transition matrix” conceptual models (DiGennaro et al. 2012), and the hierarchical conceptual model in Miller et al. (2012). It consists of two nested and linked conceptual models of increasing specificity:

1. A *general life cycle conceptual model* for the four Delta Smelt life stages (adults, eggs and larvae, juveniles, and subadults) that includes stationary landscape attributes and dynamic environmental drivers, habitat attributes, and Delta Smelt responses; and

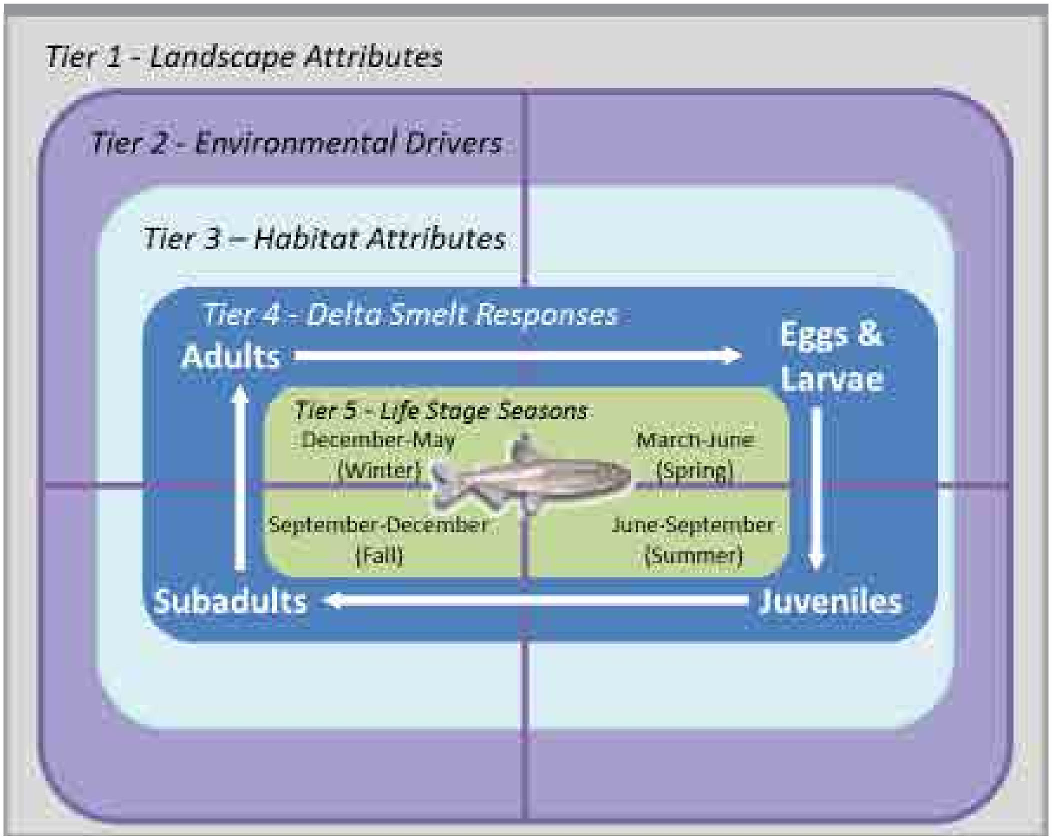
2. More detailed *life stage transition conceptual models* for each of the four Delta Smelt life stages that describe relationships between environmental drivers, key habitat attributes, and the population-level probability of successfully transitioning from one life stage to the next. This probability is dependent on the effects of environmental drivers and habitat attributes on the growth, survival, reproduction, and movements of Delta Smelt but data are currently inadequate to provide causal links for most of these processes individually.

General Life Cycle Conceptual Model

The updated general life cycle conceptual model for Delta Smelt (Fig. 8) follows the FLaSH Panels (2012) recommendation to “ensure Delta Smelt vital rates remain central to thinking” and is structurally similar to the basic POD conceptual model (Fig. 6). The general life cycle conceptual model is divided vertically and horizontally into four sections representing four Delta Smelt life stages from eggs and larvae to adults occurring in four “life stage seasons” indicated in the center of the diagram (Fig. 8; tier 5 box, green shading). This is similar to the four seasonal compartments of the species-specific conceptual model diagram in Baxter et al. (2010). Importantly, these life stage seasons are not exactly the same as calendar-based seasons. Instead, they have somewhat variable duration and overlapping months. This is because life stage transitions from eggs to adults are gradual and different life stages of Delta Smelt often overlap for a period of one to three months. Delta Smelt responses (Fig. 8; tier 4 box with dark blue shading) to important habitat attributes throughout their usually annual life cycle are placed within a box representing habitat attributes important to their growth and survival, which conveys the idea that biotic and abiotic habitat elements drive Delta Smelt responses (Peterson 2003; Fig. 8; tier 3 box with light blue shading). For each life stage season, there are a set of natural and anthropogenic environmental drivers associated with the estuarine environment (Fig. 8; tier 2 box with purple shading) that generate the habitat attributes important to Delta Smelt growth and survival. Surrounding the environmental drivers box is a fourth, outer box that represents the stationary (geographically and temporally fixed) landscape attributes of the estuarine ecosystem associated with its physical geometry and the orientation and connections of its component waterbodies (Fig. 8; tier 1 box with grey shading). In contrast to this outer box, the components and processes described in the inner boxes of this conceptual model are dynamic in space and time. Note that the fixed landscape attributes are considered fixed in the context of Delta Smelt population biology in any particular year rather than across longer time scales. The different spatial and temporal scales for each tier of the conceptual model are shown in Figure 9.

The tiered components of the general life cycle conceptual model for Delta Smelt can vary over a wide range of spatial and temporal scales (Fig. 9). Landscape attributes of the San Francisco Estuary (tier 1) encompass local to estuarine-wide features and change slowly over decades or longer periods. Environmental drivers (tier 2) that affect Delta Smelt habitat attributes vary and manifest over the broadest range of spatial and temporal scales, from local variations over tidal or daily cycles to long-term changes at the watershed or even larger geographic scales. Similar to environmental drivers, habitat attributes of Delta Smelt (tier 3) can be highly dynamic at small spatial and temporal scales or change gradually over many years, but they don’t extend beyond the geographic range of the species, which in the case of Delta Smelt is the SFE. Delta Smelt responses (tier 4) vary in response to changing habitat attributes within subregions of the estuary. In this small fish species with its maximum age of two years and extremely small geographic range, population-level responses can range from rapid (e.g., in response to toxic spills) to more

Figure 8. **A new conceptual model for Delta Smelt showing Delta Smelt responses (dark blue box) to habitat attributes (light blue box), which are influenced by environmental drivers (purple box) in four "life stage seasons" (green box). Environmental drivers are influenced by landscape attributes (grey box).**



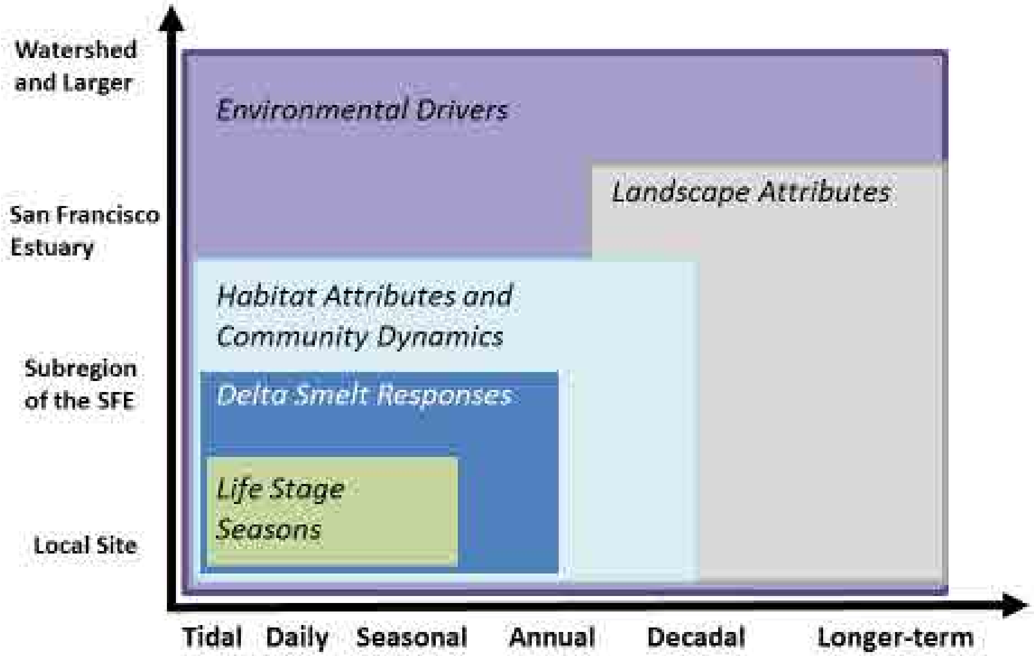
slowly over the course of one or more years. Life stage seasons (tier 5) occur over the course of a year in seasonally occupied areas of the estuary.

Similar to the POD and DRERIP conceptual models, the updated Delta Smelt life cycle conceptual model includes only those landscape attributes and environmental drivers with plausible mechanistic linkages to outcomes, which in this case are changes in habitat attributes and resulting Delta Smelt responses in the four life stage seasons. These mechanistic linkages are depicted as arrows in a series of four new conceptual models for each life stage season (Fig. 10). These life stage season conceptual models are nested components of the general life cycle conceptual model as shown in Fig. 8. They will be described in detail in Chapter 5.

Data Sources

Our examination of environmental drivers in Chapter 4, Delta Smelt life history and population dynamics and trends in Chapter 6, and the evaluation of hypotheses about Delta Smelt responses to changing habitat attributes in Chapter 7 rely largely on results of previously published data and analyses, but in several cases we update these analyses with more recent data. We also include some additional analyses (described below). All these analyses depend largely on environmental monitoring data collected by IEP agencies during routine, long-term monitoring surveys

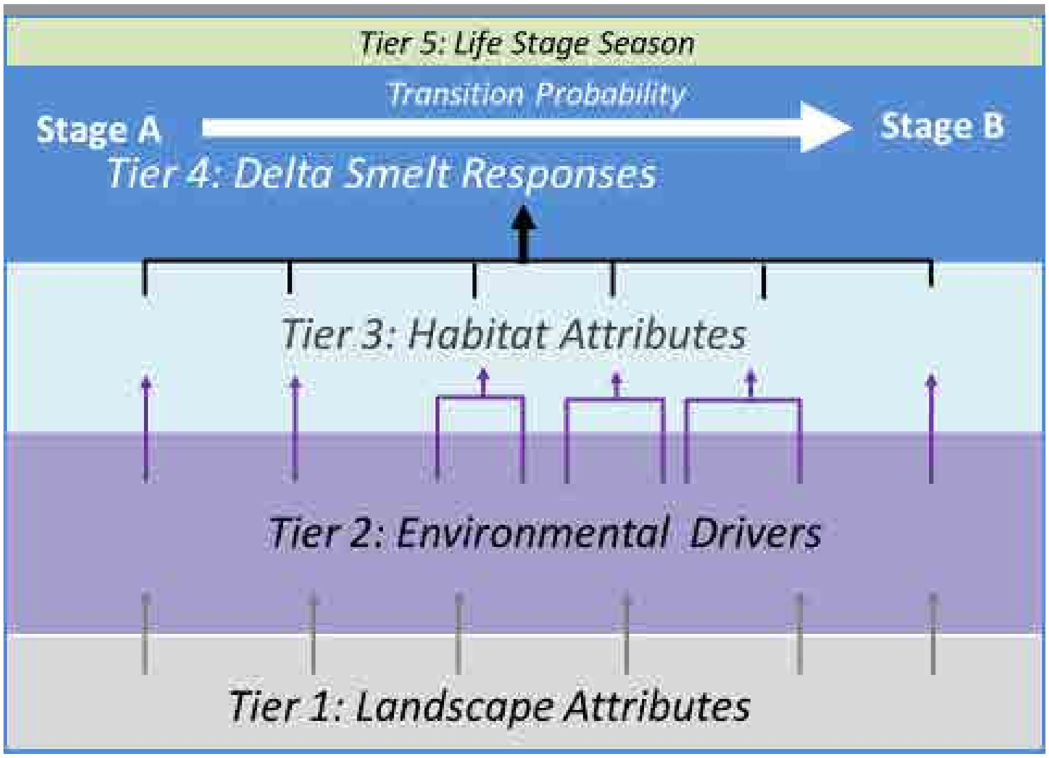
Figure 9. **Spatial and temporal scales of the component tiers in the general life cycle conceptual model framework for Delta Smelt.**



(http://www.water.ca.gov/iep/products/data.cfm). These surveys provide the long-term records and geographic coverage necessary and the data collected by these surveys are publicly available. Available data includes data on fish, invertebrates, phytoplankton, water quality variables, and flow. Use of these particular data sources does not reflect any preference for those data. Results from other ongoing research efforts were included as appropriate.

For the purposes of this report, we consider each stage, larvae through adults, of the Delta Smelt life cycle in the context of the monitoring programs that provide data on the Delta Smelt population. Delta Smelt eggs are not monitored and have in fact never been found in the wild. Monitoring surveys in the late winter and spring include the spring Kodiak trawl (SKT, Fig. 11), which samples maturing, spawning and post-spawning adults. The SKT is conducted monthly from January through May. Spring also includes the 20 mm survey (20 mm, Fig. 12), which samples larval and post-larval Delta Smelt and is conducted every two weeks from mid-March through mid-July. Summer includes the summer townet survey (TNS, Fig. 13); which samples juvenile fish and currently runs every two weeks from June through August. The Fall Midwater Trawl (FMWT, Fig. 14) survey samples subadult Delta Smelt monthly from September through mid-December. Each of these surveys samples fishes broadly within the upper SFE and generally covers the geographic habitat range used by Delta Smelt (Merz et al. 2011). Exceptions to complete coverage occur in some high outflow years when Delta Smelt can temporarily inhabit San Pablo Bay in association with decreased salinities caused by increased Delta outflows (Moyle 2002) and in other years when some adult fish move upstream of the geographic range of these surveys (probably to spawn) in the Yolo Bypass and Sacramento River (e.g., Feyrer et al. 2006, Merz et al. 2011). Also, FMWT and TNS sampling in the Cache Slough complex was instituted over several years starting in the 1990s for FMWT and 2000s for TNS. The current sampling locations have been in place since 2011. These exceptions to complete spatial coverage are believed to reflect small fractions of the population. Additional geographic coverage along

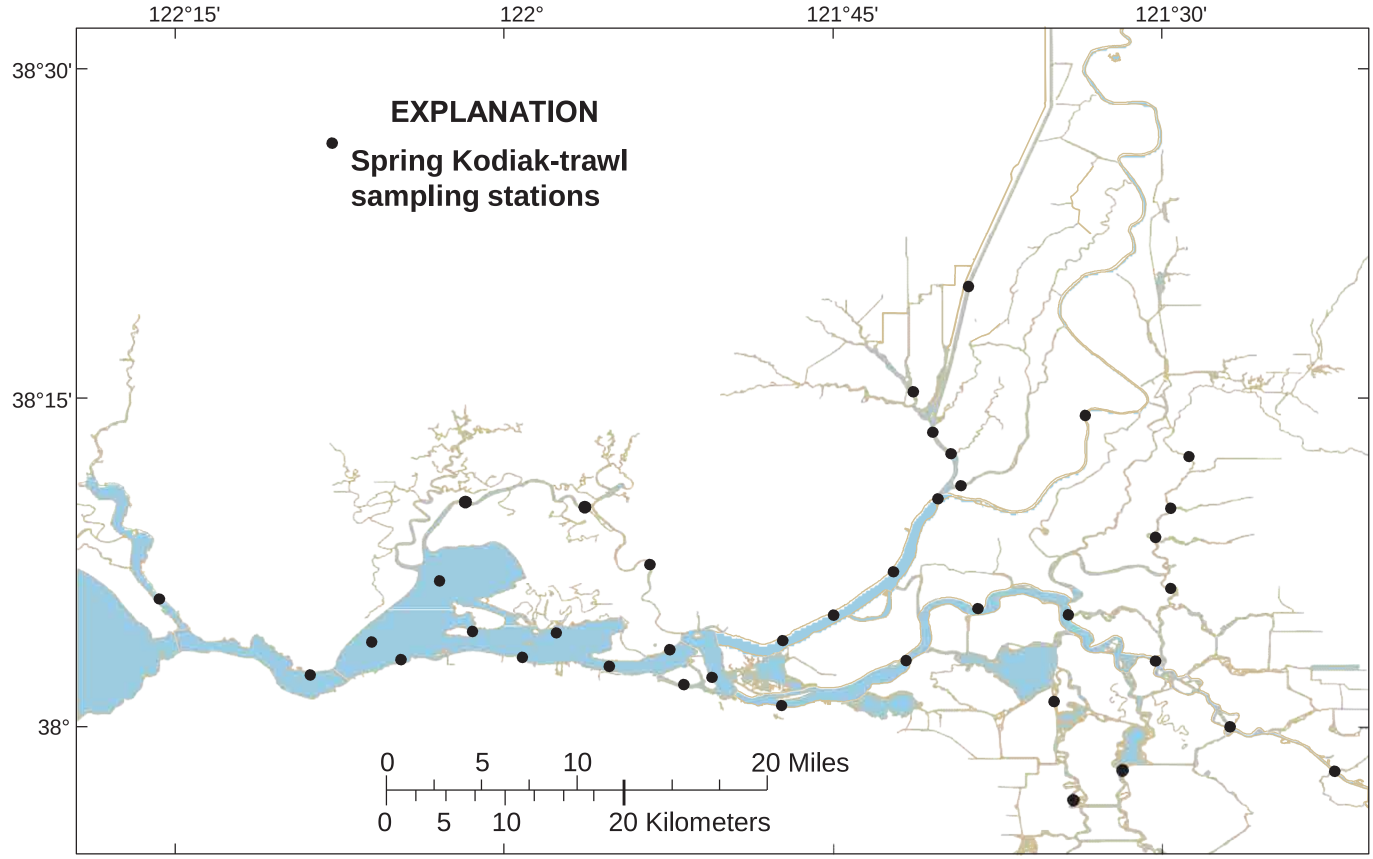
Figure 10. **Framework for the Delta Smelt life stage season conceptual models.**



or outside of the margins of the other four monitoring surveys is provided by other IEP fish monitoring surveys such as the San Francisco Bay Study, trawling and seining conducted by the Delta Juvenile Fish Monitoring Program in the Sacramento River and the north Delta, as well as the fish salvage monitoring at the fish protection facilities associated with the SWP and CVP export pumps in the south Delta. All Delta Smelt life stages (larvae-adult) are also commonly collected from nearshore habitats and in shallow open water where trawls cannot be used effectively (e.g., Aasen 1999, Nobriga et al. 2005, Brown and May 2006); however, there are no data indicating these are preferred habitats, that these fish represent different populations (see Fisch et al. 2011), or that their abundance varies differently than data from the aforementioned trawl surveys would suggest.

Annual abundance indices for Delta Smelt life stages are calculated from the catch data provided by each of the four surveys (See Appendix B for details). Together, they provide a comprehensive account of long-term changes in the relative abundance of Delta Smelt (Fig. 3). The long series of abundance index records for the summer and fall have provided the basis for many data analyses and modeling studies (e.g., Jassby et al. 1995, Kimmerer 2002a,b, Bennett 2005, Manly and Chotkowski 2006, Thomson et al. 2010, MacNally et al. 2010, Maunder and Deriso 2011, Miller et al. 2012) and for regulatory actions (USFWS 2008). They have also been used to estimate absolute population abundance (Newman 2008). The Delta Smelt and other SFE fish abundance indices are generally considered useful indicators of the status and trends of the Delta Smelt population as well as of the status of other resident fishes in the SFE in general and serve as performance metrics for the success of management actions. All monitoring surveys have strengths and weaknesses, and the long-term fish monitoring programs in the SFE are no exception (Honey et al. 2004). In the case of Delta Smelt, strengths include reasonably good coverage of the geographic extent of Delta Smelt habitat and coverage of all life stages except

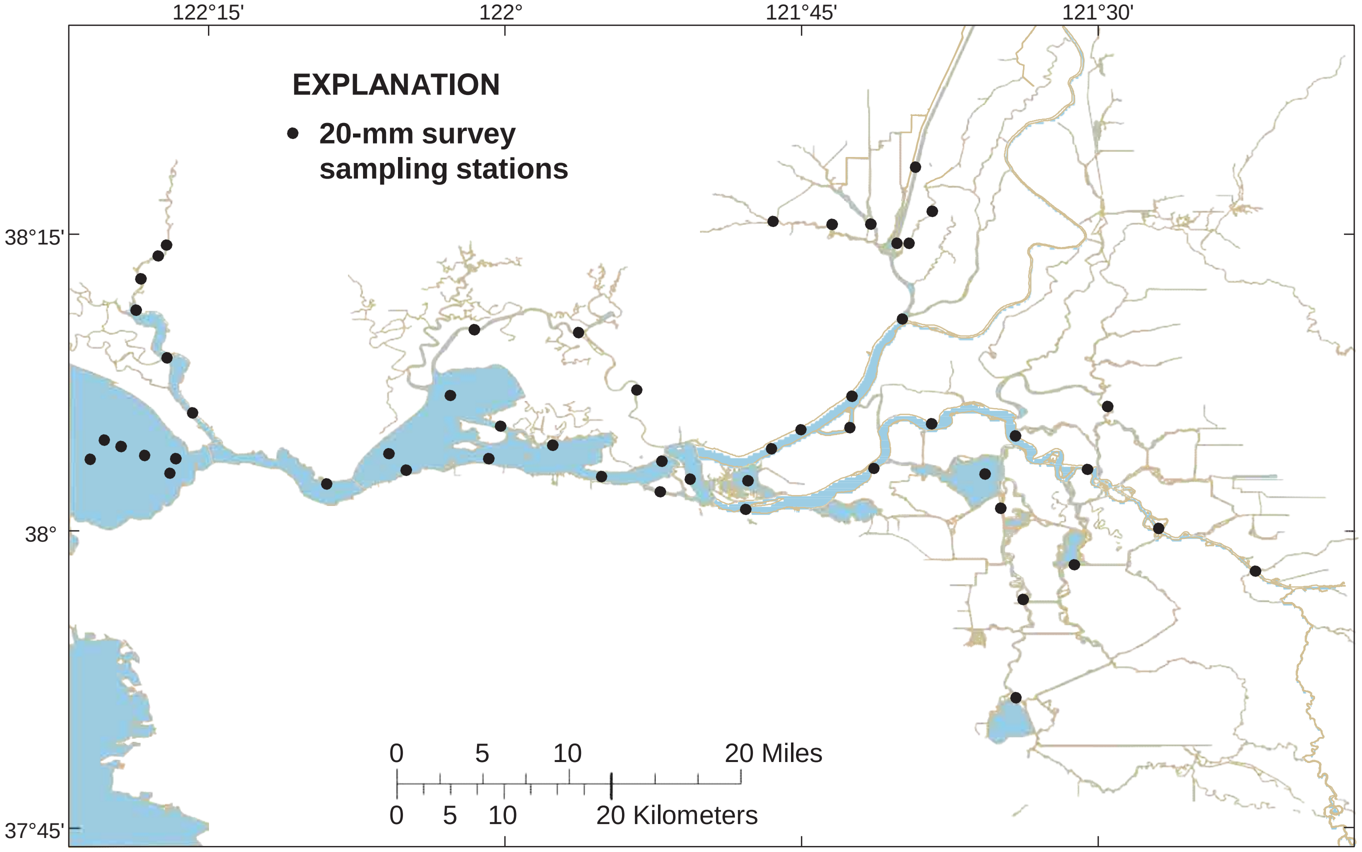
Figure 11. Map of Spring-Kodiak Trawl Survey sampling stations.



eggs (Gaines et al. 2006). They also include exceptionally long and consistent data records going back to 1959 in the case of the TNS, the oldest of the four surveys described here. There is a large amount of ancillary data (covariates), including data collected during the fish surveys, additional fish data from other monitoring surveys (Honey et al. 2004) as well as invertebrate, phytoplankton, water quality and hydrological data. Possible weaknesses include no measure of precision of abundance indices and imprecise estimates due to a high frequency of zero catches of Delta Smelt. These problems combine with survey design issues such as differences in Delta Smelt catchability with different nets and trawl regimes under changing environmental conditions, behavioral changes in distribution (Newman 2008) and the current low abundance of the species. For example, several studies have shown that Delta Smelt can exhibit lateral and vertical movements associated with tide and time of day (Bennett et al. 2002, Feyrer et al. 2013, Bennett and Burau 2014) but the overall frequency or effects of such local movements on abundance indices are unclear. Studies to further evaluate and address these issues are currently underway.

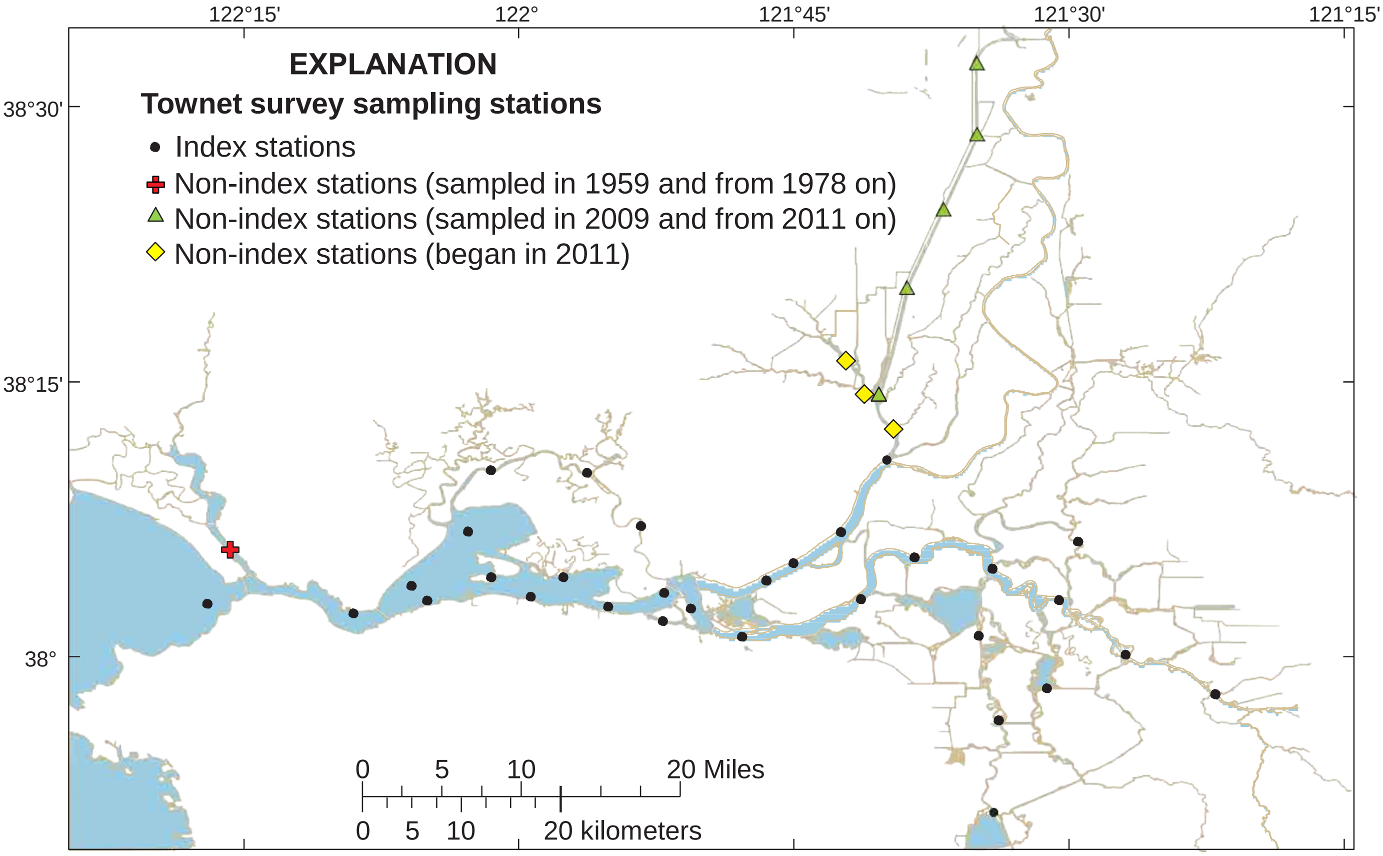
Two of the four fish monitoring surveys described here specifically target Delta Smelt; the other two do not. The SKT was designed and implemented specifically to improve detection of maturing adult Delta Smelt moving upstream in the winter and spring, particularly into the central and south Delta (Souza 2002). The 20 mm survey was designed and implemented specifically to capture late-stage larval Delta Smelt of about 20 mm in length; the SKT and 20 mm survey data help managers assess the risk of entrainment of these life stages by south Delta

Figure 12. **Map of 20 mm Survey sampling stations.**



export pumps (Dege and Brown 2004). The TNS was designed to target small juvenile Striped Bass of about 17-50 mm fork length (the distance from the snout to the indentation of the tail fin) (Stevens 1977, Turner and Chadwick 1972); however, Delta Smelt tend to be of appropriate size for capture by the TNS net during the survey period. This occurs because Delta Smelt (see below) and Striped Bass spawning overlaps in time and growth of both are linked to water temperature, such that peak larval abundance occurs in April or May in most years. The TNS traditionally started and ended based on mean length of Striped Bass; however, young Delta Smelt attain sizes vulnerable to the TNS net during the same time period Striped Bass are vulnerable (Miller 2000). The survey ends when young Striped Bass surpassed 38 mm fork length (Miller 2000). Thus, regardless of the particular number of sampling surveys in a year or the index calculation method, Delta Smelt juveniles are generally vulnerable to the TNS whenever it samples. Similarly, the FMWT survey was designed to capture young-of-the-year Striped Bass, but in the 60-140 mm fork length size range (Stevens 1977). Although the survey and gear is generally effective for small pelagic fishes, the cod-end mesh (1.3 mm stretch mesh) on the net is large enough to allow some smaller sub-adult Delta Smelt to escape during the first couple survey months (see Newman 2008 for an approach to correct this effect). Even though the gear is not completely effective at retaining all sub-adult Delta Smelt, FMWT provides a reasonable relative measure of sub-adult abundance through time (Kimmerer and Nobriga 2005), albeit with low precison at the current low catch levels and given additional variation related to changes in growth, and thus changes in retention in the net from year to year. With the aforementioned caveats, we believe these surveys provide useful and valid relative abundance measures to examine the various life stage transition

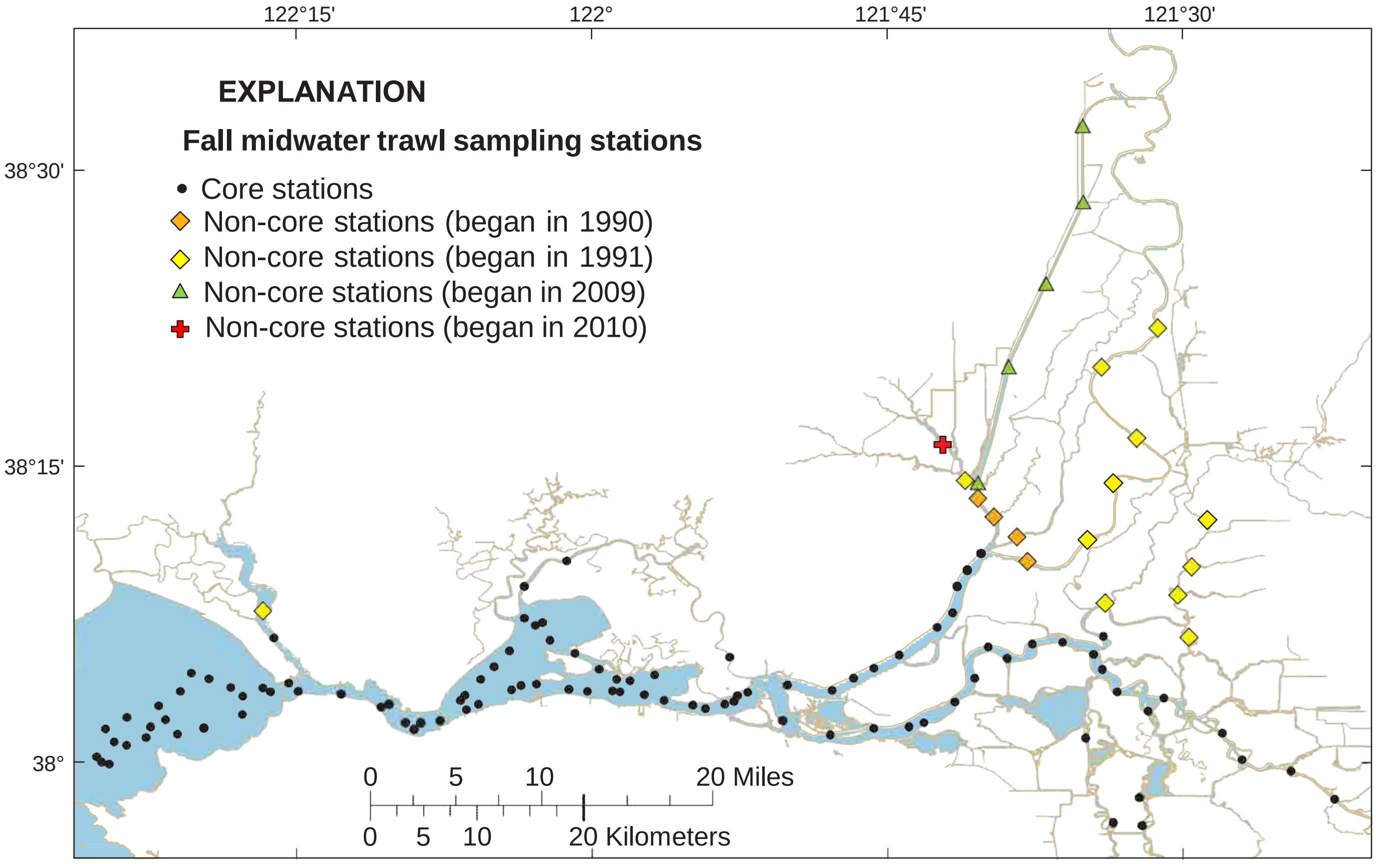
Figure 13. Map of Summer Townet Survey sampling stations.



relationships described in this report as well as in many of the previously published studies cited in this report.

In addition to the annual abundance indices for Delta Smelt provided by the monitoring surveys described above, we also present annual indices of recruitment and survival. In this report, a survival index is simply the ratio of an abundance index for a particular life stage divided by the abundance index for a preceding life stage of the same Delta Smelt cohort. A recruitment index is the ratio of an abundance index for a particular life stage divided by an abundance index for a life stage of the preceding Delta Smelt year-class. These types of indices have been used in previous analyses (e.g. Miller et al. 2012), but it is important to note that they may compound the observation errors inherent in the annual abundance indices in complicated ways. This is likely more problematic for survival and recruitment indices that use the TNS and FMWT abundance indices because these surveys were not specifically designed to target Delta Smelt. It may be less problematic for the recruitment index calculated by dividing the 20 mm abundance index for larval and post-larval Delta Smelt by the preceding SKT abundance index for adult Delta Smelt because both surveys specifically target Delta Smelt. We use this recruitment index in some additional analyses included in this report. All other survival and recruitment indices are only used as a rough approximation and illustration of differences in recruitment and survival rates among different annual cohorts and life stages; they are not used for additional analyses.

Figure 14. Map of Fall Midwater Trawl Survey sampling stations.



Data Analysis

As noted previously, we review long-term trends in this report using published results, but in some cases include some additional analyses of long-term monitoring data (Chapters 4 and 7). These analyses are kept deliberately simple, for example, simple graphical explorations of time series, examinations of simple statistics such as medians and arithmetic means, and investigation of univariate relationships using simple correlation and least squares regression analyses. Such analyses are readily reproducible with the publicly available data described above. The purpose of presenting the results of these new analyses is to update previously published information with the most recent data. In many cases, the data presented in this report are summarized using boxplots. The center horizontal line in each box represents the median of the data. The upper and lower ends of the box represent the upper and lower quartiles of the data. These are also known as “hinges.” The “whiskers” are the lines extending above and below the box. The whiskers show the range of values falling within 1.5 times the inter-quartile distance from the nearest hinge. Values outside this range are shown as individual symbols. Asterisks denote values within 1.5 to 3.0 times the inter-quartile distance and circles denote values greater than 3.0 times the inter-quartile distance. Other types of plots are explicitly identified in the figure caption.

Some graphs and analyses refer specifically to the POD period. Analyses suggest the POD period started as early as 2002 or as late as 2004 (Thomson et al. 2010). We somewhat arbitrarily selected 2003-present as the POD period for this report. This period is not being recommended as the baseline for management agencies to use when considering recovery of Delta Smelt. The time period simply reflects the consistently low level of Delta Smelt abundance in recent years and a useful baseline for identifying years with improved Delta Smelt abundance indices, which would indicate improved environmental conditions for Delta Smelt. Similarly, we also consider the 1982-2001 period between the two major step declines in Delta Smelt abundance identified by Thomson et al. (2010) separately in some graphs and analyses. Finally, some graphs and analyses refer to calendar years while others refer to water years. In California, a water year starts on October 1 and ends on September 30 of the next calendar year. California water year classifications are based on calculations of annual unimpaired runoff, which represents the natural water production of a river basin, unaltered by upstream diversions, storage, and export of water to or import of water from other basins.

In Chapter 7, we explore a series of hypothesized driver-outcome linkages using a comparative approach. The purpose is to demonstrate the utility of our conceptual model framework for generating hypotheses about the factors that may have contributed to the 2011 increase in Delta Smelt abundance. Specifically, we compare Delta Smelt responses to habitat conditions in four recent years with moderate to wet hydrology: the two most recent wet years (2006 and 2011) and the two drier years immediately before them (2005 and 2010). This comparative approach and data sources (described in Chapter 4) are deliberately similar to the comparative approach used in the FLaSH investigation (Brown et al. 2014). This approach allows us to place the results of the FLaSH investigation in a year-round, life cycle context and to more comprehensively evaluate factors that may have been responsible for the strong Delta Smelt abundance and survival response in 2011, including any possible relevant antecedent conditions from 2010. We attempt to draw comparisons with a similar set of data collected during 2005 and 2006. Our working assumption is that different Delta Smelt abundances in 2006 and 2011 should be attributable to differing environmental conditions, in some cases attributable to management actions, and subsequent ecological processes affecting the Delta Smelt population.

In Chapter 9 we briefly describe three examples of additional mathematical modeling approaches that can be used to further explore some of the linkages and interactions in our conceptual models and complement previously published and other ongoing mathematical modeling efforts for Delta Smelt. Importantly, results from the three modeling examples in Chapter 9 are included for illustrative purposes only; peer-reviewed publications of these analyses need to be completed before they can be used to draw firm conclusions.

Chapter 4: Environmental Drivers and Habitat Attributes

The general approach of this Chapter is to focus on how environmental drivers and interactions among them create habitat attributes of importance to Delta Smelt. Specifically, we review and synthesize existing information about drivers and habitat attributes and Delta Smelt responses to habitat attributes with a focus on new information since Baxter et al. (2010). We use the drivers and habitat attributes depicted in the basic POD conceptual model (Fig. 6) as the basis for this synthesis. We consider habitat attributes important when there are published studies suggesting ecological responses by Delta Smelt. Each section focuses on a habitat attribute that can be the outcome of one or more environmental drivers. Physical habitat attributes are presented first, followed by biological habitat attributes. The order of presentation does not imply any kind of ranking of relative importance. For simplicity, we consider all habitat attributes discussed here as equally important because, as noted in Chapter 2, habitat arises from the combination of *all* physical and biological attributes affecting a species. We fully acknowledge that as Delta Smelt research proceeds and the system continues to change, additional habitat attributes my need to be added to the conceptual model, while others may be deemphasized or even deleted.

Each section starts with the general importance of a specific habitat attribute for estuarine biota followed by a brief discussion of its linkages with environmental drivers and its dynamics in space and time. Each habitat attribute is then placed in the context of Delta Smelt biology.

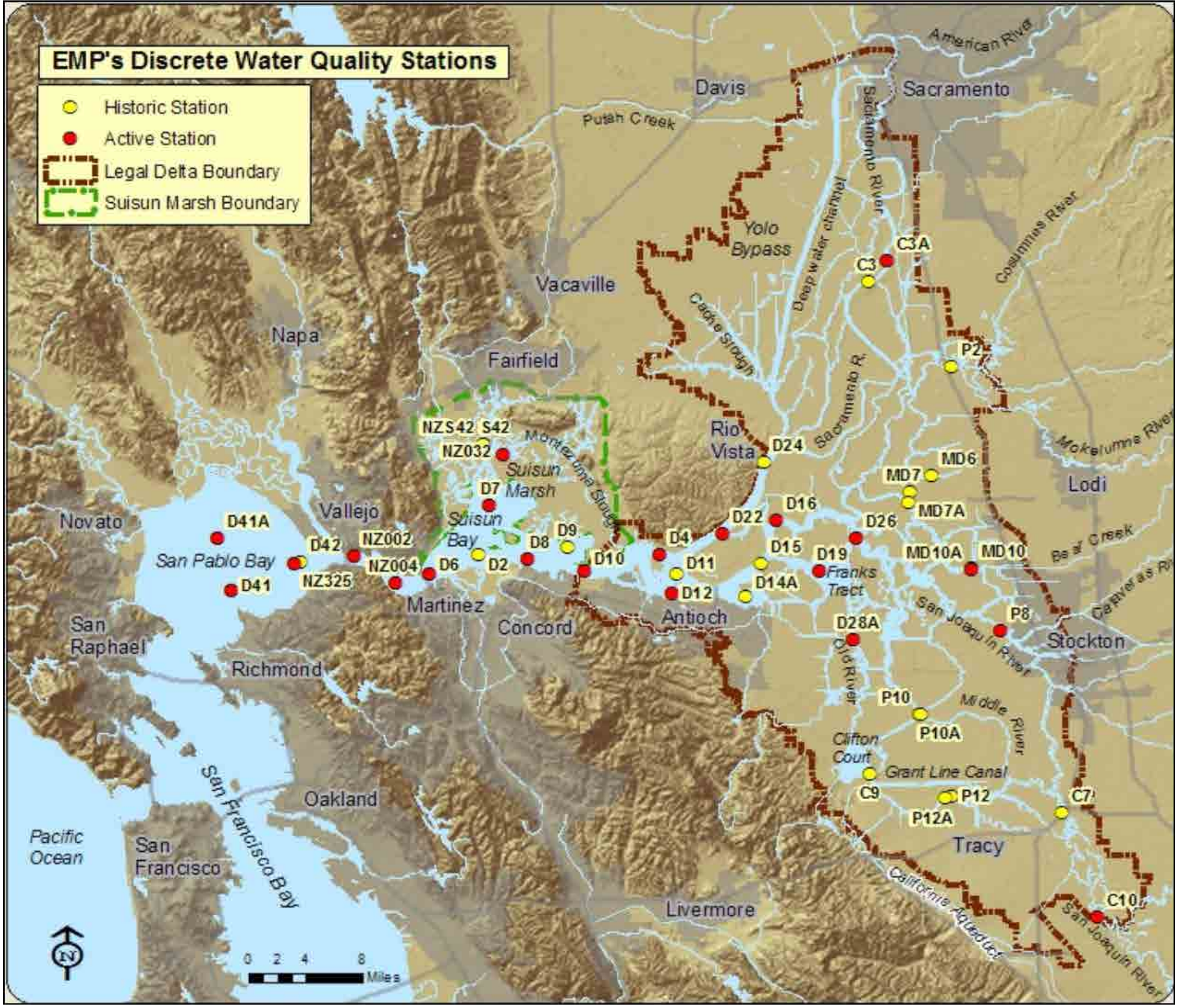
Water Temperature

Water temperature is fundamental to aquatic ecosystem health and function. It directly influences biological, physical, and chemical properties such as metabolic rates and life histories of aquatic organisms, dissolved oxygen levels, primary productivity, and cycling of nutrients and other chemicals (Vannote and Sweeney 1980, Poole and Berman 2001, Null et al. 2013). Water temperature is an important variable for ectothermic ("cold-blooded") animals, including all fishes and invertebrates in the SFE. In the most extreme case, when water temperature exceeds the thermal tolerance of an organism, it will die. Temperatures within the thermal tolerance of an organism control the rate and efficiency of many physiological processes, including activity, digestion, growth, reproductive development, and reproductive output. We return to these processes after giving an overview of water temperature variability and its drivers in the Delta.

Long term temperature records from selected sites in the SFE show substantial seasonal and daily fluctuations in water temperature (Kimmerer 2004). While daily variations are evident and likely important to organisms, seasonal variations are much greater (Wagner et al. 2011). Median water surface temperatures across all stations monitored by the IEP Environmental Monitoring Program (EMP) (Fig. 15) from 1975-2012 range from 9 °C in January (minimum: 6 °C) to 22 °C in July (maximum: 28 °C). There are also clear regional variations in water temperature (Fig. 16). In July and August, the hottest summer months, water temperatures are usually highest at monitoring stations in the south Delta (average 23-26 °C, maximum 28 °C), lower at stations in the northern and western Delta (average 21-23 °C, maximum 25 °C) and lowest at stations in Suisun and San Pablo Bays (average 19-21 °C, maximum 24 °C). In January, the coldest winter month, average water temperatures are uniformly below 10 °C in the entire Delta, but above 10 °C in San Pablo Bay.

There is currently little evidence for increasing water temperatures in the Delta, although with climate change such increases are expected over the course of the century (Cloern et al. 2011, Wagner et al. 2011, Brown et al. 2013). In Spring (March-June) water temperature at IEP EMP water quality monitoring stations in the Delta increased during 1996–2005 by about 0.2 °C per year, but a similar trend was not apparent for the longer-term data record from 1975-2005 or for stations in Suisun Bay (Jassby 2008). These findings are similar to the results of Nobriga et al. (2008) who found no long-term (1970-2004) trends in temperature data collected during summer fish monitoring surveys in the Delta. Nobriga et al. (2008) also noted that the long-term (1970-2004) mean July water temperature at TNS fish monitoring stations in the southern region of the Delta is 24 °C, with current mid-summer temperatures often exceeding 25 °C. This agrees with average monthly EMP data from 1975-2012 which shows July and August water temperatures at

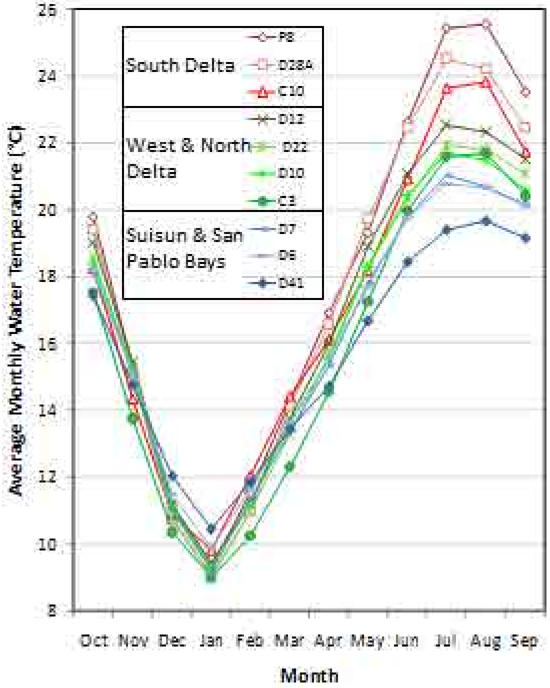
Figure 15. Map of active and historic IEP Environmental Monitoring Program (EMP) sampling stations.



a monitoring station located in Old River (station D28A) and in the San Joaquin River near the Port of Stockton (station P8) of more than 24 °C and 25 °C, respectively (Fig. 16).

In tidal systems, water temperature at a particular location is determined by the interaction between atmospheric forcing (e.g., air temperature and wind), tidal dispersion and riverine flows across the estuarine landscape (Monismith et al. 2009). In particular, estuarine water temperature is driven by heat exchange at the air–water interface and mediated by tidal and riverine flow dynamics and estuarine geomorphology (Enright et al. 2013). Wagner et al. (2011) found that regional weather patterns including air temperature and insolation (sunlight), are the primary drivers of water temperature variations in the SFE. Water flow and interaction with the stationary topography of the system also affects water temperature in the SFE, especially over shorter time scales and at smaller spatial scales. For example, Enright et al. (2013) showed that interaction

Figure 16. **Average monthly water temperature for stations monitored by the Environmental Monitoring Program from 1975-2012.**



of tides with tidal marsh topography can have a mediating effect on water temperature in tidal sloughs and on thermal variability at smaller spatial scales. Wagner et al. (2011) showed that high winter and spring flows can temporarily lower water temperatures. Greenberg et al. (2012) found that the present riparian vegetation on Delta levees lowers insolation by about 9% compared to a hypothetical situation without vegetation and suggested that riparian vegetation thus contributes to locally cooler water temperatures. This suggests that at least to some degree, water temperature can be managed locally and for short periods. Over larger scales, however, these types of locally mediated effects are overwhelmed by the effects of air temperature and insolation.

Air temperature and insolation in the SFE are correlated with each other (Wagner 2012) and vary strongly with proximity to the Pacific Ocean because of the contrasting climate regimes prevailing in inland central California and the central California coast. While inland central California has a large annual air temperature range with hot, dry, sunny summers and cool, wet, and often foggy winters, the central California coast has a smaller annual air temperature range with cooler and often foggy summers and milder winters (Conomos et al. 1985). The SFE has a transitional climate with greater spatial and temporal variability in air temperature than either the coastal or the inland regions (Whipple et al. 2012). This is due to the interplay of the dynamic air masses from these regions across the stationary estuarine topography. In the summer, this interplay often results in strong afternoon winds from the ocean locally known as the “Delta breeze.” These onshore winds usually advance into the western and central Delta and, depending on the depth of the marine layer, often also into its marginal areas. In the Delta, these southwest to northeast winds can persist throughout the night and into the next morning and produce a marked decline in daily temperature. In the morning, this low is often followed by rapid warming once the winds subside and the high temperature inland air masses return to dominance (National Weather Service 2003). In the winter, ocean winds are weak and, during calm periods, cold air flows from the mountains into the estuary. This results in the formation of dense, overnight, near-surface fog locally known as “tule fog.” These calm and foggy periods are interrupted by winter storms. Many of these storms arrive from the south and southeast as “atmospheric rivers” that can often produce gale force winds and heavy rains lasting several days (Conomos et al. 1985, Dettinger and Ingram 2013).

The large variability in air temperature in the Delta is reflected by the larger annual variability in water temperature measured from 1998-2002 at continuous monitoring stations in the interior Delta compared to stations further upstream or downstream (Wagner et al. 2011). This high variability is also apparent in monthly water temperature data collected by the IEP Environmental

Monitoring Program since 1975 (Fig. 11). From 1975 to 2012, annual fluctuations in average monthly water temperature were greatest at stations in the south Delta (14-16 °C), smaller at stations in the northern and western Delta (12-13 °C), and lowest at stations in Suisun and San Pablo Bays (9-12 °C). Jassby (2008) reported that maximum daily air temperature could explain almost half the variability in maximum daily water temperature at the continuous monitoring station at Antioch during the summer months. The relationship between air and water temperature was also strong in all other months except January.

Wagner et al. (2011) and Wagner (2012) developed simple regression models for predicting water temperature at fixed temperature monitoring stations in the SFE using only air temperature and insolation on the day of interest and the water temperature from the previous day. Water temperature from the previous day accounts for both previous air temperature and the sources of water to the site, including advective flow from rivers or dispersive flow from more downstream reaches of the SFE. Each model had a different set of coefficients because of the differing influences of incoming river water or tidal exchange with San Francisco Bay. For stations with greater than 1 year of calibration data, model R^2 for daily average temperature exceeded 0.93, indicating that water temperature was highly predictable within the limits of the calibration data sets. High winter and spring flows were responsible for the largest divergences of the model outputs from measured temperatures.

The simple statistical models for water temperature developed by Wagner et al. (2011) and Wagner (2012) should be used with caution because they only predict temperature at the site of the recording instrument and do not explicitly account for mechanistic heat exchange. The analyses therefore do not incorporate the possible effect of site-specific features such as shading by riparian vegetation (Greenberg et al. 2012). Similarly, there are lateral and vertical variations in temperature on daily time scales (Wagner 2012) that could be important to organisms. For example, such variation might include substantial heterogeneity and formation of thermal refugia, which may be important to Delta Smelt.

In contrast to statistical modeling, which produces site-specific results, water temperature across regions is commonly modeled with computation-intensive deterministic simulation models. Such models use energy budgets to predict water temperature. Simple stochastic models are also possible. Like most statistical models, these stochastic models generally rely on the relationship between air and water temperature (Caissie 2006, Null et al. 2013). We are not aware that these types of models have been developed for the San Francisco Estuary.

Upper temperature limits for juvenile Delta Smelt survival are based on laboratory studies and corroborated by field data. Interpretation of the laboratory results is somewhat complicated as temperature tolerances can be affected by various factors including acclimation temperature, salinity, turbidity, and feeding status. Based on the critical thermal maximum, CT_{max}, juvenile Delta Smelt acclimated to 17 °C could not tolerate temperatures higher than 25.4 °C (Swanson et al. 2000). However, for juvenile Delta Smelt acclimated to 11.9, 15.7 and 19.7 °C, consistently higher CT_{max} were estimated (27.1, 28.2 and 28.9 °C, respectively; Komoroske et al. 2014), which corresponded closely to the maximum water temperatures recorded in the TNS and FMWT surveys. Swanson et al. (2000) used wild-caught fish, while Komoroske et al. (2014) used hatchery-reared fish, which may have contributed to the differences in results. Based on the TNS (Nobriga et al. 2008) and the 20 mm Survey (Sommer and Mejia 2013), most juvenile Delta Smelt were predicted to occur in field samples when water temperature was below 25 °C. In a multivariate autoregressive modeling analysis with 16 independent variables, MacNally et al. (2010) found that high summer (June – September) water temperature had a negative effect on Delta Smelt subadult abundance in the fall. Water temperature was also one of several factors affecting Delta Smelt life stage dynamics in the state-space model of Maunder and Deriso (2011) and in an individual-based Delta Smelt life-cycle model (Rose et al. 2013a,b).

In addition to lethal effects, water temperature also has direct effects on the bioenergetics (interaction of metabolism and prey density) of Delta Smelt (Bennett et al. 2008) and it may affect their tolerance to other habitat attributes, such as toxicity (Brooks et al. 2012) and predation risk. Responses of different life stages of Delta Smelt to various temperature, salinity, and turbidity conditions are currently being further assessed as part of a larger UC Davis laboratory study about the “fundamental niche” of Delta Smelt (Komoroske et al. 2014, R. Connon et al., U.C. Davis, unpublished data).

The topic of bioenergetics is an important consideration in much of the remainder of this report, so we address it in more detail here. In general, the total metabolic rate of a fish will increase with temperature to an optimum temperature at which, given unlimited food, there is the maximum ability to grow and develop reproductive products (eggs or sperm) in addition to maintaining the basal metabolic rate required for survival, which also increases with temperature (Houde 1989, Hartman and Brandt 1995). As temperature increases beyond the optimum, metabolic rate continues to increase but physiological processes become less and less efficient and more energy is required just to meet the basal metabolic rate of the organism. Eventually, the metabolic rate begins to decline as temperatures approach the physiological limits of the organism and the basal metabolic rate can no longer be maintained.

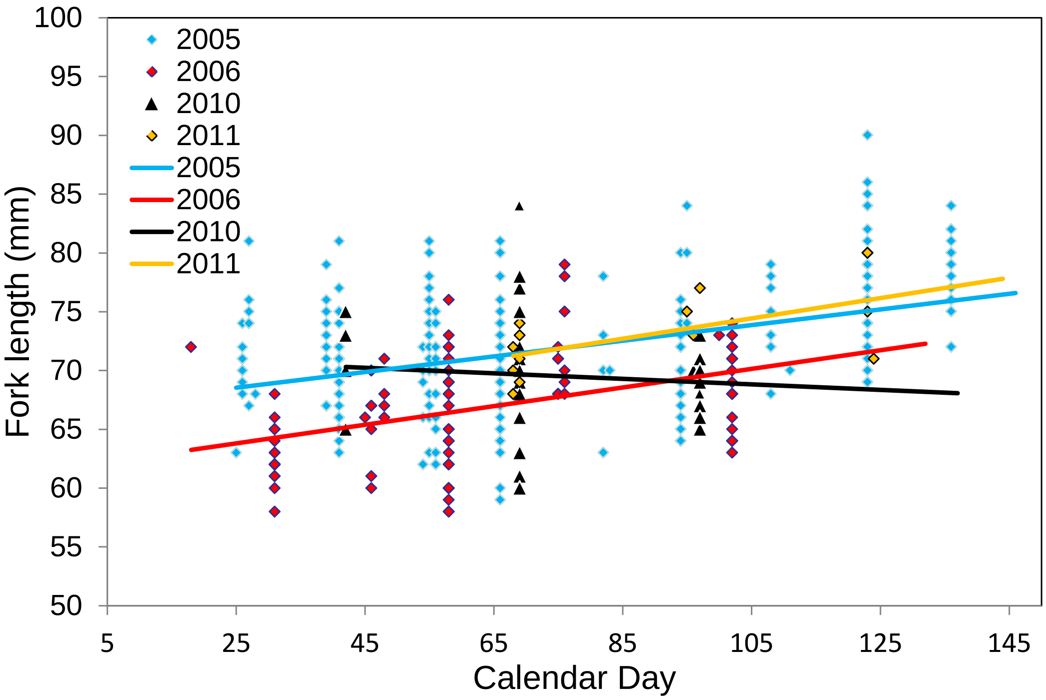
At temperatures beyond the optimum, the ability to grow and mature becomes increasingly impaired. Long-term exposure to such stressful temperatures can eventually be lethal. In addition, resistance to disease and contaminants can also be affected (Brooks et al. 2012). The responses to contaminants can vary depending on the type of contaminant. For example, low temperatures can decrease the toxicity of organophosphate insecticides, but increase the toxicity of pyrethroid and organochlorine insecticides (Harwood et al. 2009), a characteristic that has been used in toxicity identification and evaluation (Weston and Lydy 2010). The previous discussion assumes unlimited food, which is unlikely to be the case for Delta Smelt or any organism in nature. Even at the optimum temperature, growth and reproductive development will depend on the quantity and quality (energy and nutrient content) of the food consumed. If the fish is unable to ingest enough food to meet its nutrient and energetic requirements, including the energy expended to capture and digest prey, it will starve, after first depleting any available energy stores (fat or muscle). Given an array of food items, fish will generally choose larger prey items. This is because the energy required to detect, chase, and capture multiple smaller prey that are equivalent in nutritional value to a single large prey item will, in many cases, exceed the energy required to capture the single prey item. Note that these same ideas apply to predatory fish that might consume Delta Smelt.

Water temperature is also thought to affect the number of eggs produced by female Delta Smelt. Egg production (i.e., fecundity) of the population is influenced not only by individual female size and number (Bennett 2005, DFW unpublished), but also by the duration of a temperature “spawning window” (Bennett 2005, Mac Nally et al. 2010), variously defined as: 15-20 °C by Bennett (2005); 7-15 °C by Wang (1986); and 12-15 °C by Baskerville-Bridges et al. (2004b). Bennett (2005) further stated that during cool springs this spawning window persists longer, allowing more cohorts to recruit. Given a sufficiently long spawning window, individual females may also repeat-spawn during the spawning season. This has been documented in culture (see Bennett 2005; J. Lindberg, U.C. Davis, personal communication 2013) and appears to occur in the wild as well (L. Damon, CDFW, written communication 2012). Lindberg (U.C. Davis, personal communication 2013) observed that most females in culture spawned twice, some spawned three times and a very small number spawned four times. Each spawning was separated by a 4-5 week refractory period during February through June when water temperatures remained within the spawning window. Though laboratory conditions may not necessarily be representative of conditions in the wild, ripe females ready to release their second complete batch of eggs and developing a third batch have been detected in the wild during March and April (i.e., mid-season) suggesting that three spawns are possible (L. Damon, CDFW, written communication 2012). Thus, a longer spawning window would allow more females to repeat spawn adding both additional cohorts hatching under different conditions, and multiplying the fecundity of each repeat spawner (i.e., increasing the total fecundity of the individual), and thus, the total fecundity of the population. Moreover, in culture, individual females continued to grow through the spawning season and become more fecund with each batch of eggs (J. Lindberg, U.C. Davis, personal communication 2013). In the wild, the size of mature females generally increases month to month through the spawning season (Fig. 17), suggesting a potential increase in fecundity with each batch, but this has yet to be confirmed for wild fish. However, in culture, fish hatched later in the spawning season (mid-May to mid-June) grew up to be smaller-sized adults that started spawning later and had progeny with lower survival than the progeny of fish hatched earlier in the season (Lindberg et al. 2013). These observations are consistent with the reproductive patterns suggested for the wild Delta Smelt population (Bennett 2011). Overall, the effect of a prolonged spawning season on Delta Smelt population size and dynamics would seem to be positive; however, there is some uncertainty.

In the culture experiments reported by Bennett (2005), temperature strongly influenced hatching success of eggs. Specifically, Bennett (2005) reported that optimal hatching success and larval survival were estimated to occur at 15–17 °C based on studies conducted at 10, 15, and 20 °C. The data indicated that as incubation and early rearing temperatures increased, size at hatching and size at first feeding linearly decreased, possibly because basal metabolism of the developing embryo used more energy leaving less for growth. Fish that hatch relatively late in the season may experience high temperatures at a small size, which may reduce larval survival by several possible mechanisms. First, small size would limit the size of food items that the larvae could ingest because of smaller mouth size (see Nobriga 2002). Temperature may also affect food type and availability as discussed below. Second, small larvae are likely vulnerable to a larger range of predators for a longer period compared to larger larvae (e.g., “stage duration hypothesis;” Anderson 1988). Third, these fish could be potentially more vulnerable to transport toward the CVP and SWP export facilities, when Old and Middle River (OMR) flow restrictions are lifted. Restrictions are lifted when the 3-day mean water temperatures in Clifton Court Forebay (CCF) reach 25 °C or by the end of June.

As explained above, higher water temperatures increase energetic requirements and thus the food requirements of fish. To meet the increased need for food, it is possible that Delta Smelt spend more time foraging during the day. Since greater foraging time during the day increases visibility to predators, and those predators would also increase their foraging rates at higher temperatures, the encounter rate of predator and prey would likely increase at higher water temperatures. The net effect could be an increase in Delta Smelt predation risk (e.g., Walters and Juanes 1993). High temperatures can also decrease antipredator behavior, as described for Sacramento River Chinook Salmon (*Oncorhynchus tshawytscha*) (Marine and Cech 2004). In other words, the fish may make a behavioral choice to feed, grow, and become less vulnerable to predators as rapidly as possible, even though the short-term predation risk might increase. Water temperatures in the upper SFE are usually highest from June to September and decline rapidly between October and December

Figure 17. Individual female fork lengths by calendar day for mature female Delta Smelt collected in the Spring Kodiak Trawl Survey, January through May, 2005, 2006, 2010 and 2011. These data include both monthly distribution survey fish and directed survey fish. The directed survey (which targeted smelt spawning areas) was discontinued after January 2010.



(Fig. 16). The reported optimal culture temperatures for Delta Smelt larvae and late-larvae are 16.4 ± 0.25 °C (Komoroske et al 2014). Moreover, the chronic lethal thermal maximum for Delta Smelt varies by life stage (Komoroske et al. 2014). Juvenile and subadult Delta Smelt are observed in the field most commonly at temperature near or below 20 °C (Bennett et al. 2008, Nobriga et al. 2008), a temperature which is often exceeded beginning in May or June and continuing through September and more rarely in October (see Chapter 7). Thus, we suggest that the same tradeoffs between feeding and predation risk may persist through the warmer months and into early fall, but become less likely as the season progresses into late fall and winter. Note, however, that predation risk is also influenced by a complex suite of other factors such as turbidity, life stage, and proximity to predator habitat, so the level of risk to Delta Smelt can’t be determined.

Another possible indirect effect of higher water temperatures is that they may promote harmful agal blooms (HAB) (Lehman et al. 2005), which may degrade Delta Smelt habitat quality in the summer and early fall (Baxter et al. 2010). In the Delta, Lehman et al. (2013) found that blooms of the harmful cyanobacteria (blue-green algae) *Microcystis aeruginosa* required a water temperature of at least 19 °C for initiation. Other drivers of HABs and the possible effects of HABs are discussed more fully in a separate section of this Chapter. The combination of large seasonal and regional water temperature variability in the SFE and substantial direct and indirect effects of water temperature for all life stages of Delta Smelt means that this variable should be considered one of the most important habitat attributes for Delta Smelt. Differences in water temperature between regions or time periods may have important effects on the Delta Smelt population (Rose et al. 2013b).

Salinity and the Size and Location of the Low Salinity Zone

A dynamic salinity gradient from fresh water to salt water is one of the most characteristic features of an estuary (Kimmerer 2004). It originates from the mixing of fresh inland water with salty ocean water through tidal dispersion and gravitational circulation (Monismith et al. 2002). Many estuarine-dependent organisms occur in distinct salinity ranges (e.g., Kimmerer 2002a) and the extent and location of water with suitable salinities is thus an important habitat attribute for estuarine organisms. Over the time period of available monitoring data, there is no clear long-term trend in salinity levels and distributions in the estuary. Significant increases and decreases linked to changing flow patterns have been detected for various stations and months (e.g., Jassby et al. 1995, Enright and Culberson 2009, Shellenbarger and Schoellhamer 2011, Cloern and Jassby 2012).

The brackish (oligohaline) "low salinity zone" (LSZ) is an important region for retention of organisms and particles and for nutrient cycling. In the SFE, the LSZ provides important habitat for numerous organisms including Delta Smelt (Turner and Chadwick 1972, Kimmerer 2004, Bennett 2005). In this report we define the LSZ as salinity 1-6; however, other salinity ranges have been used by others, such 0.5-6 (Kimmerer et al. 2013) or 0.5-5 (Jassby 2008).

In the SFE, the position of the LSZ is commonly expressed in terms of X2, which is the distance from the Golden Gate in km along the axis of the estuary to the salinity 2 isohaline measured near the bottom of the water column (Jassby et al. 1995). X2 represents the approximate center of the LSZ (Kimmerer et al. 2013).

X2 is an index of the physical response of the estuary to freshwater outflow from the Delta; it decreases with increasing outflow because increasing freshwater outflow prevents seawater from moving landward. The X2 index was developed two decades ago as an easily-measured, policy-relevant "habitat indicator." Its ecological significance for multiple species and processes was established through statistical analyses of biological responses to seasonally or annually averaged X2 values (Jassby et al. 1995) and has since been reaffirmed in additional studies (e.g., Kimmerer et al. 2002a,b, 2009, 2013, Thomson et al. 2010, Mac Nally et al. 2010). There is, however, still much uncertainty regarding the causal mechanisms for the observed biological responses of biota to X2. As with all statistically derived functional relationships, biological responses to X2 do not necessarily reflect direct causal relationships and it is generally recognized that some of the causal mechanisms may not be directly linked to the size and location of the LSZ.

Most of the scientific and management attention has focused on the LSZ and X2 from late winter to early summer (hereafter "spring X2") depending on the species of interest, but in recent years the LSZ and X2 during the fall months ("fall X2") has also received considerable scientific and policy attention. Annual abundance indices of several estuarine fish and invertebrate species have a negative relationship with spring X2, meaning that abundance indices increase when X2 and the LSZ are more westward and Delta outflow is higher in the late winter and spring months (Jassby et al. 1995, Kimmerer 2002a, Kimmerer et al. 2009). Delta Smelt summer abundance indices have a significant relationship with prior fall X2 and fall abundance (USFWS 2008, Mount et al.

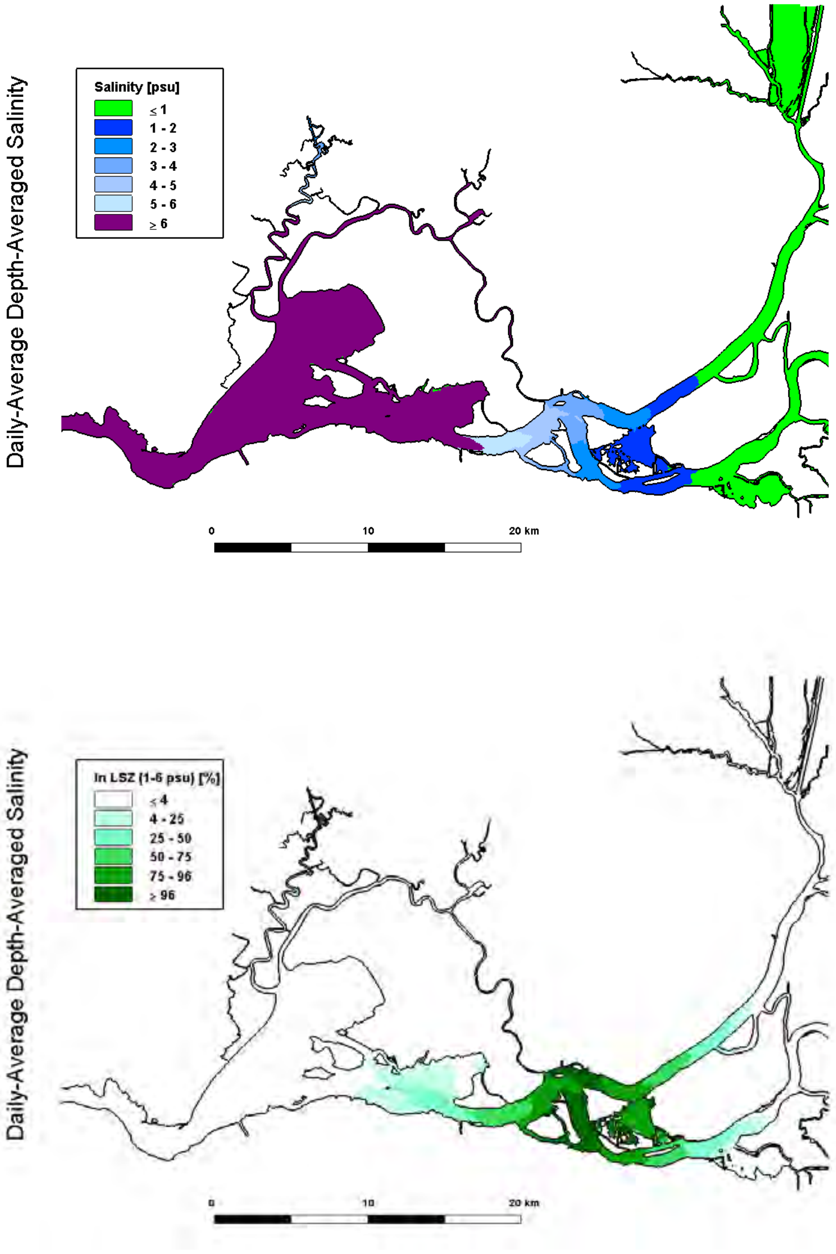
2013). Changes in spring and fall X2 have also been linked to long-term fish declines in the SFE (Thomson et al. 2010, Mac Nally et al. 2010).

The size and location of the LSZ are considered key factors determining the quanity and quality of low salinity rearing habitat available to Delta Smelt and other estuarine species. LSZ size and location are determined by the interaction of dynamic tidal and river flows with the stationary topography of the region (Reclamation 2011, 2012, Kimmerer et al. 2013). In a recent study, Kimmerer et al. (2013) used the three-dimensional hydrodynamic “UnTRIM” model which has an unstructured grid (Casulli and Zanolli 2002, 2005) to produce detailed maps of the distribution of salinity in the SFE under different outflow conditions. These maps (figure 2 in Kimmerer et al. 2013 and Fig. 18 and 19 in this report) show that under low outflow conditions typical of summer and fall months (outflow = 140 $m^3 s^{-1}$, X2 = 85 km), the LSZ is in the western Delta confluence region, including the Sacramento and San Joaquin Rivers upstream of Chipps Island (Fig. 18), while under high outflow conditions typical of wet winter months (outflow = 1,440 $m^3 s^{-1}$, X2 = 51 km), the LSZ is much further west in San Pablo Bay. At intermediate outflows (intermediate X2 = 74 km).), it is located east of Carquinez Strait and covers Suisun Bay and parts of Suisun Marsh (Fig. 19).

Kimmerer et al. (2013) also examined the relationships between X2 and the area, average depth, and volume of the LSZ. They found that these relationships were bimodal, with the largest volumes and areas and shallowest depths at X2 values below 50 km when the LSZ is located in the large San Pablo Bay, and secondary peaks at X2 values between 60 and 75 km when the LSZ overlays the smaller Suisun Bay (Fig. 20). Area and volume were smallest and depth greatest when the LSZ was constricted in Carquinez Strait (X2~50-60 km) and in the confluence region of the Sacramento and San Joaquin Rivers (X2~80-85 km).

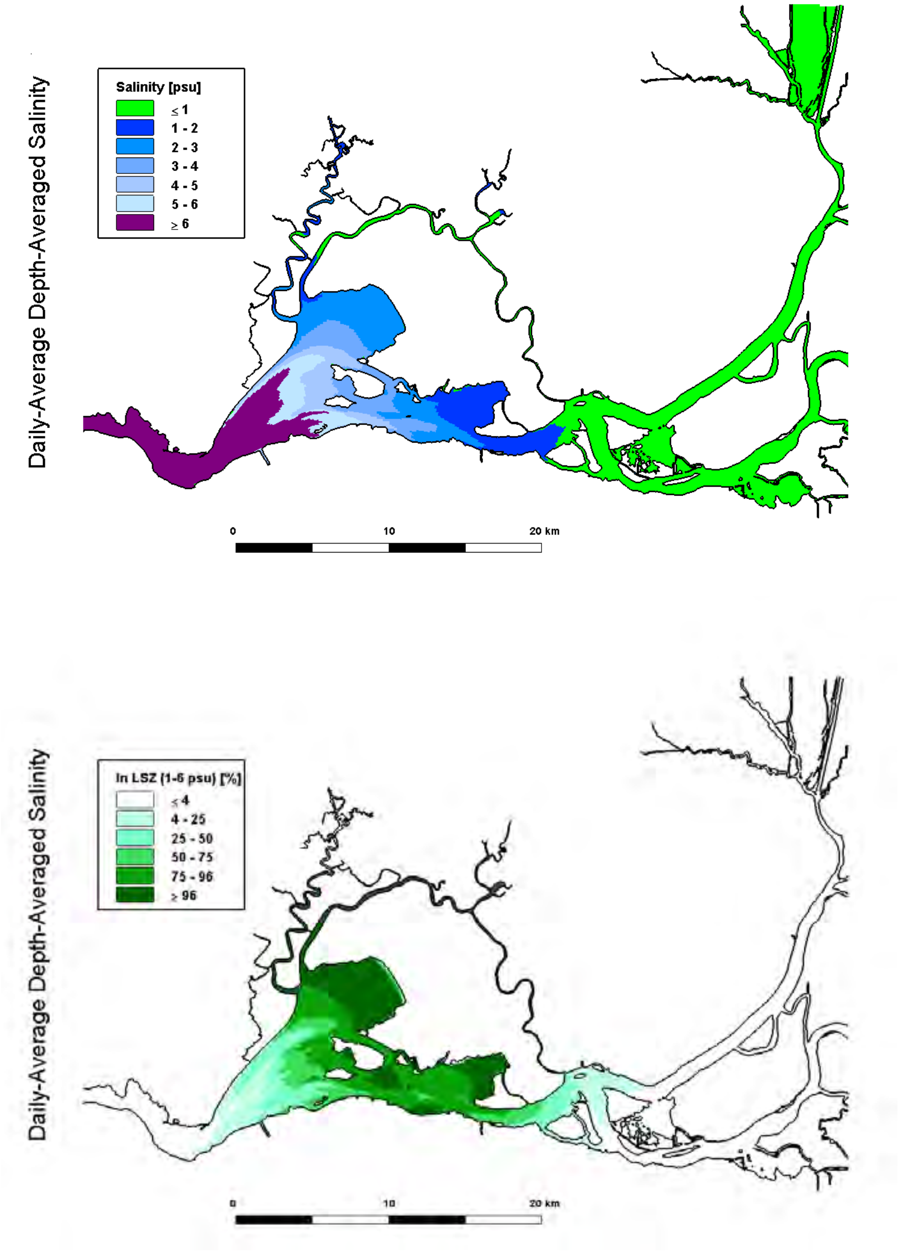
Paleosalinity investigations going back several thousand years indicate that the Delta has historically been largely fresh, while the Suisun region has alternated between brackish (oligohaline) and fresh (Ingram and Malamud-Roam 2013, Drexler et al. 2014). The LSZ and X2 likely moved according to predictable annual and interannual rhythms. Interannually, X2 was most variable in the higher-flow winter and spring months and least variable in the low-flow fall months. Seasonally X2 moved from the west in winter and spring to the east in summer and fall. CDWR (CDWR 2007) computes monthly “unimpaired” outflows which remove the effects of dam operations and water diversions. Annual X2 dynamics based on these unimpaired flows may give a sense of these historical fluctuations (Fig. 21). It is important to note, however, that unimpaired flows are not the same as historical “natural” flows because they do not take into account upstream water losses (e.g., consumption and evaporation) or physical water body alterations such as channelization, groundwater depletion, draining of wetlands, and disconnection of floodplains. The historical wetlands, floodplains, and groundwater basins would have naturally retained and released water (Whipple et al. 2012) and likely affected flows and the LSZ in different ways than today’s man-made reservoirs. Work is currently underway at UC Davis, the San Francisco Estuary Institute, and elsewhere to explore these issues, but results have not yet been published (W. Fleenor, U.C. Davis, personal communication). At this time, considerable uncertainty remains regarding the natural ranges in the timing and volume of the historical seasonal and interannual freshwater flows and how they caused the LSZ to spread out and contract across the estuary’s historical landscape. There is, however, little doubt that interannual variations in precipitation and hence river flows caused a high degree of interannual variability in the size and location of the low-salinity zone (Dettinger 2011).

Figure 18. Salinity distribution at low outflow. The upper panel shows the area of the low-salinity zone (4,262 hectares) at X2 = 85 km, when positioned mostly between Antioch and Pittsburg. Connections to Suisun Bay and Suisun Marsh are minimal. The lower panel shows the percentage of day that the low-salinity zone occupies different areas.



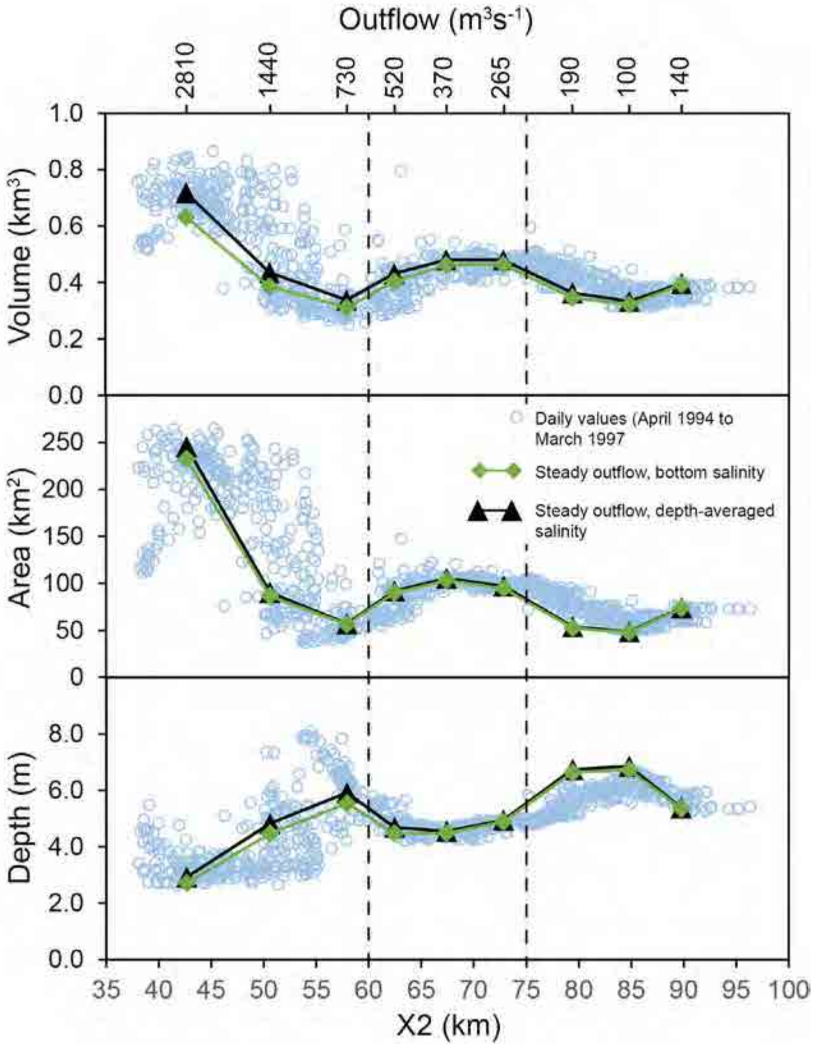
There is also no doubt that human water use and landscape alterations have changed flows into and out of the Delta and, consequently, salinity dynamics in the SFE, though changing precipitation patterns also play a role (Enright and Culberson 2009). Before the construction of today's major reservoirs, upstream water diversions coupled with the isolation of floodplains and wetlands, which had naturally stored runoff, from river channels by levees exacerbated salinity intrusions into the Delta in dry years. This was especially evident during the severe drought from

Figure 19. **Salinity distribution at intermediate outflow. The upper panel shows the area of the low-salinity zone (9,140 hectares) at X2 = 74 km (at Chipps Island). The lower panel shows the percentage of day that the low-salinity zone occupies different areas.**



1929 to 1934 when salinities of 2 were observed at Paintersville Bridge which is located on the Sacramento River at a distance of about 136 km from the Golden Gate (Mathew 1931). Operation of the large CVP and SWP reservoirs that were constructed after this drought has prevented such severe salinity intrusions since then and X2 has remained west of Rio Vista located on the Sacramento River 100 km upstream of the Golden Gate. Beginning with the salinity requirements in SWRCB water right decision D-1275 of 1967, salinity and the position of the LSZ have also

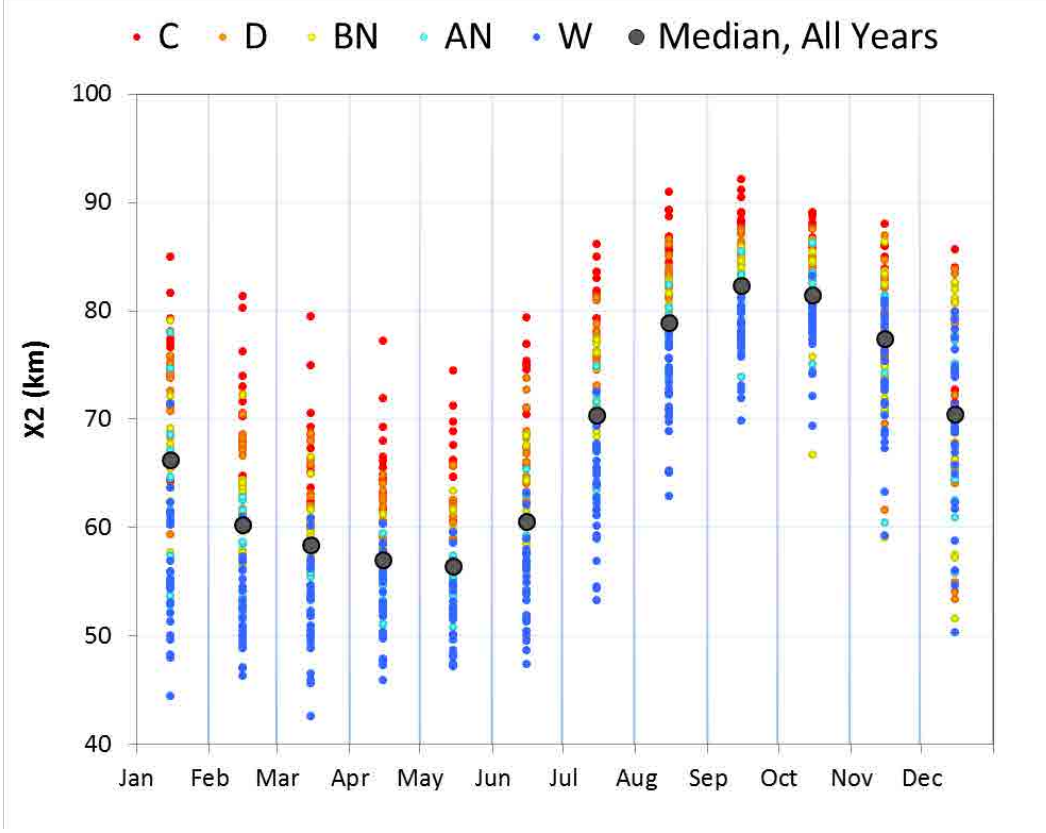
Figure 20. Modeled volume, area, and depth of the low salinity zone (salinity 0.5 to 6 at various values of X2 for 9 steady state values of outlow using bottom salinity (green diamonds) and depth-averaged salinity (black diamonds and for daily values based on variable values from April 1994 through March 1997 (blue circles) (modified from Kimmerer et al. 2013). The top axis gives the Delta outflow corresponding to the 9 steady state scenarios.



been increasingly regulated to protect "beneficial uses," including habitat and fish protections (see Chapter 1).

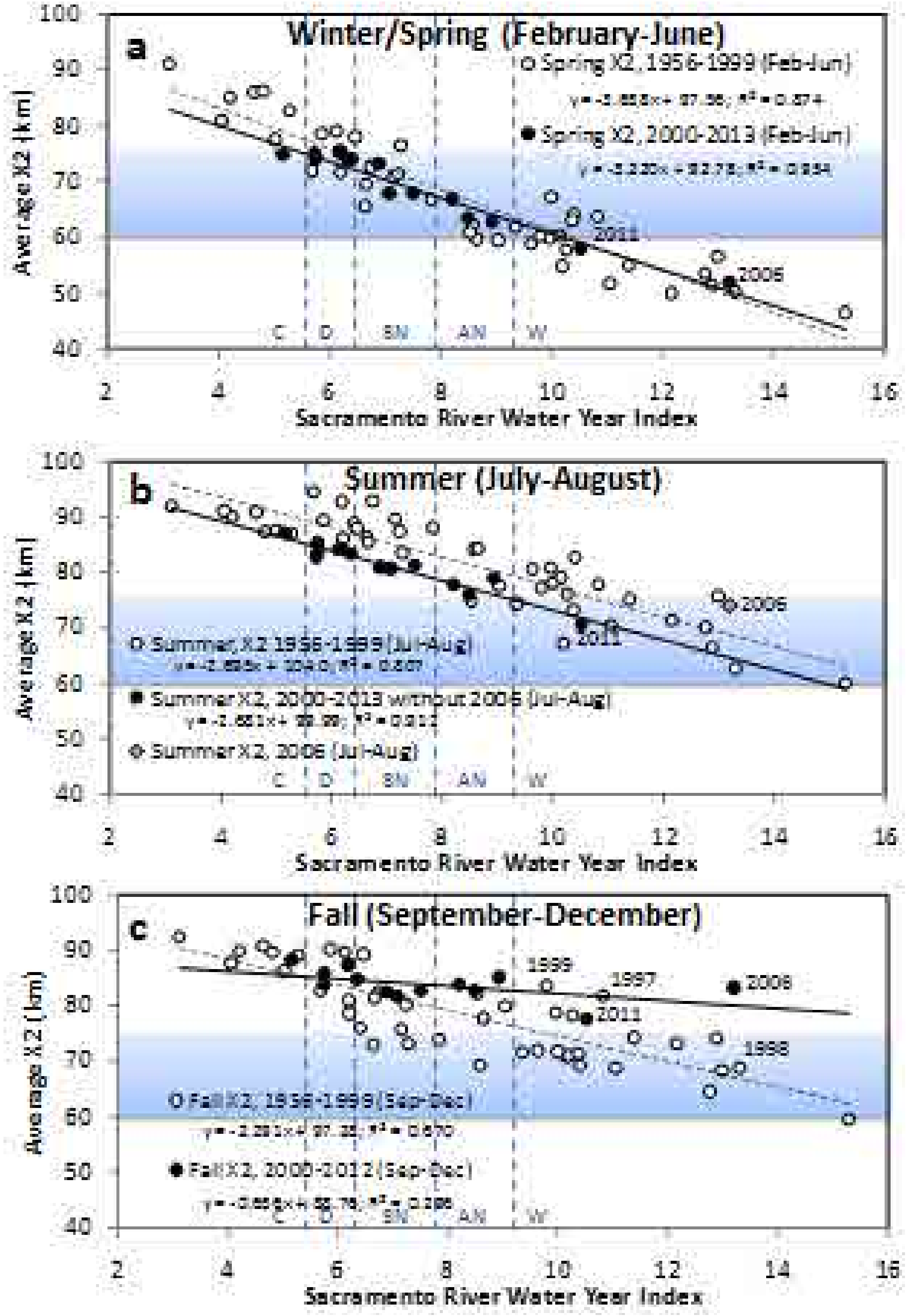
CVP and SWP water exports from the Delta began in the early 1950s with the completion of the CVP C.W. Bill Jones Pumping Plant (formerly known as the Tracy Pumping Plant) in 1951 and then increased with the completion of SWP's Harvey O. Banks Pumping Plant in 1968. Long-term variability in the trend of Delta outflow has been reduced seasonally for the period 1921-2006, in part due to water project operations (Enright and Culberson 2009), but also due to overriding climate changes. Analyzing data from 1956–2010, Cloern and Jassby (2012) found significant increases in water exports from the Delta in all months of the year except May, but in the first half of the year, these increases in exports did not significantly affect Delta outflow. We

Figure 21. **Plot of monthly X2 (km) values calculated from mean monthly unimpaired Delta outflows from 1921-2003. X2 values are categorized by water year type for the Sacramento Valley. Also shown are the median X2 values from 1921-2003 across all water year types (grey circles) C, red dots: critically dry; D, orange dots: dry; BN, yellow dots: below normal; AN, light blue dots: above normal; W, dark blue dots: wet. Water year type data from http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST. Unimpaired flow data from DWR 2007 (available at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/dwr_2007a.pdf). X2 equation from Jassby et al. 2005.**



show this by plotting the relationship between the Sacramento River Water Year Index, a measure of runoff, and average spring X2 (February-June) for two periods before (1956 to 1999) and after (2000-2013) the current flow and salinity requirements in SWRCB water right decision D-1641 became mandatory. The relationship appeared to remain essentially unchanged when the two time periods were compared (Fig. 22a). Cloern and Jassby (2012) further found that inflow to the Delta significantly increased in July and August, but these increases in inflow did not translate into significant increases in Delta outflow due to concurrent increases in exports during these months. Nevertheless, plots of recent data show that July and August outflows increased and the relationship between the Sacramento River Water Year Index and summer-time X2 (July-August) shifted downward in the years since the SWRCB water right decision 1641 went into effect in 2000 relative to previous years (Fig. 22b). The wet year 2006 did not fit this pattern because it had high summer X2 in spite of a high water year index. This means that with the exception of 2006, the LSZ has generally been located somewhat more westward in July and August since 2000 than from 1956 to 1999 under similar runoff conditions.

Figure 22. Plots of monthly X2 as a function of the Sacramento River Water Year Index (a measure of runoff) for the years 1956 to 1999 and 2000 to 2013 for: a, winter/spring; b, summer; and c, fall. The regression equation for each set of points is also shown. The index is calculated as: 0.4 * Current April to July Runoff Forecast (in millions of acre feet, maf) + 0.3 * Current October to March Runoff in (maf) + 0.3 * Previous Water Year's Index (if the Previous Water Year's Index exceeds 10.0, then 10.0 is used) (see http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST for futher detail).



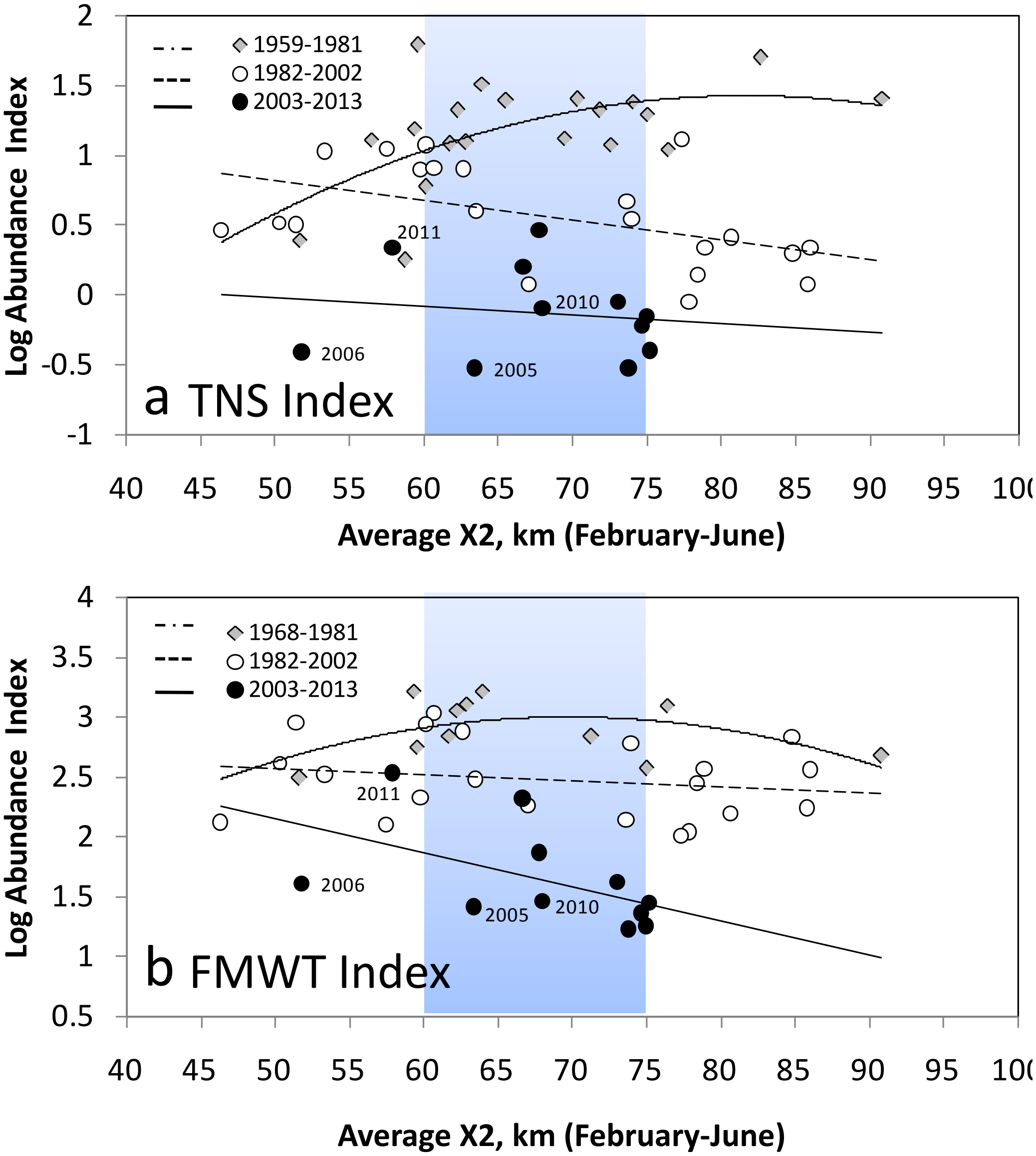
Cloern and Jassby (2012) also showed that significantly increasing exports combined with declining inflows led to significant declines in Delta outflow in each month from September to December. In plots of recent data, this led to a shallower slope of the relationship between the Sacramento River Water Year Index and fall X2 (September-December) and a more eastward LSZ location in the fall months of wetter years (below normal, above normal, and wet water year types) during 2000-2012 compared to 1956-1999, with the exception of two wet years at the end of the time series, 1997 and 1999, which fall on the 2000-2012 line (Fig. 16c, see also Feyrer et al. 2007, 2010). The areas with light blue shading in the three plots shown in Figure 16 show the range of X2 that places the LSZ over Suisun Bay and are associated with a high LSZ volume, area, and shallow LSZ depths (Kimmerer et al. 2013, Fig. 14). Fall X2 commonly fell into this range from 1956-1999 (in 18 of 44 years; Fig. 22c), but never after 2000. In 2011, the most recent wet year, fall X2 was lower than in the preceding wet years of 2006, 1997, and 1999, but still elevated relative to the majority of previous wet years. Overall, the changes in flows in the summer and fall months described by Cloern and Jassby (2012) have resulted in more muted seasonal and interannual variations in X2 and in the size and location of the LSZ in more recent years and possibly also relative to historical variability (Fig. 21).

Delta Smelt are found in the estuary at salinities up to 18 (Bennett 2005), but are most common in the in the LSZ (< 6) (Moyle et al. 1992, Sommer and Mejia 2013, Kimmerer et al. 2013). Sommer et al. (2011a) described Delta Smelt as a “diadromous species that is a seasonal reproductive migrant.” In the winter, adult Delta Smelt move upstream into fresh water for spawning. In the spring and summer, young Delta Smelt are transported or swim downstream into the LSZ (Dege and Brown 2004). Delta Smelt usually rear in low salinity habitat in the summer (Nobriga et al. 2008) and fall (Feyrer et al. 2007), although some Delta Smelt remain year-round in fresh water (Sommer et al. 2011a, Merz et al. 2011, Sommer and Mejia 2013).

The recruitment success of Longfin Smelt and age-0 Striped Bass increases linearly with more westward positions of the LSZ during spring (Jassby et al. 1995, Kimmerer 2002a). In contrast, the relationships of annual Delta Smelt indices with spring X2 are more complex because they have not been consistent over the period of record (Fig. 23). Jassby et al. (1995) found that from 1968-1991, the highest fall abundance indices for Delta Smelt coincided with intermediate values of average April-July X2 when the LSZ was positioned in Suisun Bay. Low fall abundances were, however, also observed at these intermediate X2 values. The analyses by Jassby et al. (1995) were later updated and augmented with an analysis of the relationship between Delta Smelt summer abundance and spring X2 (Kimmerer 2002a, Kimmerer et al. 2009).

We updated the analyses by Jassby et al. (1995) with more recent data and data from additional monitoring surveys to examine the hypothesis that during periods of relatively stable abundance (i.e. without step changes, Thomson et al. 2010), the abundance of different Delta Smelt life stages is related to spring outflow and the position of the LSZ as expressed by spring X2. To obtain spring X2, we first calculated mean monthly X2 values calculated from daily X2 values. We then averaged the mean monthly X2 values for February to June. This is different from the April-July period used by Jassby et al. (1995) for their Delta Smelt analyses, but similar to the spring X2 averaging period used by Kimmerer (2002a). Note that different averaging methods for calculating seasonal X2 values account for the small quantitative differences between results presented here and those of previously published analyses that used the same data, but this does not affect the overall patterns. We partitioned the data into the periods before, between, and after the 1981 and 2002 step declines in Delta Smelt abundance identified by Thomson et al. (2010). The 1981-1982 partition, but not the 2002-2003 partition, has been previously applied by Kimmerer (2002a) and Kimmerer et al. (2009).

Figure 23. Plots of the log transformed a) Delta Smelt Summer Townet Survey abundance index and b) Delta Smelt Fall Midwater Trawl Survey abundance index, in relation to monthly averaged daily X2 position from February to June. Lines are either simple linear least squares regression (lines) or quadratic regression (curves).



Kimmerer (2002a) and Kimmerer et al. (2009) found that the relationship between spring X2 and Delta Smelt juvenile abundance indices was positive before the step decline in Delta Smelt abundance that started in 1981 (Thomson et al. 2010), suggesting that historically, Delta Smelt population recruitment may have benefitted from lower outflows and a more upstream LSZ in the late winter and spring. In our analysis, we found that the relationship was perhaps more unimodal than linear (Table 1, Fig. 23a) because a model that included a quadratic spring X2 term explained more of the variation in the data than a linear model that did not, although the statistical significance of the linear model was slightly higher than that of the quadratic model because of the loss of a degree of freedom due to the additional quadratic term included in the quadratic model. Similar to Kimmerer (2002a) and Kimmerer et al. (2009), we found that in the period after the 1981 step change and also in the period after the 2002 step change, the relationship of log-transformed summer abundance with spring X2 shifted downward and became more clearly negative than unimodal (Fig. 23a). The relationship remained statistically significant at the $P < 0.05$ level in the period after the 1981 step decline, but is no longer statistically significant after 2001. Similarly, the relationship is also not significant across the entire 52-year time series (Table 1).

Kimmerer et al. (2009) found a non-significant and essentially flat relationship between spring X2 and the entire log-transformed sub-adult abundance time series for Delta Smelt; this remains the case when data from the five most recent years is included in the analysis (Table 1). Similar to Jassby et al. (1995), we found a weakly unimodal relationship between spring X2 and log-transformed Delta Smelt subadult abundance indices before the first step change, but this relationship was not statistically significant at the $P < 0.05$ level (Table 1, Fig. 23b). Similar to juvenile abundance, the relationship of log-transformed subadult abundance with spring X2 shifted downward in the periods after each of the two step changes and became more negative than unimodal (Fig. 23b), but again these relationships were not statistically significant at the $P < 0.05$ level (Table 1).

Taken together, these findings are generally consistent with previous conclusions that moderate hydrological conditions in the late winter and spring and a large LSZ located in the Suisun region can be beneficial to Delta Smelt population abundance (Jassby et al. 1995). Historically, this may have been the case for several life stages. At present, however, juvenile and subadult Delta Smelt seem to barely respond to spring X2. As Jassby et al. (1995) point out, this does not mean that there is no longer an effect of spring X2 on juveniles and subadults; the spring X2 effect may just be masked or weakened by changes in other habitat attributes. The relationships between these life stages and spring X2 clearly underwent downward shifts after each step decline. These persistent downward shifts indicate that occasional years with beneficial spring X2 conditions continue to have a positive effect on Delta Smelt, but they are by themselves not enough to overcome the depressed abundance levels and recover the population.

The downward shifts and changes in shape of the spring X2-Delta Smelt abundance index relationships (Fig. 23) also illustrate the difficulties of determining and understanding functional responses of biota to dynamic physical habitat attributes in changing ecosystems; the species of interest, other habitat attributes, and their interactions may all change as much or more than the habitat attribute under consideration. Further, these changes may not always be gradual, but can take the form of sudden step changes that may be associated with system-wide regime shifts (Davis et al. 2010, Baxter et al. 2010, Cloern and Jassby 2012). Moreover, prior conditions and prior abundance may also influence outcomes. In Chapter 9 of this report we give a relatively simple example of additional multivariate analyses aimed at exploring the effects of hydrology and prior abundance on the abundance and recruitment of Delta Smelt larvae. More sophisticated multivariate life cycle modeling that greatly exceeds the scope of this report is needed to account for these simultaneous changes and interactive effects on all life stages.

Changes in the size, location, and dynamics of the LSZ likely also interact in complex ways with other changes, such as changes in sediment and nutrient loadings and resulting turbidity and nutrient dynamics and their effects on Delta Smelt and the food web. For example, LSZ position affects recruitment of the invasive clam *Potamocorbula amurensis,* which may in turn affect phytoplankton and zooplankton biomass, size, and production (Thompson 2005, Winder and Jassby 2011), and has likely affected fish-X2 relationships (Kimmerer et al. 2002a).

Table 1. Summary of relationships between log-transformed annual abundance indices for four Delta Smelt life stages (response variable) and spring X2 (February-June, see text): Survey: see description of monitoring surveys in Chapter 3; Regression: least squares linear or quadratic regression: n, number of observations (years); P, statistical significance level for the model; R^2, coefficient of determination; adjusted R^2, R^2 adjusted for the number of predictor terms in the regression model. Bold font indicates statistically significant relationships.

Life Stage	Season	Survey	Period	Regression	n	P	R^2	Adjusted R^2
Juvenile	Summer	TNS	1959-2013	Linear	52	0.614	0.005	
Juvenile	Summer	TNS	1959-1981	Linear	20	0.033	0.230	0.187
Juvenile	Summer	TNS	1959-1981	Quadratic	20	0.052	0.295	0.212
Juvenile	Summer	TNS	1982-2002	Linear	21	0.023	0.243	0.203
Juvenile	Summer	TNS	2002-2013	Linear	11	0.689	0.019	
Subadult	Fall	FMWT	1968-2013	Linear	43	0.290	0.027	0.003
Subadult	Fall	FMWT	1968-1981	Linear	11	0.699	0.017	
Subadult	Fall	FMWT	1968-1981	Quadratic	11	0.295	0.263	0.079
Subadult	Fall	FMWT	1982-2002	Linear	21	0.394	0.038	
Subadult	Fall	FMWT	2002-2013	Linear	11	0.107	0.263	0.181

Ongoing studies coordinated by the IEP as part of the POD and FLaSH studies focus on the processes that link physics, chemistry, and biology in the LSZ and its habitat value for Delta Smelt and other native and non-native species. Similar to Monismith et al. (2002), preliminary results indicate that the strength of physical mixing (lateral dispersion) in the LSZ changes with the volume of freshwater outflow, underscoring the importance of variable hydrodynamics on not just the location of the LSZ, but how ecological services (nutrient mixing, organism dispersal) are influenced by variable estuarine outflow (Monismith, U.C. Berkeley, personal communication).

Turbidity

In this report, turbidity is considered an environmental driver that interacts with other environmental drivers, resulting in habitat attributes that directly affect Delta Smelt responses, rather than a stand-alone habitat attribute. Clearly, studies have shown that distribution of Delta Smelt is correlated with turbidity (e.g., Feyrer et al. 2007, Nobriga et al. 2008, Grimaldo et al. 2009, Sommer and Mejia 2013). In the conceptual model we chose to incorporate turbidity as a modifier of several important linkages between environmental drivers and habitat attributes that are important to Delta Smelt, primarily food visibility for small larvae and predation risk for all life stages. If we had incorporated turbidity as a habitat attribute and, for example, predation risk was discussed separately from turbidity, there would have been a great deal of overlapping text between the two sections because turbidity interacts with the presence of predators to determine predation risk. Our approach is not ideal but should reduce redundant text and contribute to clarity of presentation. Nonetheless, we recognize that turbidity by itself could reasonably be considered as a habitat attribute. For example, it is possible that Delta Smelt experience stress in low turbidity habitat, which would in turn affect survival (likely through predation) but also in other direct ways such as lower growth and reduced egg production. However, we do not have evidence at this point to support that hypothesis.

In addition to salinity gradients, estuaries often have turbidity gradients. Turbidity is an optical property of water, which is the loss of transparency due to scattering of light by suspended particles. Typically, the upper reaches of estuaries have areas with high levels of suspended particles known as “estuarine turbidity maxima.” In many estuaries, these areas are located in or near the low salinity zone and are associated with higher numbers and enhanced growth for larvae of some species (Sirois and Dodson 2000a, b, Shoji et al. 2005). In the SFE, turbidity is largely determined by the amount of suspended inorganic sediment in the water (Cloern 1987, Ganju et al. 2007, Schoellhamer et al. 2012), although organic components can also play a role (USGS 2008). Sediment particles are constantly deposited, eroded, and resuspended, and are transported into, within, and out of the estuary. The amount of sediment that is suspended in the water column depends on the available hydrodynamic energy, which determines transport capacity, and on the supply of erodible sediment in the estuary and suspended sediments from the watershed.

In the upper SFE there are two main physical processes controlling turbidity. Suspended sediment is transported from the tributary watersheds into the system during high flows associated with winter and spring storm runoff (Schoellhamer et al. 2012). The first large storm of the rainy season often carries the highest concentrations of suspended sediment. Some portion of the transported sediment moves through the system to San Pablo and San Francisco Bay and the remainder is stored within the system as bottom sediment. During the remainder of the year, turbidity is primarily caused by interactions of this stored sediment with other environmental drivers (Schoellhamer et al. 2012). Water moving with the tides can resuspend fine sediments because of turbulence resulting from interactions between the bottom and water moving at high tidal velocities. At a larger scale, irregularities in the bottom topography may define geographic regions of greater turbulence and greater turbidity. In the upper estuary, such regions occur at a large bathymetric sill between Carquinez Strait and Suisun Bay and at another location within Suisun Bay (Schoellhamer 2001). Sediments may also be resuspended by turbulence related to wind waves. This process is mainly limited to areas with fine sediments on relatively shallow shoals where wind wave turbulence reaches the bottom. This process is most important in the shallows of Suisun, Grizzly, and Honker Bays and Liberty Island (Ruhl and Schoellhamer 2004, Warner et al. 2004, Morgan-King and Schoellhamer 2013). Thus, turbidity at any particular location is the result of several environmental drivers, including hydrology (transport from the watershed) and weather (wind and precipitation) interacting with the physical configuration of the upper SFE. Further, annual variation in these factors may have important effects. For example, during a drought there is little transport of suspended sediment and the same wind patterns during the summer may result in less turbidity than would occur after a wet year because less sediment was stored as benthic sediment during the winter. There is also evidence of longer term changes in turbidity (Schoellhamer et al. 2011, Hestir et al. 2013), along with regional differences.

In addition to the inorganic component of turbidity, organic matter (e.g., phytoplankton) also contributes to both suspended solids and the sediment load on the bed that is re-suspended with wind and wave action (McGann et al. 2013). In the SFE, phytoplankton concentration varies spatially, seasonally, and on an inter-annual scale (Cloern et al. 1985, Jassby 2008, Cloern and Jassby 2012), and is controlled by multiple factors, including benthic grazing, climate, river inflows (Jassby et al. 2002), and nutrient dynamics (Glibert et al. 2011, Parker et al. 2012, Dugdale et al. 2013), which in turn are likely to affect the organic component of turbidity. Phytoplankton dynamics are discussed in detail in the 'Food and Feeding' section (below), but it is important to note here that plankton concentration comprises part of the SFE turbidity and is significant as it relates to productivity at higher trophic levels.

Among the geographic regions of the upper SFE, the Suisun region is one of the most turbid, when the system is not being influenced by storm flows. This results from strong turbulent hydrodynamics in the Suisun region caused by strongly interacting tidal and riverine flows, bathymetric complexity, and high wind speeds, which create waves that resuspend erodible benthic sediment in the large and open shallow bays of the Suisun region. The North Delta, especially the large open expanse of Liberty Island (flooded since 1998) and the adjacent Cache Slough region are also relatively turbid. Recent evidence suggests that Liberty Island acts as a sediment sink in the winter and a sediment source for the surrounding Cache Slough complex in the summer (Morgan-King and Schoellhamer 2013).

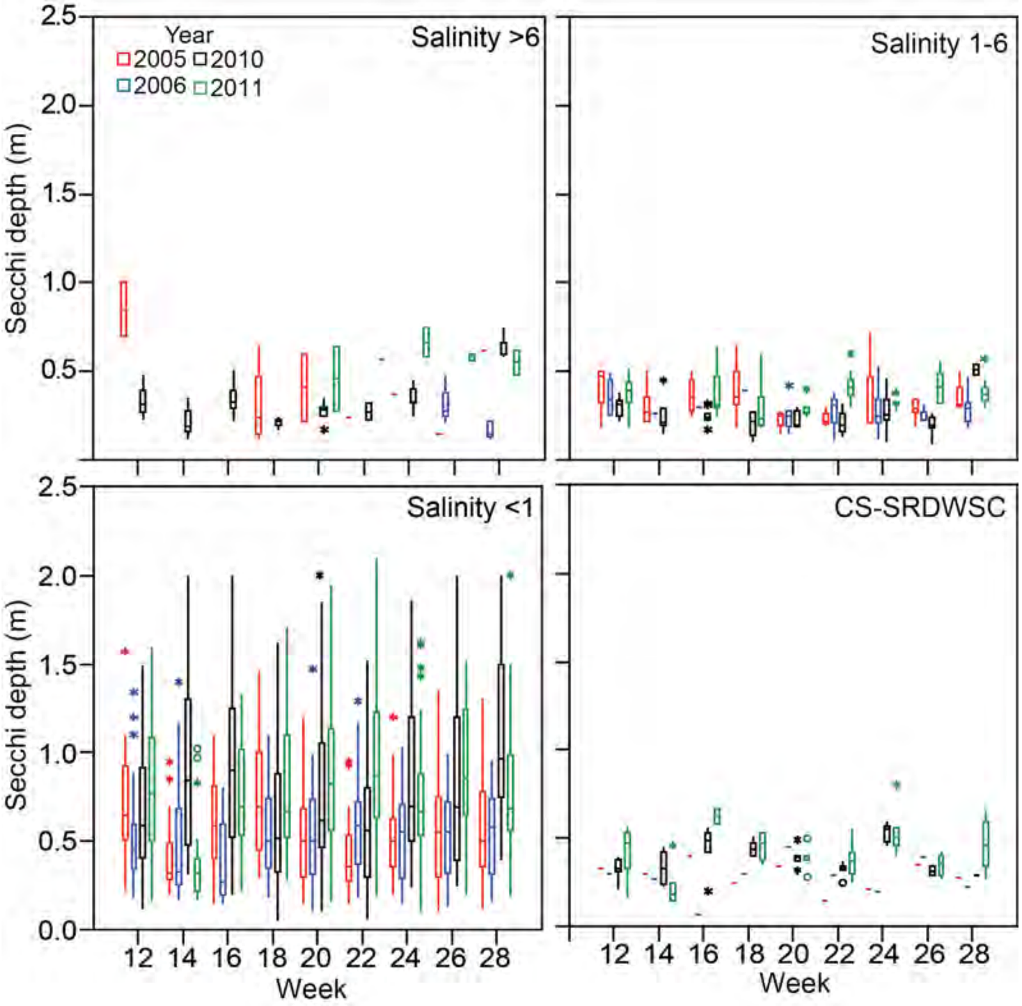
Turbidity is usually lower in the channels of the confluence of the Sacramento and San Joaquin Rivers compared to the Suisun region and North Delta region. Turbidity dynamics in the deep channels of the river confluence are driven more by riverine and tidal processes while high wind and associated sediment resuspension has little if any effect (Ruhl and Schoellhamer 2004). Turbidity is generally lowest in the south Delta (Nobriga et al. 2008). This may in part be due to sediment trapping by large, dense beds of *Egeria densa*, an invasive species of submerged aquatic vegetation (Hestir 2010). In winter/spring during the comparison years the highest Secchi disc depths (lowest turbidity) were found in the freshwater regions of the estuary (< 1 salinity), except for the Cache Slough region in the north Delta which was as turbid as the saltier regions of the estuary (Fig. 24).

There is strong evidence for an initial increase followed by a more recent long-term decline in sediment transport into the upper estuary, likely due to anthropogenic activities during the last century and a half (Schoellhamer et al. 2013, Wright and Schoellhamer 2004). Schoellhamer et al. (2013) presented a conceptual model of the effects of human activities on the sediment supplies in the SFE with four successive regimes:

1. The natural state.
2. Increasing sediment supplies due to mining, deforestation, agricultural expansion, etc.
3. Decreasing sediment supply due to sediment flushing during high flow events and sediment trapping behind dams and dikes.
4. A new altered state of low sediment supplies. The pulse of increased sediment inputs during and after the California gold rush and the more recent decline in these inputs is apparent in isotopic data from sediment cores taken in the estuary (Drexler et al. 2014).

The recent declines in sediment supplies have led to a long-term increase in water clarity in the upper Estuary (Jassby et al. 2002, Feyrer et al. 2007, Jassby 2008). Jassby et al. (2002) documented a 50% decrease in total suspended-solids concentration (TSS, a laboratory measurement of total suspended solids), approximated by suspended sediment concentration

Figure 24. **Secchi depth data collected during the 20 mm Survey. Surveys are conducted biweekly March-July. See Chapter 3: Data Analyses for explanation of boxplots.**



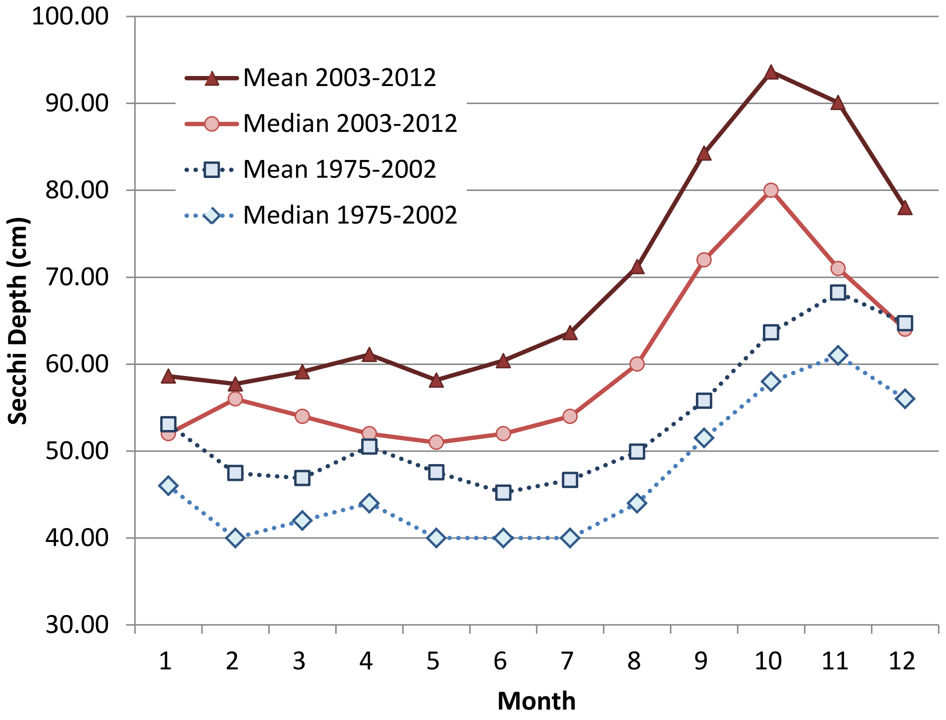
(SSC, an optical measurement done in the field for these data) in the Delta from 1975-1995. Jassby (2008) found that the downward trend continued in the decade after 1995, although at a slower pace than over the entire 1975-2005. From 1975-2005, there were significant declines in SSC of up to 6% per year at 8 of 10 Delta stations (Jassby 2008). Jassby et al. (2005) showed that TSS concentrations in the north Delta dropped sharply toward the end of the 1982–1983 El Niño-Southern Oscillation (ENSO) event, which was associated with extremely high outflows, and did not recover afterward. This step decrease after 1983 has been corroborated by further trend analyses of TSS (Hestir 2013). Following the El Niño event of 1997–1998, there was a 36% step decrease in SSC in San Francisco Bay as the threshold from transport to supply regulation was crossed as an anthropogenic erodible sediment pool was depleted (Schoellhamer 2011). Sediment trapping by dense beds of *Egeria densa* may be further reducing available sediment in the Delta (Hestir 2010). While other anthropogenic factors may have also contributed to long-term changes in turbidity (e.g., export operations; Arthur et al. 1996), quantitative analyses of the effects of these factors have not been conducted.

Before the step decline in SSC and the onset of the pelagic organism decline in the late 1990s and early 2000s (i.e. the "pre-POD" period), water transparency (roughly the opposite of turbidity) measured with a Secchi disc at all IEP EMP stations was usually highest in November and lowest in June (Fig. 25). From 2003-2012 (i.e. the "POD" period), average water transparency was not only higher (by an average of 16 cm Secchi depth) than in the previous period, but the annual dynamics also shifted forward by a month, to greatest transparency (i.e. lowest turbidity) in October and lowest transparency in May. The greatest differences in average water transparency between the pre-POD and POD periods occurred in September and October (28 and 30 cm difference between monthly averages, respectively) and the smallest differences in January-May (10 cm). While the EMP has collected turbidity data (nephelometric turbidity (NTU) measurements) since 1975, long-term fish monitoring surveys have traditionally collected Secchi disc data and only in recent years have incorporated turbidity. Therefore, Secchi disc data are presented in the majority of this report when relating Delta Smelt abundance to water clarity conditions.

Multiple field and modeling studies have established the association between elevated turbidity and the occurrence and abundance of Delta Smelt. The abundance of larval/postlarval Delta Smelt larvae was well explained by salinity and Secchi depth, a proxy for turbidity (Kimmerer et al. 2009). Sommer and Mejia (2013) and Nobriga et al. (2008) found that late-larval and juvenile Delta Smelt are strongly associated with turbid water, a pattern that continues through fall (Feyrer et al. 2007). Long term declines in turbidity may also be a key reason that juvenile Delta Smelt now rarely occur in the south Delta during summer (Nobriga et al. 2008). Thomson et al. (2010) found that turbidity (water clarity) was the only significant predictor variable that was shared by three of the four POD species; all other significant predictor variables were unique to each species. Grimaldo et al. (2009) found that the occurrence of adult Delta Smelt at the fish salvage facilities was linked, in part, with high turbidity associated with winter "first flush" events. Turbidity may also serve as a behavioral cue for small-scale (lateral and vertical movements in the water column) and larger-scale (migratory) Delta Smelt movements (Bennett and Burau 2014).

Delta Smelt are visual feeders, and feed primarily between dawn and dusk (Hobbs et al. 2006, Slater and Baxter 2014). As for all visual feeders, visual range and prey density determine feeding success of Delta Smelt. Visual range depends on size, contrast and mobility of the prey, retinal sensitivity and eye size of the visual feeder, and on the optical habitat attributes such as light scattering, absorption, and intensity (Aksnes and Giske 1993). Optical habitat attributes are affected by turbidity from suspended organic particles, such as algae and detritus, and inorganic particles, such as sand and silt. Somewhat counterintuitively, some level of turbidity appears important to the feeding success of larval Delta Smelt. Baskerville-Bridges et al. (2004a) conducted laboratory experiments in which alga densities (0, 0.5 x 10^6 cell/mL, and 2 x 10^6 cell/mL or 1, 3, and 11 NTU) and light levels (range tested: 0.01 µmoles/s x m^2, 0.3 µmoles/s x m^2, 1.9 µmoles/s x m^2) were manipulated and first-feeding success of larval Delta Smelt was quantified. They found that maximum feeding response occurred at the highest alga concentrations and light levels tested. In a subsequent experiment, when algae were removed entirely, the feeding response was very low. The addition of algae or some other form of suspended particle is standard practice for successfully rearing Delta Smelt larvae in culture facilities (Mager et al. 2004, Baskerville-Bridges et al. 2005, Werner et al. 2010b, Lindberg et al. 2013). Presumably the suspended particles provide a background of stationary particles that helps the larvae detect moving prey. Sufficient turbidity also appears to be important to reduce overall environmental stress and increase survival of larval Delta Smelt (Lindberg et al. 2013). Thus, it seems likely that turbidity is important to the feeding success and survival of larval Delta

Figure 25. Average and median Secchi depth in cm from monthly sampling at IEP Environmental Monitoring Program stations. Data are shown for the time period up to the pelagic organism decline (1975-2002) and after the decline (2003-2012).



Smelt in the wild. Recent research on juvenile Delta Smelt, however, suggests that influence of turbidity on feeding success may vary across life stages and field conditions. Hasenbein et al. (2013) exposed juveniles to varying turbidities (5-250 NTU) and observed a negative relationship between turbidity and feeding rates, with a marked decline in feeding at 250 NTU. However, feeding rates were highest at 12 NTU and stable in the 12-120 NTU turbidity range, which is likely within the range experienced by juvenile Delta Smelt in typical summer conditions in the Delta. Turbidity values of 250 NTU are generally not observed during the summer; therefore, the typical summer turbidity range in the Delta likely does not limit juvenile feeding success.

In addition to its effects on feeding, turbidity may also reduce predation risk. Based on the general recognition that fish assemblages are often partitioned between turbid-water and clear-water assemblages (Rodríguez and Lewis 1997, Whitfield 1999, Quist et al. 2004), and that turbidity can influence the predation rate on turbid-adapted fishes (Rodríguez and Lewis 1997, Gregory and Levings 1998, Quist et al. 2004), it has generally been assumed that juvenile and adult Delta Smelt are closely associated with turbidity in order to minimize their risk of predation in their generally open-water habitat. There may also be complex interactions between feeding and predation risk that are mediated by turbidity. Recent laboratory work has shown that in light (as opposed to dark) conditions, the vertical distribution of larval Delta Smelt shifts upward in the water column when turbidity is increased from clear (< 2 NTU) to 24 NTU (L. Sullivan, San Francisco State University, unpublished data), suggesting that larval Delta Smelt may use turbidity to safely forage in surface waters that may be more food-rich. Interestingly, when a predator cue (water, after containing juvenile Striped Bass for 1 hr) is added to clear water, the distribution of larval Delta Smelt becomes bimodal, with increased densities near the surface and closer to the bottom (L. Sullivan, San Francisco State University, unpublished data). Thus, while laboratory studies have demonstrated that larvae have improved feeding success at higher (but not too high, see above) turbidities, in natural settings, turbidity and predation risk may interact (e.g., Miner and Stein 1996) to affect Delta Smelt habitat choice and feeding success.

Turbidity may also be a migration cue for Delta Smelt. A recent field study investigated behavioral responses of Delta Smelt to winter "first flush" events in the Sacramento and San Joaquin Rivers near their confluence (W. Bennett, U.C. Davis, unpublished data). A first flush is defined as an increase in flow and turbidity associated with the onset of winter rain. This study found lateral turbidity gradients that changed with the tides and before and after first flush events and coincided with lateral Delta Smelt movements toward the channel during flood tides and toward the shoreline during ebb tides. The researchers concluded that this behavior likely facilitates maintaining channel position or moving upriver and cross-channel gradients in water turbidity may act as a behavioral cue. Feyrer et al. (2013) also found small-scale lateral and vertical gradients in turbidity in the lower Sacramento River just prior to a winter-time first flush event. In their study, turbidity and salinity were highest in the lower half of the water column and during flood tides and lowest during ebb tides in the center of the channel in the upper half of the water column. This coincided with observations of Delta Smelt which were more frequently caught throughout the water column during flood tides than during ebb tides when they were observed only in the lower half of the water column and sides of the channel. Feyrer et al. (2013) concluded that Delta Smelt may actively move in the water column by keying in on turbidity and salinity gradients or because of the physics underlying them.

Entrainment and Transport

The egg, larval, and juvenile stages of estuarine fishes and invertebrates along with small and weakly swimming adult stages are subject to involuntary transport (advection) by riverine and tidal flows. Entrainment is a specific case of involuntary transport. It refers to situations when altered flows misdirect and transport fish and other organisms in directions in which they would not normally travel or where they will encounter unfavorable conditions and increased risk of mortality. In this report, we use the term entraiment to specifically refer to the incidental removal of fishes and other organisms in water diverted from the estuary, primarily by CVP and SWP export pumping (Arthur et al. 1996, Grimaldo et al. 2009, Castillo et al. 2012).

Ultimately, watershed hydrology determines how much water can flow into and through the Delta; however, water flows into, within, and out of the Delta are manipulated in many ways. Water is: routed through and around artificial channels, gates, and barriers; stored in and released from reservoirs; discharged from agricultural and urban drains; and diverted with large and small pumps. Perhaps the greatest flow alterations in the Delta have taken place in Old and Middle Rivers (collectively referred to as "OMR") in the central Delta (Fig. 2). Historically, these river channels were part of the tidal distributary channel network of the San Joaquin River (Whipple et al. 2012). Today, they are a central component of the CVP and SWP water conveyance system through the Delta. Water from the Sacramento River in the north now flows through the northern Delta (down Georgiana Slough, through Three-Mile Slough and around Sherman Island) and eastern Delta (via the artificial "Delta cross-channel" and down the forks of the Mokelumne River) to OMR in the central Delta, then to the SWP and CVP. The SWP and CVP pumps are capable of pumping water at rates sufficient to cause the loss of ebb tide flows and to cause negative net flows (the advective component of flow after removal of the diffusive tidal flow component) through OMR toward the pumps (see Grimaldo et al. 2009), thus greatly altering regional hydrodynamics and water quality (Monsen et al. 2007). Under these conditions, fish and other aquatic species in the Delta may be transported toward the pumps (Arthur et al 1996, Brown et al. 1996, Moyle et al. 2010), may swim toward the pumps if they are behaviorally inclined to follow net flow (Grimaldo et al. 2009), or may move toward the pumps if they are employing tidal surfing behavior (Sommer et al. 2011).

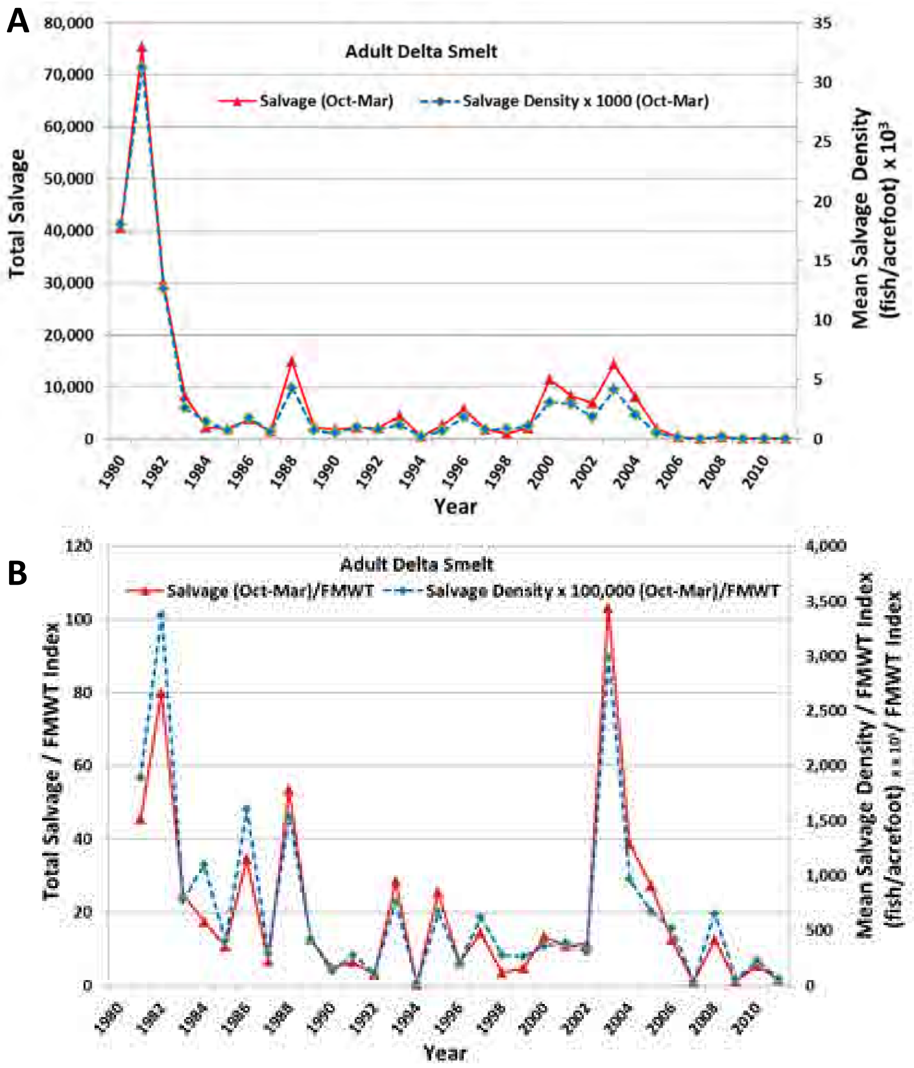
The SWP and CVP have large fish salvage facilities intended to reduce fish loss from the system due to entrainment - the State Skinner Fish Protective Facility (SFPF) and the federal Tracy Fish Collection Facility (TFCF). The SFPF and TFCF are located at the intakes to the State and federal export pumps on Old River in the southwestern Delta (Fig. 2). Both facilities have fish directing louvers and collecting screens that are used to capture and collect fish before they reach the pumps. The "salvaged" fish are then trucked to and released back into the western Delta. A variable fraction of these fish survive the capture, handling, trucking and release process (Miranda et al. 2010a,b, Aasen 2013, Afentoulis et al. 2013, Morinaka 2013a). The number of salvaged fish is monitored and reported as an index of SWP and CVP salvage and entrainment losses (Morinaka 2013b, more information and data available at http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx). The SWP differs from the CVP in having a regulating reservoir, Clifton Court Forebay that temporarily stores water from Old River to improve operations of the SWP pumps. A change in the location of SWP water diversion from Italian Slough to Old River through CCF in 1969 may have led to a substantial increase in pre-screen losses at the SWP (Heubach ca. 1973, Kano 1990).

Fish have been salvaged since 1958 at the TFCF and since 1968 at SFPF, and the quality of the historical salvage data has improved over time. Delta Smelt salvage data is available since May 1979 for both the TFCF and SFPF (ftp://ftp.delta.dfg.ca.gov/salvage/). Juveniles less than 30 mm fork length are less efficiently captured in the salvage facilities (Kimmerer 2008, Morinaka 2013a) and Delta Smelt larvae less than 20 mm fork length have not been reported in the salvage data, although entrainment losses of Delta Smelt larvae have been calculated to be substantial under some circumstances (Kimmerer 2008). Development of a quantitative monitoring methodology for entrained Delta Smelt larvae at the CVP and SWP was recognized as necessary to refine triggers for protective actions (USFWS 2008). The current methodology for monitoring larval Delta Smelt at the TFCF and SFPF has provided presence-absence data since 2008 (Morinaka 2013b). Improved methods for sampling fish larvae have been reported at the TFCF (Reyes et al. 2012).

Despite these caveats salvage of Delta Smelt has been used as a rough index of entrainment losses. Delta Smelt salvage data since 1993 is considered more reliable than salvage data from earlier years. The difference in reliability is due to a change in count frequency from twice a day (0100 and 1300) from July 1978 to July 1992 to every two hours thereafter and an increased focus on proper identification of Delta Smelt following its State and federal listings as threatened (Morinaka 2013b).

Similar to the TNS and FMWT results for Delta Smelt, Delta Smelt salvage has declined dramatically since the beginning of this time series (Fig. 26). This is similar to trends for Chinook Salmon and Striped Bass salvage (not shown), but opposite to trends for Largemouth Bass and Bluegill (*Lepomis macrochirus*) salvage (Fig. 27), two species that may be benefiting from conditions resulting from an apparent ecological regime shift (Baxter et al. 2010). The ratio of Delta Smelt salvage divided by the previous year's FMWT index has been used as a simple indicator of relative interannual entrainment losses. For adult (December-March) salvage, this ratio has been variable over time, but particularly high in the first three years of this time series (1980-1982, with 1982 being a wet year) and again during the beginning of a series of drought years in 1989 and in the fairly dry "POD" years 2003-2005 (Fig. 26). Current management

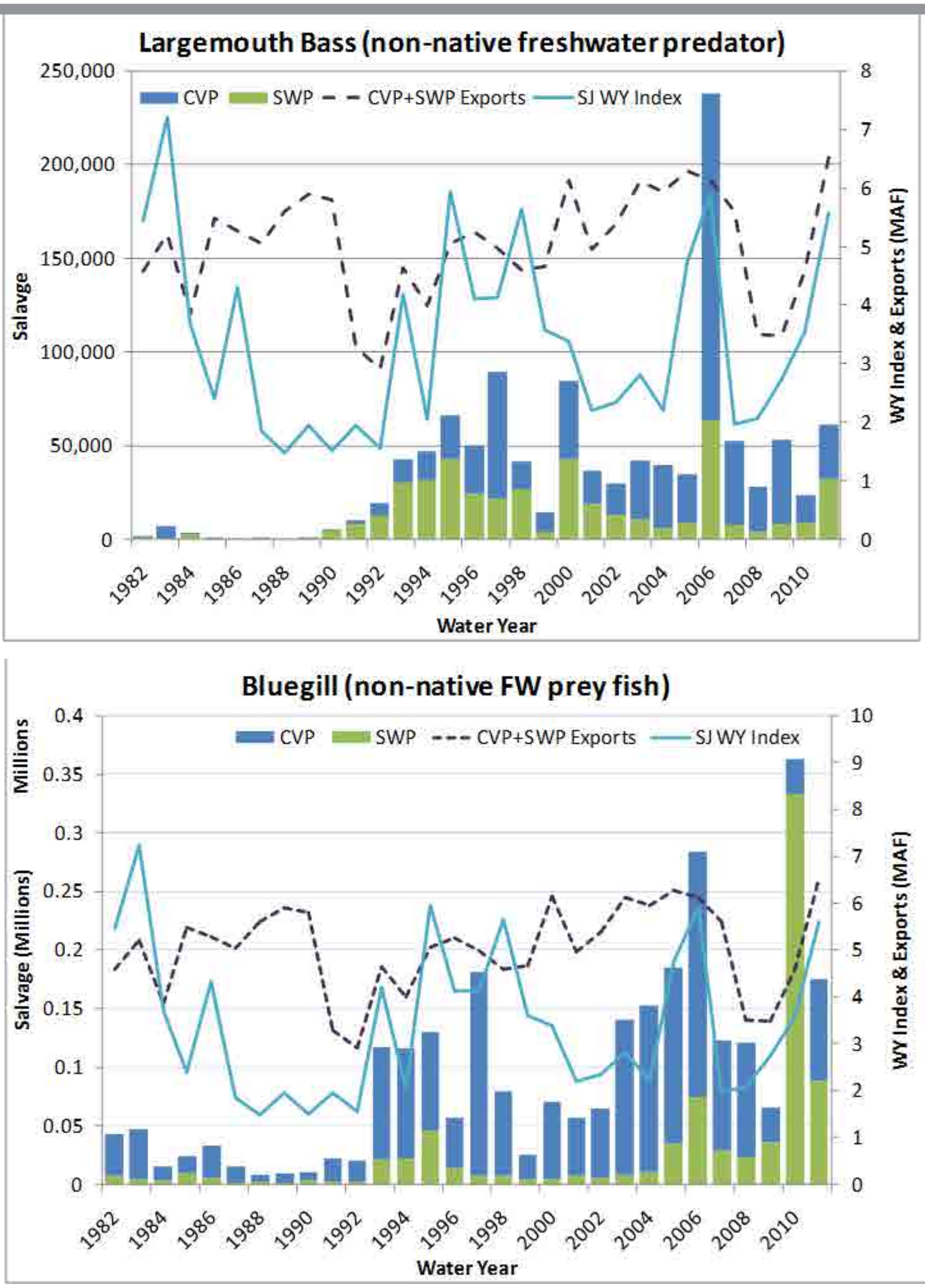
Figure 26. **A: Total reported October-March salvage for adult Delta Smelt and the corresponding mean salvage density based on the total monthly salvage and water volume exported by CVP and SWP. B: Both salvage and salvage density standardized by the Fall Midwater Trawl (FMWT) index for the previous year.**



provisions to protect Delta Smelt (USFWS 2008) are aimed at keeping this ratio at no more than the average during the period of 2006-2008.

Delta Smelt were salvaged nearly year-round in the beginning of this time series. Delta Smelt salvage since 2005 has occurred mostly from January through June, with substantial decline of May-June juvenile salvage since the mid 2000s (Fig. 28) and virtual disappearance of older juveniles from July-August salvage since the year 2000 (Fig. 29) and subadults since the early 1990s (Fig. 30). These patterns coincide with the near disappearance of Delta Smelt from the central and southern Delta in the summer (Nobriga et al 2008) and in the south Delta in the fall (Feyrer et al. 2007). Historically, adult and larval-juvenile (> 20 mm FL) Delta Smelt salvaged were not separately recorded and reported, but based on length measurements of a subset of salvaged fish, adults were predominantly salvaged between December and March or April

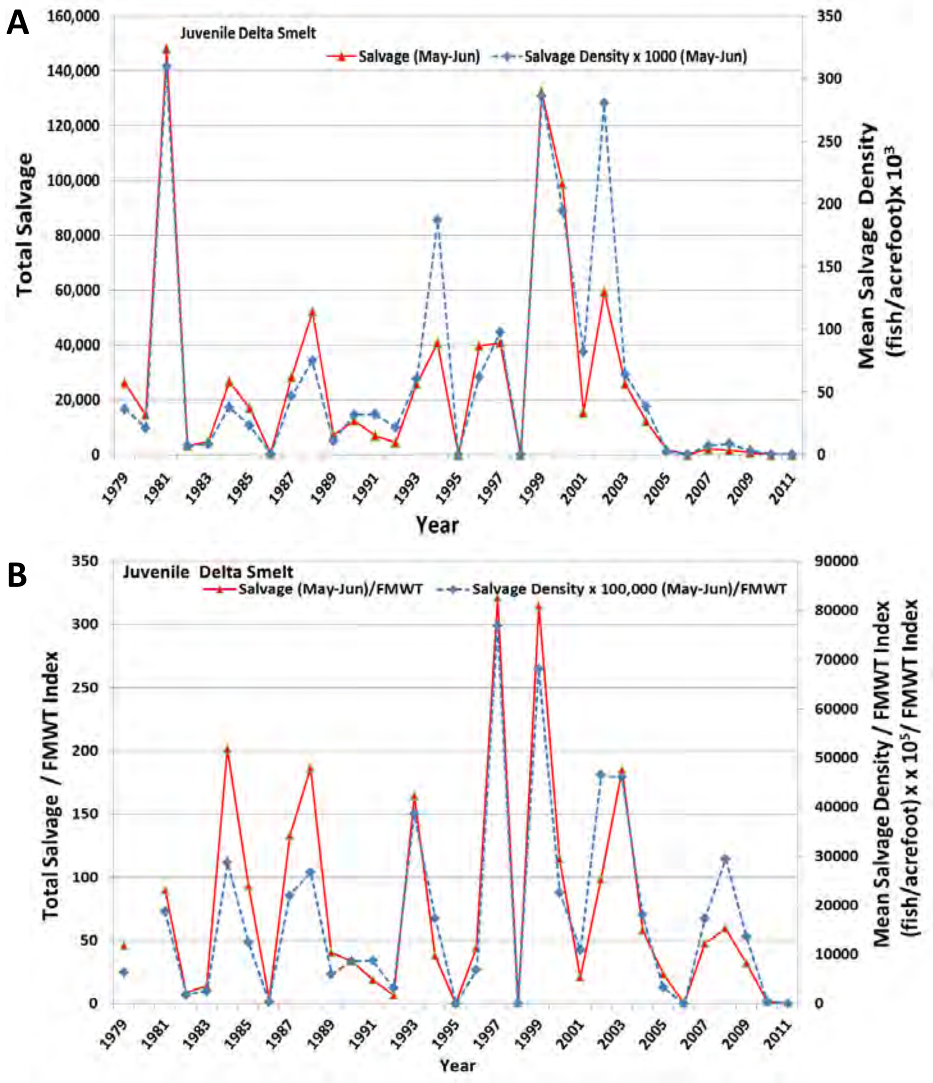
Figure 27. Annual time series of Largemouth Bass (top graph) and Bluegill (bottom graph) salvage at the CVP (blue bars) and SWP (green bars) fish protection facilities. Also shown are the annual San Joaquin Valley Water Year Index (SJWY Index) (blue line) and the combined annual (water year) SWP and CVP water export volume (purple line; MAF, million acre feet).



and most Delta Smelt larvae and juveniles were historically salvaged from April through July (Kimmerer 2008, Grimaldo et al. 2009).

Salvage data are routinely used to track and manage incidental take at the SWP and CVP and have been used to explore factors affecting entrainment and to estimate the effects of the SWP and CVP on Delta fishes. For example, Grimaldo et al. (2009) found that OMR flows and

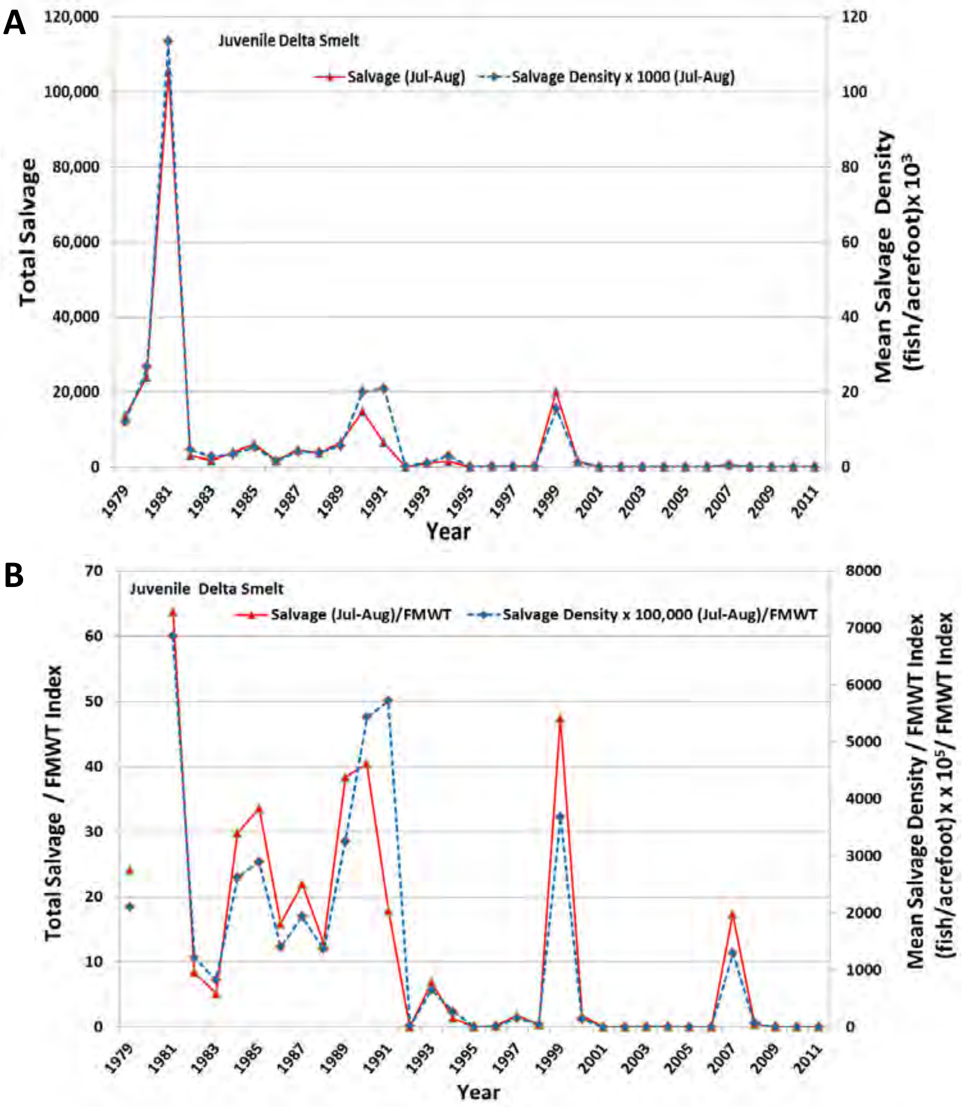
Figure 28. A: Total reported May-June salvage for juvenile Delta Smelt and the corresponding mean salvage density based on the total monthly salvage and water volume exported by CVP and SWP. B: Both salvage and salvage density standardized by the Fall Midwater Trawl (FMWT) index for the previous year.



turbidity account for much of the intra-annual variability in the salvage for juvenile and adult Delta Smelt.

It is important to remember, however, that salvage is only a very rough indicator of Delta Smelt entrainment. Based on mark-recapture experiments using cultured Delta Smelt, salvage was a very small fraction of total entrainment losses because of major pre-screen losses and low fish facility efficiency (Castillo et al. 2012). Experimental studies with cultured Chinook Salmon, Steelhead (*Oncorhynchus mykiss*), and Striped Bass have consistently shown that a large fraction (63% to 100%) of the entrained fish are not salvaged due to pre-screen losses and capture inefficiencies at the SWP fish facility (Brown et al. 1996, Gingras 1997, Clark et al. 2009). In addition, a mark–recapture test using field collected juvenile Chinook Salmon in CCF resulted in only 0.32% of the fish being salvaged (see Castillo et al. 2012). Pre-screen losses are generally

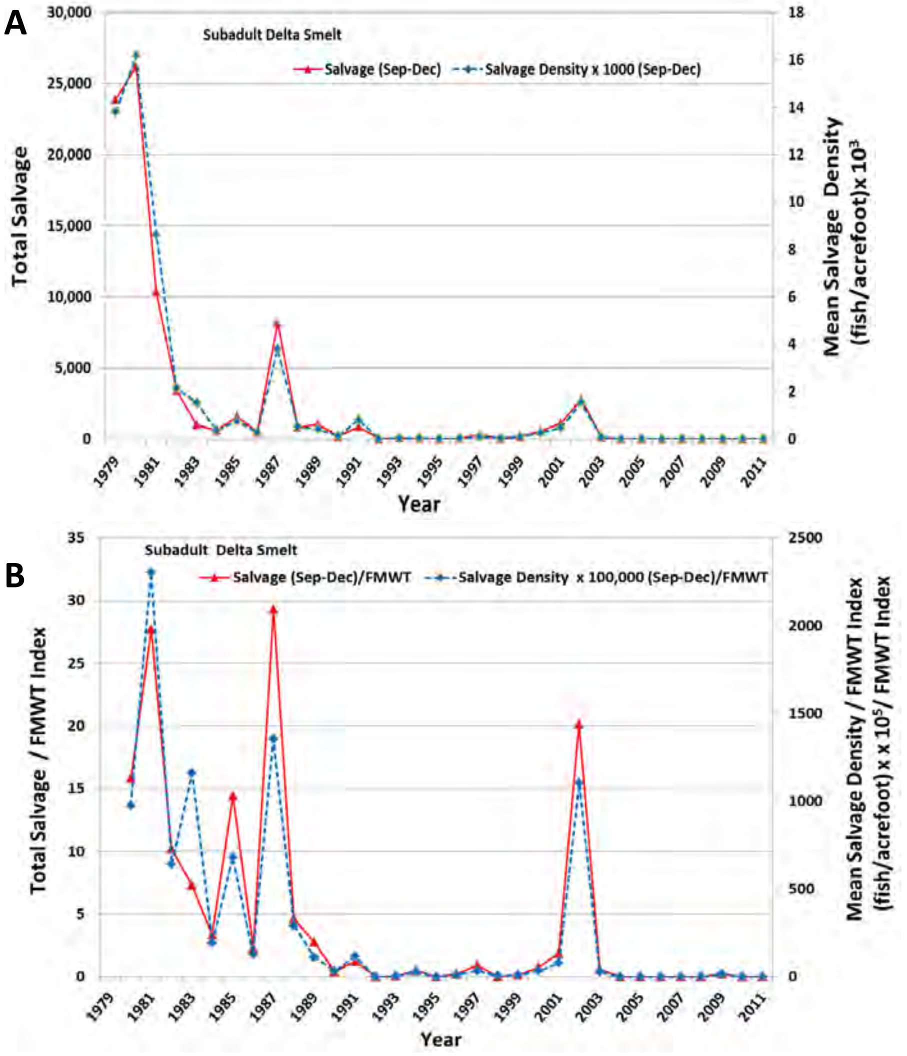
Figure 29. A: Total reported July-August salvage for juvenile Delta Smelt and the corresponding mean salvage density based on the total monthly salvage and water volume exported by CVP and SWP. B: Both salvage and salvage density standardized by the Fall Midwater Trawl (FMWT) index for the previous year.



attributed to increased predation and other unfavorable habitat conditions near the SWP and CVP pumps (e.g. Kano 1990, Brown et al. 1996, Gringas and McGee 1997, Clark et al. 2009, Castillo et al. 2012). For juvenile and adult Delta Smelt, Castillo et al. (2012) found that 94.3% to 100% of marked fish groups released into the SWP CCF were never salvaged and that salvage of marked fish decreased as the distance from the release site to SFPF increased and as residence time in CCF increased.

Large pre-screen losses of Delta Smelt in CCF are likely due to increased predation, especially when Delta Smelt spend a relatively long time in the reservoir in the presence of predators. MacWilliams and Gross (2013) used a particle tracking model to estimate residence time of passive particles, which can be considered surrogates for weakly swimming Delta Smelt. In 21-

Figure 30. **A: Total reported July-August salvage for sub-adult Delta Smelt and the corresponding mean salvage density based on the total monthly salvage and water volume exported by CVP and SWP. B: Both salvage and salvage density standardized by the Fall Midwater Trawl (FMWT) index for the same year.**



day simulations with the three-dimensional (3D) hydrodynamic model UnTRIM, MacWilliams and Gross (2013) found that the time particles spend in CCF varies greatly with wind and SWP operating conditions. They estimated transit times for passive particles (e.g., larval Delta Smelt) from the radial gates to the SFPF of 4.3 days under moderate export conditions (average daily SWP export rate of 2,351 cfs) and 9.1 days under low export conditions (689 cfs). The CVP does not have a regulating reservoir in the Delta and CVP pre-screen losses in the river channels leading to the TFCF are likely different from SWP pre-screen losses, but there are no studies quantifying these differences.

In general, Delta Smelt salvage increases with increasing net OMR flow reversal (i.e., more negative net OMR flows) and when turbidity exceeds 10-12 NTU (USFWS 2008, Grimaldo et al. 2009). Based on field and salvage data, Kimmerer (2008) calculated that from near 0% to 25% of larval-juvenile and 0% to 50 % of the adult Delta Smelt population can be entrained at the CVP and SWP annually, in years with periods of high exports. Although methods to calculate proportional loss estimates have since been debated (Kimmerer 2011, Miller 2011), a number of modeling efforts suggest that entrainment losses can adversely affect the Delta Smelt population (Kimmerer 2011, Maunder and Deriso 2011, Rose et al. 2013a, b).

High winter entrainment of Delta Smelt has been suspected as a contributing cause of both the early 1980s (Moyle et al. 1992) and the POD-era declines of Delta Smelt (Baxter et al. 2010). In addition to entraining Delta Smelt, water exports may likely also have indirect effects on Delta Smelt by contributing to adverse alterations of their habitat, for example, by changing Delta outflow and the size and location of the LSZ (see above) or by entraining food organisms (Jassby et al. 2002). The magnitude of these indirect effects of water exports on the Delta Smelt population has, however, not yet been quantified.

Delta Smelt are most vulnerable to entrainment when, as adults, they move from brackish water into fresh water, or as larvae, when they move from freshwater in the southern and central Delta into the brackish water of Suisun Bay. While some Delta Smelt live year-round in fresh water far from the CVP and SWP, most rear in the low-salinity regions of the estuary, also at a relatively safe distance from the SWP and CVP pumps. The timing, direction and geographic extent of the spawning movements of adult Delta Smelt affect their entrainment risk (Sweetnam 1999, Sommer et al. 2011a). Unlike the years prior to the 1990s, when high salvage of adult and juvenile Delta Smelt occurred at high, intermediate or low export levels, the risk of entrainment for fish that move into the central and south Delta is currently highest when net Delta outflow is at intermediate levels (~20,000 to 75,000 cfs) and OMR flow is more negative than -5000 cfs (USFWS 2008). In contrast, when adult Delta Smelt move upstream to the Sacramento River and into the Cache Slough region or do not move upstream at all, entrainment risk is appreciably lower. As explained later in this report, adult Delta Smelt may not move very far upstream during extreme wet years because the region of low salinity habitat becomes fresh and suitable for spawning (e.g., Suisun Bay or Napa River).

Transport mechanisms are most relevant to larval fishes, which have comparatively little ability to swim or otherwise affect their location. Dispersal from hatching areas to favorable nursery areas with sufficient food and low predation is generally considered one of the most important factors affecting the mortality of fish larvae (Hjort 1914, Hunter 1980, Anderson 1988, Leggett and Deblois 1994). Larvae of various smelt species exhibit diverse behaviors to reach and maintain favorable position within estuaries (Laprise and Dodson 1989, Bennett et al. 2002). Such nursery areas provide increased feeding success, growth rates and survival (Laprise and Dodson 1989, Sirois and Dodson 2000a, b, Peterson 2003, Hobbs et al. 2006). Until recently it was thought that larval Delta Smelt were transported from upstream hatching areas to downstream rearing areas, particularly the shallow productive waters of Suisun Bay (Moyle et al. 1992). Spring distributions of post-larval and small juvenile Delta Smelt support this view (Dege and Brown 2004). The distributions of these life stages were centered upstream of X2, but approached X2 as fish aged. These distributions could be displaced, and shifted up or down estuary with outflow and the shifting position of X2 (Dege and Brown 2004). More recent evidence suggests, however, that the timing and extent of downstream movement by young Delta Smelt is more variable than previously thought and that some may remain in upstream areas throughout the year (Sommer et al. 2011a, Contreras et al. 2011, Merz et al. 2011, Sommer and Mejia 2013).

Adult spawning site selection affects the potential importance of transport and entrainment to larvae. The risk of larval entrainment appears to increase with proximity to the south Delta export pumps (Kimmerer and Nobriga 2008). Larvae hatching in the San Joaquin River channel from

Big Break upstream to the city of Stockton and tidal channels south of these locations, can be affected by several interacting processes. Flows from the San Joaquin, Calaveras, Mokelumne and Cosumnes rivers act to cause net downstream flow, whereas export levels at the south Delta pumps act to reverse net flows in the lower San Joaquin River. High export rates can create negative flows past Jersey Point on the lower San Joaquin River ("Qwest," see Dayflow documentation: http://www.water.ca.gov/dayflow/output/Output.cfm) and negative OMR flows (Fig. 31). Since the onset of the POD in 2002, positive average monthly OMR flows have only occurred in 9 months (6%) during the wettest years and average monthly Qwest flows were negative in just under half (49%) of all months (Fig. 31). Tidal conditions can also act in favor of downstream transport or entrainment depending upon whether the Delta is filling or draining in response to the fortnightly spring-neap cycle (Arthur et al. 1996). The combination of high export and low inflow can create very asymmetrical tides in OMR that covary with net negative flow resulting in stronger floods compared to ebbs, which may also contribute to fish entrainment.

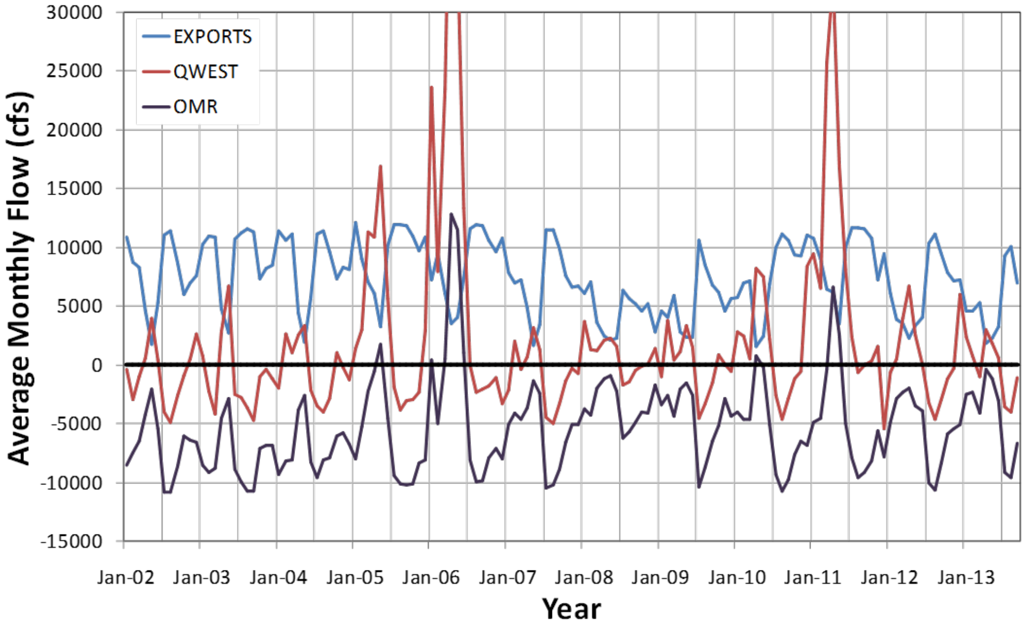
Predation Risk

Small planktivorous fishes, including osmerids, serve as prey for larger fishes, birds and mammals. As prey, they have the critically important trophic function of transferring energy to higher trophic levels. Consequently, they are often subjected to intense predation pressure (Gleason and Bengsten 1996, Jung and Houde 2004, Hallfredsson and Pedersen 2009). Prey fish populations compensate for high mortality through high reproductive rates, including strategies such as repeat spawning by individuals and rapid maturation (Winemiller and Rose 1992, Rose et al. 2001). Predation can be a dominant source of mortality for fish larvae, along with starvation and dispersion to inhospitable habitats (Hjort 1914, Hunter 1980, Anderson 1988, Leggett and Deblois 1994).

Since predation is a natural part of functional aquatic ecosystems, predators are likely not responsible for long-term declines in populations of prey fishes, such as Delta Smelt, without some additional sources of stress that disrupt the predator-prey relationship (Nobriga et al. 2013). Predation may become an issue when established predator-prey relationships are disrupted by habitat change or species invasions (Kitchell et al. 1994). As described in Chapter 1, the SFE has been extensively modified (Nichols et al. 1986, Cohen and Carlton 1998, Whipple et al. 2012, Cloern and Jassby 2012) so disrupted relationships between predators and prey are certainly plausible. For example, prey may be more susceptible to predation if they are weakened by disease, contaminants, poor water quality, or starvation. Similarly, the creation of more "ambush habitat" (e.g. structures, weed beds), declines in turbidity levels, or the introduction of a novel piscivore also may dramatically shift the existing predator-prey relationships (Ferrari et al. 2014). All of these changes have in fact taken place in the estuary, especially in the central and south Delta (Feyrer and Healey 2003, Nobriga et al. 2005, Brown and Michniuk 2007).

Virtually all fishes of appropriate size will feed on fish larvae when available and predation is theoretically maximal when larvae lengths are 10% of the length of the predator (Paradis et al. 1996). Presently, Mississippi Silverside (*Menidia audens*) is thought to be the most substantial predator of Delta Smelt larvae (Bennett and Moyle 1996, Bennett 2005, Baerwald et al. 2012). Juvenile and adult Delta Smelt have also been reported from the stomach contents of Striped Bass (Stevens 1963, Stevens 1966, Thomas 1967), White Catfish (*Ictalurus catus*) and Black Crappie (*Pomoxis nigromaculatus*) (Turner 1966a,b). Stevens (1963) reported "freshwater smelt" to be a very common component of Striped Bass stomach contents (nearly 100% frequency of occurrence in fifteen stomachs with food) on the Sacramento River near Paintersville Bridge

Figure 31. **Flows in cubic feet per second for Qwest (positive values are seaward), Old and Middle River (OMR) (positive values are seaward), and total exports for years since the beginning of the pelagic organism decline (POD). Maximum monthly average Qwest values in 2006 and 2011 omitted to improve graph display, values are 50,086 cfs in April 2006, 35,477 in May 2006, and 32,884 cfs in April 2011 (Qwest and Export data are from 2013 Dayflow, OMR data are from USGS).**



during March-April 1963. During 1963-1964, Stevens (1966) also evaluated seasonal variation in the diets of juvenile Striped Bass throughout the Delta; only age 2 and age 3 Striped Bass contained more than trace amounts of Delta Smelt. The highest reported predation on Delta Smelt was 8% of the age 2 Striped Bass diet by volume during the summer. Thomas (1967) reported on spatial variation in Striped Bass diet composition based on collections throughout the SFE and the Sacramento River above tidal influence. The field collections occurred from 1957-1961; data were collected on age 1 and older Striped Bass but data were only summarized as all ages combined. Delta Smelt accounted for 8% of the spring diet composition and about 16% of the summer diet composition in the Delta.

Several authors tested hypotheses about inverse correlations between estimates of adult and juvenile Striped Bass abundance and indices of Delta Smelt relative abundance or survival (Mac Nally et al. 2010, Thomson et al. 2010, Maunder and Deriso 2011, Miller et al. 2012, Nobriga et al. 2013). None of these statistical analyses has found evidence for the expected inverse correlation. Modeling studies indicate that Striped Bass predation rates on prey are affected by temperature and predator abundance (mostly the latter; Loboschefsky et al. 2012). However, the links between prey abundance and predator abundance vary from strong to non-existent, depending on the strength of their interaction in the food web (Essington and Hansson 2004). It is not currently known if changes in juvenile Striped Bass abundance correspond with changes in population-level or per capita Striped Bass predation rate on Delta Smelt (Nobriga et al. 2013).

Recent modeling efforts show that Delta Smelt declines are negatively associated with metrics assumed to reflect the abundance of predators in the estuary (Maunder and Deriso 2011, Miller et al. 2012). These metrics are composites of the relative abundance of Mississippi Silverside, Largemouth Bass and other centrarchids; species that are potential predators of concern because of their increasing abundance (Fig. 27; Bennett and Moyle 1996, Brown and Michniuk 2007, Thomson et al. 2010), and because of inverse correlations between Largemouth Bass abundance and Delta Smelt abundance (Nobriga and Feyrer 2007, Thomson et al. 2010, Maunder and Deriso 2011). These correlations could represent predation on Delta Smelt by Largemouth Bass, or alternatively, the very different responses of the two species to changing habitat within the Delta (Moyle and Bennett 2008). Current data suggest that Largemouth Bass populations have expanded as the SAV *Egeria densa* has expanded and have come to dominate parts of the Delta (Brown and Michniuk 2007). *E. densa* and Largemouth Bass are particularly prevalent in the central and southern Delta (Brown and Michniuk 2007) and Largemouth Bass may contribute to the pre-screen losses of Delta Smelt entrained into the SWP and CVP export pumps (see above). Largemouth Bass will readily eat Delta Smelt when the opportunity exists (Ferrari et al. 2014). However, there is little evidence that Largemouth Bass are major consumers of Delta Smelt due to low spatial co-occurrence (Nobriga et al. 2005, Baxter et al. 2010; L. Conrad, California Department of Water Resources, unpublished data). Thus, the inverse correlations between these species may not be mechanistic. Rather, they may reflect adaptation to, and selection for, different environmental conditions.

As noted above, predation on fish larvae can also be an important source of mortality. Juvenile and small adult fishes of many species will consume fish larvae when they are available. Major predators of the eggs and larvae of nearshore coastal and pelagic estuarine forage fishes can include invertebrates (DeBlois and Leggett 1993) and numerous small fishes not typically thought of as “piscivorous” (Johnson and Dropkin 1992), including adults of their own species (Takasuka et al. 2003). Bennett and Moyle (1996) and Bennett (2005) noted this and specifically identified Mississippi Silversides (hereafter, Silversides) as potential predators on Delta Smelt larvae. These authors also documented increases in the Silverside population from the mid-1970s through 2002. Consumption of Delta Smelt larvae by Silversides in the Delta was recently verified using DNA techniques (Baerwald et al. 2012). Larval predation is discussed in more detail in the next Chapter.

Contaminants

Fish are particularly sensitive to alterations in the chemical composition of the natural aquatic environment, as these changes can have significant impacts on their behavioral and physiological systems (Radhaiah et al. 1987). Chemical alterations can be the result of natural processes, for example the changes in local water quality associated with tidal water movements or natural biogeochemical processes, or they can be caused by pollution from watershed- or land-based sources of nutrients, such as nitrogen compounds, and contaminants, such as pesticides, metals, and contaminants of emerging concerns (CECs). The movement of contaminants through aquatic ecosystems is complex and dynamic, and many contaminants are difficult to detect and expensive to monitor (Scholz et al. 2012).

Portions of the SFE are listed as “impaired” on California’s 303(d) list of Impaired Water Bodies due to metals, pesticides, legacy pollutants, and nutrients that exceed established water quality objectives (SWRCB 2010). In particular, the entire SFE has been listed as impaired due to pollution with metals, such as mercury and selenium, and pesticides such as chlorpyrifos, DDT (Dichlorodiphenyltrichloroethane), and diazinon. The entire Delta, but not the bays of the SFE, is also listed for observed toxicity to aquatic organisms. In addition, the Stockton Ship Channel in the southeastern Delta is listed for enrichment with nutrients, organic compounds, and low dissolved oxygen levels; Old River in the south-central Delta is listed for elevated salinity (electrical conductivity; EC) and total dissolved solids (TDS). Delta Smelt are likely exposed to a variety of these contaminants throughout their life cycle; however, the frequency and magnitude of the effects of contaminants on Delta Smelt health and reproduction are not very well understood in the SFE (Johnson et al. 2010, Brooks et al. 2012). The following sections describe the potential effects of key contaminants on Delta Smelt.

Pesticides

Pesticides produce many physiological and biochemical changes in freshwater organisms through their influence on the activities of several enzymes (Khan and Law 2005). Specifically, pesticides can have an adverse effect on hormones or other chemical messengers important to the health of an individual. Previous work has shown that chronic exposure to low levels of pesticides may even have a more adverse effect on fish than a single acute exposure to high levels. Chronic exposures were associated with changes in behavior and physiology that could influence survival and reproduction of wild fish (Ewing 1999). Biochemical and physiological stresses induced by exposure to pesticides can result in metabolic disturbances, retardation of growth, as well as reduction in longevity and fecundity (Murty 1986).

Pesticides are among the key contaminants believed to have contributed to the Delta Smelt decline (Johnson et al. 2010, Brooks et al. 2012, NRC 2012). Because pesticide concentrations in surface water are typically highest during the winter and spring, pesticides are most likely to affect the adult and larval life stages; however, effects may occur during any life stage as pesticides are seasonally and geographically widespread (Kuivila and Hladik 2008). Kuivila and Moon (2004) found that peak densities of larval and juvenile Delta Smelt sometimes coincided in time and space with elevated concentrations of dissolved pesticides in the spring. These periods of co-occurrence lasted for up to 2–3 weeks. While concentrations of individual pesticides were lower than would be expected to cause acute mortality, little is known of the sublethal effects of pesticides on Delta Smelt. Although little evidence exists for acute effects of pesticides on fish or invertebrates, several studies have documented sublethal effects on fish health (Werner et al. 2008, Werner et al. 2010a, Werner et al. 2010b).

Herbicides and fungicides were among the most commonly detected classes of pesticides observed in water and sediment in the Delta and are also found in fish tissue (Orlando et al. 2013, Smalling et al. 2013). Herbicides are known to affect primary producers, while insecticides can affect invertebrate prey species (e.g., Brander et al. 2009, Weston et al. 2012), which could lead to contaminant-mediated food limitation for Delta Smelt. Fungicides have been found to cause endocrine disruption in fish, including reduced fecundity (Ankley et al. 2005). Recent work has shown that the insecticide esfenvalerate affects swimming behavior of exposed larval Delta Smelt (Connon et al. 2009). It was also found to alter the expression of genes involved in neuromuscular activity and immune response, detoxification, and growth and development (Connon et al. 2009). Additionally, insecticides are known to affect predator-prey relationships for fish, as well as lead to endocrine disruptions (Scholz et al. 2000, Junges et al. 2010, Relyea and Edwards 2010, Riar et al 2013, Forsgren et al. 2013). Contamination of aquatic systems by pyrethroid insecticides was recently found to lead to genetic point mutations in the nontarget, aquatic amphipod *Hyalella azteca*, resulting in differences in pyrethroid sensitivity. Wild populations of *H. azteca* collected from areas with high sediment concentrations of pyrethroids exhibited remarkable resistance to pyrethroids compared to laboratory cultures and the observed resistance was highly coupled to the presence of a genetic mutation. The LC50s (concentration that is lethal to 50% of the exposed population) of previously-exposed wild populations were up to two orders of magnitude greater than LC50s of laboratory cultures. Moreover, the presence of a genetic mutation was detected in 100% of *H. azteca* that survived exposure to high pyrethroid concentrations. The development of such resistance can result in costs to genetic and biological diversity, including reduced fitness, and may lead to impacts to the food web (Weston et al. 2013). The presence of such resistance and genetic mutations in Delta Smelt as a result of pyrethroids or other pesticide exposure has not been investigated

It is also important to note that environmental factors such as temperature and salinity affect pesticide toxicity in fish (Coats et al. 1989, Lavado et al. 2009). For that reason, seasonal variation in environmental factors may result in greater risk to certain life stages. The results above are for dissolved pesticides; pesticides may also be bound to sediments, representing another possible mechanism of exposure. Pesticides, such as pyrethroids and organochlorines, that strongly bind to sediment may be particularly important to the adult and larval life stage of Delta Smelt as these life stages occur during the winter and spring, when rain events (including the “first flush”) transport sediment and associated contaminants into the Delta; however, as the mechanisms that influence the desorption rates of pesticides are complex (e.g., temperature, contact time, pesticide) (e.g., Xu et al. 2008, Cornelissen et al. 1998), exposure rates for Delta Smelt lifestages are likely multifaceted and difficult to predict.

Ammonia and Ammonium

Agricultural operations, wastewater treatment plant effluent, and other sources contribute to the accumulation of nutrients in the Delta. Nutrients, such as ammonium (a cation) and ammonia (its toxic, unionized form) are of particular concern in the Delta, as they can have significant negative effects on Delta Smelt and their habitat. Ammonium is increasingly converted into ammonia as pH rises. Delta Smelt spawning and larval nursery areas in the northern Delta are at particular risk to exposure to ammonia/um, mainly due to discharge by the Sacramento Regional Wastewater Treatment Plant (SRWTP) into the lower Sacramento River (Connon et al. 2011a). However, effects of nutrients such as ammonia/um are likely at all Delta Smelt life stages, as nutrients are discharged throughout the Delta year-round.

Recent work demonstrated that Delta Smelt exposed to ammonia exhibited membrane destabilization, which may lead to increased membrane permeability as well as increased susceptibility to synergistic effects of multi-contaminant exposures (Connon et al. 2011a, Hasenbein et al. 2013b); however, the concentrations of ammonia used in these studies were higher than the concentrations typically experienced by Delta Smelt in the wild. In other fish species, sublethal concentrations of ammonia/um have also led to histological effects such as gill lamellae fusions and deformities (Benli et al. 2008). Other work has also shown that neurological and muscular impacts of ammonia/um resulted in slowed escape response and subsequent mortality (McKenzie et al. 2008).

Metals and Other Elements of Concern

Historic mining sites, industrial and domestic wastewater discharges, and agricultural runoff are largely responsible for the presence of metals and other elements of concern in the Delta. Metals of particular importance in the Delta include copper and mercury; selenium is a trace element of concern. Delta Smelt exposed to copper exhibited reduced swimming velocities and suffered digestive and neurological effects (Connon et al. 2011b). Other sublethal effects on fish caused by exposure to these elements include reduced fertility and growth, impaired neurological and endocrine functions, and skeletal deformities that affect swimming performance (Boening 2000, Chapman et al. 2010). These elements are often associated with sediment and may be particularly important to the adult and larval life stages, since sediment is transported with significant rain events, including the "first flush."

Contaminants of Emerging Concern

Contaminants of emerging concern (CECs) such as pharmaceuticals, hormones, personal care products, and industrial chemicals are of increasing concern because they are widespread in the aquatic environment, biologically active, and are relatively unregulated (Kolpin et al. 2002, Pal et al. 2010). The California State Water Resources Control Board is currently investigating CECs in the Delta (http://www.sccwrp.org/ResearchAreas/Contaminants/ContaminantsOfEmergingConcern/ EcosystemsAdvisoryPanel.aspx). CECs originate from many sources including industrial and domestic wastewater. They are responsible for a myriad of sublethal effects in fish including endocrine disruption, changes in gene transcription and protein expression, and morphological and behavioral changes (Brander 2013). Though the effects of CECs have been well studied in other fish species, the extent to which they influence Delta Smelt remains unclear.

Polycyclic Aromatic Hydrocarbons (PAHs) and Polychlorinated Biphenyls (PCBs)

The PAHs and PCBs found in the Delta are largely from urban and industrial sources. PAHs are formed during the incomplete burning of coal, oil, gas, garbage, and other organic substances. PCBs are synthetic organic chemicals that were used in many industrial and commercial applications. PCBs were banned in 1979, but continue to persist in the environment. PAHs and PCBs bind strongly to sediment and therefore are likely to be associated with the "first flush" and may be particularly important to the adult and larval life stages of Delta Smelt. Almost all sediments sampled in the Delta in 2006 contained PAHs (mean concentration of 0.3 parts per million in Suisun Bay) and PCBs (mean concentration of 0.8 parts per million in Suisun Bay) (SFEI 2007). Studies have found PAHs and PCBs in surface water, with concentrations in excess of established water quality objectives (Thomson et al. 2000, Oros et al. 2006). Both PCBs and PAHs can cause endocrine disruption in fish (Brar et al. 2010, Nicolas, 1999); however, specific impacts on Delta Smelt have not been documented.

Contaminant Mixtures

While the individual effects of the aforementioned contaminants can be severe, recent work has demonstrated that the interaction of the contaminants within mixtures can have both synergistic and antagonistic effects, exacerbating potential impacts on fish physiology (e.g., Jordan et al. 2012). There is increasing evidence that compounds in mixtures show adverse effects at concentrations at which no effects were observed for single toxicants (e.g., Baas et al. 2009, Silva et al. 2002, Walter et al. 2002). For example, recent work on Mississippi Silversides has demonstrated that contaminant mixtures resulted in endocrine disruptions such as varied expression of mRNA levels for estrogen-responsive genes, reduced mean gonadal somatic indices (GSI), testicular necrosis, and biased sex ratios (Brander et al. 2013). Studies have also shown that mixtures can affect predator-prey interactions (Relyea and Edwards 2010) and cause liver abnormalities (Sacramento Splittail, *Pogonichthys macrolepidotus*; Greenfield et al. 2008). Other work on Striped Bass has demonstrated that contaminant mixtures can be maternally-transferred to fish eggs, resulting in larvae with impaired growth and abnormal brain and liver development (Ostrach et al. 2008).

Due to the unpredictability of their effects on organisms, the synergistic effects of contaminant mixtures have received a great deal of attention both within pharmacology and environmental sciences (Arnold et al. 1996, Ashby et al. 1997, Berenbaum 1989, Greco et al. 1995, Liang and Lichtenstein 1974). Currently, one of the greatest challenges in chemical mixture research is how to deal with the infinite number of combinations of chemicals and other stressors, as well as their interactive effects, on organisms (Baas et al. 2010). Additional challenges also exist trying to relate lab-based findings to wild populations for studies examining the effects of individual contaminants and contaminant mixtures on organisms using exposure concentrations that are environmentally representative. Therefore, while the potential for exposure to contaminant mixtures in all Delta Smelt life stages is highly probable, any specific effects of such interactions on Delta Smelt remain unknown.

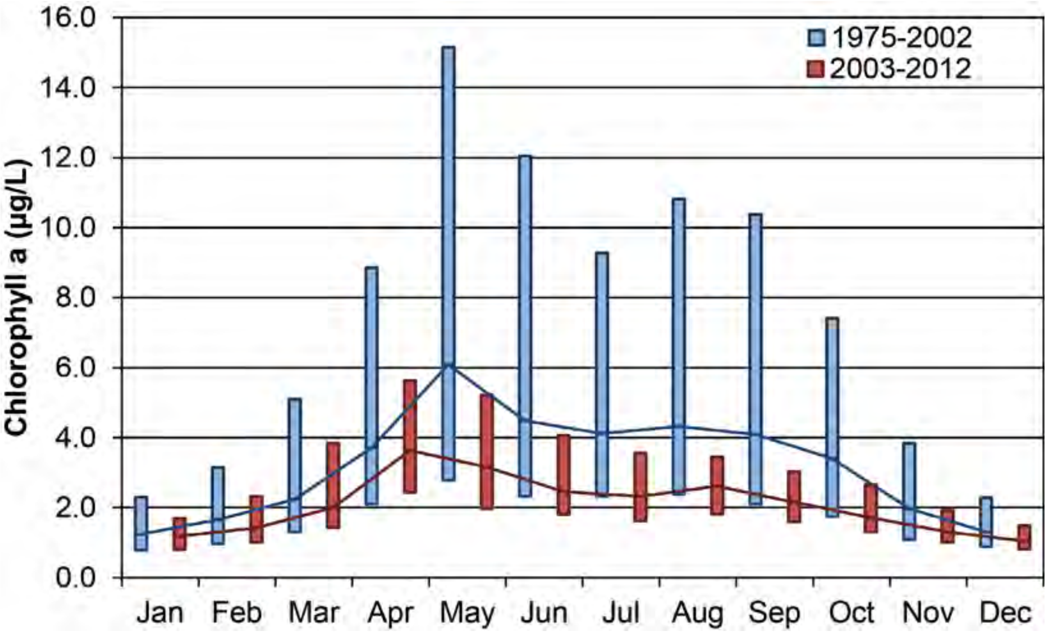
Food and Feeding

The presence of food is, obviously, a critical habitat attribute for any organism; however, the factors determining the quantity and quality of available food can be quite complex. In this section, we begin with a brief review of information about trophic processes in the upper SFE. We then discuss the available data on prey consumed by Delta Smelt. Finally, we provide a review of information on factors possibly affecting abundance and quality of food organisms.

Estuaries are commonly characterized as highly productive nursery areas for a suite of organisms. Productivity of estuarine ecosystems is often fueled by detritus-based food webs. In the SFE, much of the community metabolism in pelagic waters does result from microbial consumption of organic detritus. However, evidence suggests that metazoan production in pelagic waters is primarily driven by phytoplankton production (Sobczak et al. 2002, 2005, Mueller-Solger et al. 2002, 2006, Kimmerer et al. 2005). Protists (flagellates and ciliates) consume both microbial and phytoplankton prey (Murrell and Hollibaugh 1998, York et al. 2010) and are an additional important food source for many copepod species in the estuary (Rollwagen-Bollens and Penry 2003, Bouley and Kimmerer 2006, Gifford et al. 2007, McManus et al. 2008). However, the conversion of dissolved and particulate organic matter to microbial biomass and then to zooplankton is a relatively slow and inefficient process. Shifts in phytoplankton and microbial food resources for zooplankton might favor different zooplankton species. Moreover, phytoplankton production and biomass in the SFE is low compared to many other estuaries (e.g., Jassby et al. 2002, Kimmerer et al. 2005, Wilkerson et al. 2006, Cloern and Jassby 2012). The recognition that phytoplankton production might impose limits on pelagic fishes, such as Delta Smelt, through food availability has led to intense interest in factors affecting phytoplankton production and species composition and in management actions aimed at enhancing high-quality phytoplankton production. In addition, there is a major need to understand other trophic pathways given the observation that larger Delta Smelt periodically can take advantage of epibenthic prey (see below).

Phytoplankton biomass (measured as chlorophyll-*a*) has been routinely monitored in the estuary since the 1970s. The 1975-2012 median chlorophyll-*a* concentration across all IEP EMP stations is 2.8 µg/L (n = 13482, interquartile range (IQR) = 5 µg/L). Seasonally, the highest chlorophyll-*a* concentrations tend to be observed in May and June and the lowest concentrations in December and January (Fig. 32). Regionally, monitoring stations in the South Delta/San Joaquin River usually have the highest chlorophyll-*a* concentrations. There has been a well-documented long-term decline in phytoplankton biomass (chlorophyll-*a*) and primary productivity (estimated from measurements of chlorophyll-*a* and of water column light utilization efficiency) to very low levels in the Suisun Bay region and the lower Delta (Jassby et al. 2002). Jassby et al. (2002) detected a 47% decline in June–November chlorophyll-*a* and a 36% decline in June–November primary production between the periods 1975–1985 and 1986–1995. Jassby (2008) updated the phytoplankton analysis to include the more recent data (1996–2005) from the Delta and Suisun Bay. Jassby (2008) confirmed a long-term decline in chlorophyll-*a* from 1975 to 2005 but also found that March–September chlorophyll-*a* had an increasing trend in the Delta from 1996 to 2005. Suisun Bay did not exhibit any trend during 1996–2005. A similar pattern was noted for primary production in the Delta. These chlorophyll-*a* patterns continued to hold through 2008 according to a more recent study by Winder and Jassby (2011). In the most recent decade (2003-2012), the median chlorophyll-*a* concentration across all IEP EMP stations was 2 ug/L (n = 2620, IQR = 2 ug/L), compared to the 1975-2002 median chlorophyll-*a* concentration of 3 ug/L (n = 10862, IQR = 6 ug/L) (Fig. 32). Most of the decrease was due to declines during May-October and especially the near-elimination of the formerly common “spring bloom” of phytoplankton in May (Fig. 32). In summary, phytoplankton biomass and production in the Delta and Suisun Bay seem to have reached a low point by the end of the 1987–1994 drought. While they recovered somewhat in the Delta, chlorophyll-*a* stayed consistently low in Suisun Bay through the POD years.

Figure 32. **Interquartile ranges (boxes) and medians (lines) for chlorophyll-*a* measured monthly at all IEP EMP stations from 1975-2002 (blue) and 2003-2012 (red). Data from http://www.water.ca.gov/bdma/.**



A major reason for the long-term phytoplankton reduction in the upper SFE after 1985 is benthic grazing by the invasive overbite clam (*Potamocorbula amurensis* also known as *Corbula amurensis*) (Alpine and Cloern 1992), which became abundant by the late 1980s (Kimmerer 2002). The overbite clam was first reported from San Francisco Estuary in 1986 and it was well established by 1987 (Carlton et al. 1990). Prior to the overbite clam invasion, the invasive Asiatic freshwater clam (*Corbicula fluminea*) (introduced in the 1940s) colonized Suisun Bay during high flow periods and the estuarine clam *Mya arenaria* (also known as *Macoma balthica*, an earlier introduction) colonized Suisun Bay during prolonged (> 14 month) low flow periods (Nichols et al. 1990). Thus, there were periods of relatively low clam grazing rates while one species was dying back and the other was colonizing, resulting in neither reaching high abundances. The *P. amurensis* invasion changed this formerly dynamic clam assemblage because *P. amurensis*, which is tolerant of a wide range of salinity, can maintain large, permanent populations in the brackish water regions of the estuary. *P. amurensis* biomass and grazing usually increase from spring to fall which contributes to the reduction in phytoplankton biomass from May to October relative to historical levels. In addition, the grazing influence of *P. amurensis* extends into the freshwater Delta beyond the clam's typical brackish salinity range, presumably due to tidal dispersion of phytoplankton-depleted water between regions of brackish water and fresh water (Kimmerer and Orsi 1996, Jassby et al. 2002).

Phytoplankton production in the SFE has been considered primarily light-limited because nutrient concentrations commonly exceed concentrations limiting primary production. According to some recent work, shifts in nutrient concentrations and ratios may, however, also contribute to the phytoplankton reduction and changes in algal species composition in the SFE. Nutrients may also play a larger role in regulating phytoplankton dynamics in the estuary as the estuary clears and light availability increases (see turbidity section above).

While phosphorus (total phosphorous and soluble reactive phosphorous) concentrations declined in the Delta and Suisun Bay region over the last few decades, nitrogen (total nitrogen and ammonium) concentrations increased. These changes have been attributed to the operation of the Sacramento Regional Wastewater Treatment Plant (SRWTP), a large secondary treatment facility that was completed in 1984 (VanNieuwenhuyse 2007, Jassby 2008). As stated previously, ammonia has two forms, un-ionized ammonia (NH_3) which is toxic to aquatic organisms and the ammonium ion (NH_4+) which is considerably less toxic to animals and an important nutrient for plants and algae (Thurston et al. 1981). Ammonia exists in equilibrium between the two forms dependent primarily on the pH of the water, but also temperature, with increases in pH and temperature favoring the un-ionized form (Thurston et al. 1981). Dugdale et al. (2007) and Wilkerson et al. (2006) found that high ammonium concentrations prevented the formation of diatom blooms but stimulated flagellate blooms in the lower estuary. They propose that this occurs because diatoms preferentially utilize ammonium in their physiological processes even though it is used less efficiently and at high concentrations ammonium can prevent uptake of nitrate (Dugdale et al. 2007). Thus, diatom populations must consume available ammonium before nitrate, which supports higher growth rates, can be utilized or concentrations of ammonium need to be diluted. A recent independent review panel (Reed et al. 2014) found that there is good evidence for preferential uptake of ammonium and sequential uptake of first ammonium and then nitrate, but that a large amount of uncertainty remains regarding the growth rates on ammonium relative to nitrate and the role of ammonium in suppressing spring blooms.

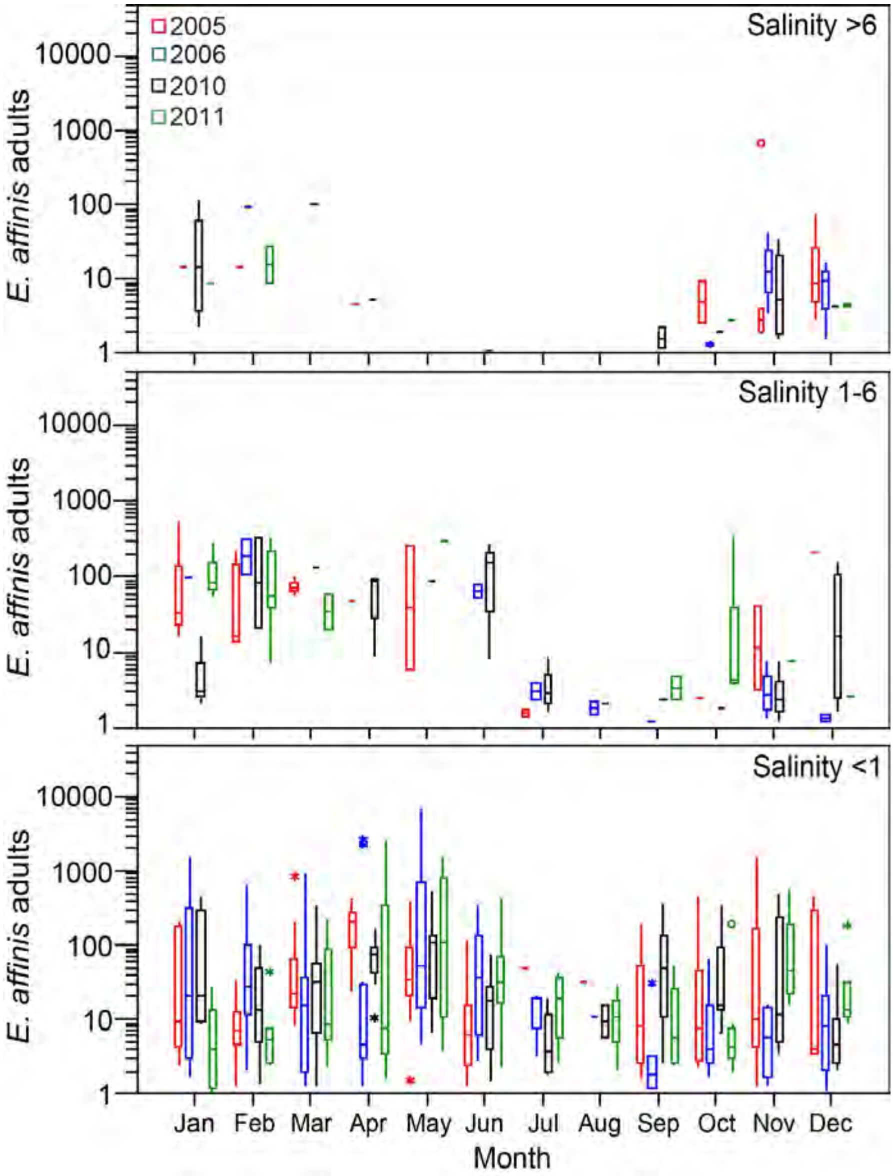
Glibert (2012) analyzed long-term data (from 1975 or 1979 to 2006 depending on the variable considered) from the Delta and Suisun Bay and related changing forms and ratios of nutrients, particularly changes in ammonium, to declines in diatoms and increases in flagellates and cyanobacteria. Similar shifts in species composition were noted by Brown (2009), with loss of diatom species, such as *Thalassiosira sp*., an important food for calanoid copepods, including *Eurytemora affinis* and *Sinocalanus doerri* (Orsi 1995). More recently, Parker et al. (2012) found that the region where blooms are suppressed extends upstream into the Sacramento River to the SRWTP, the source of the majority of the ammonium in the river (Jassby 2008). Parker et al. (2012) found that at high ambient ammonium concentrations, river phytoplankton cannot efficiently take up any form of nitrogen including ammonium, leading to often extremely low biomass in the river. A study using multiple stable isotope tracers (Lehman et al. 2014) found that the cyanobacteria *M. aeruginosa* utilized ammonium, not nitrate, as the primary source of nitrogen in the central and western Delta. In 2009, the ammonia concentration in effluent from SRWTP was reduced by approximately 10%, due to changes in operation (K. Ohlinger, Sacramento Regional County Sanitation District, personal communication). In spring 2010 unusually strong spring diatom blooms were observed in Suisun Bay that co-occurred with low ammonia concentrations (Dugdale et al. 2013).

Jassby (2008) suggested the following comprehensive explanation for his observations. Phytoplankton production in the lower Delta is associated with flow and residence time; however, other factors introduce a substantial degree of interannual variability. Benthic grazing by *C. fluminea* is likely a major factor as grazing can exceed rates of primary production (Lucas et al. 2002, Lopez et al. 2006) and are abundant year round at some locations in the Delta (Fuller 2012). Current data are inadequate to estimate the overall magnitude of the grazing effect of *C. fluminea*. In Suisun Bay, benthic grazing by *P. amurensis* is a controlling factor that keeps phytoplankton at low levels. Thus, metazoan populations in Suisun Bay are dependent on importation of phytoplankton production from the upstream portions of the Delta. Upstream Delta phytoplankton can be lost via exports and within-Delta depletion; Cloern and Jassby (2012) reported phytoplankton losses equivalent to 30% of the primary production in the Delta. Ammonium concentrations and water clarity have increased; however, these two factors should have opposing effects on phytoplankton production. These factors likely also contribute to variability in the interannual pattern but the relative importance of each is unknown. The interactions among primary production, grazing, and transport time can be complex (Lucas et al. 2002, 2009a,b, Lucas and Thompson 2012).

The changes in phytoplankton production and invasion and establishment of the overbite clam *P. amurensis* were also accompanied by a series of major changes in consumers (Winder and Jassby 2011). Many of these changes likely negatively influenced pelagic fish production, including Delta Smelt. The quantity of food available to Delta Smelt is a function of several factors, including but not limited to seasonal trends in prey abundance and prey species specific salinity tolerances, which influence distribution (Kimmerer and Orsi 1996, Hennessy and Enderlein 2013). Seasonal peaks in abundance vary among calanoid copepods consumed as prey by Delta Smelt, *E. affinis* in April-May (Fig. 33), *P. forbesi* in July (Fig. 34), and *A. sinensis* in Sep-Oct (Fig. 35). Upstream, the calanoid copepod *S. doerrii* is most abundant May-June (Fig. 36). The seasonal trend in cladocerans (Fig. 37) and mysid (Fig. 38) prey are similar, being most abundant in summer.

From March through June, larval Delta Smelt rely heavily on first juvenile, then adult stages of the calanoid copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi*, as well as cladocerans (Nobriga 2002, Hobbs et al. 2006, Slater and Baxter 2014), and *Sinocalanus doerrii* (Fig. 39). Nobriga (2002) found that Delta Smelt larvae expressed positive selection for *E. affinis* and *P. forbesi*, consuming these prey species in greater proportion than available in the environment. Such selection was not noted for other zooplankton prey. Regional differences in food use occur,

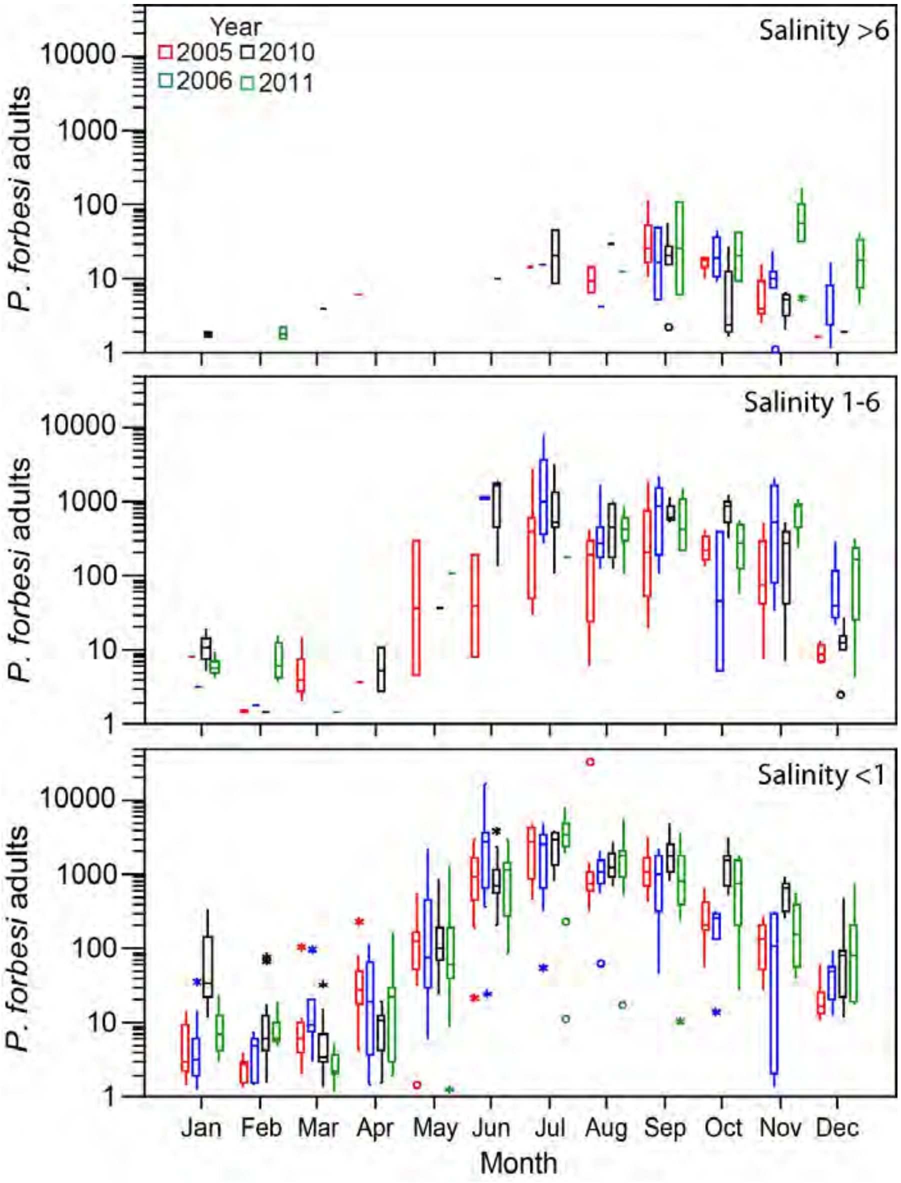
Figure 33. Density (number/m³) of adult *Eurytemora affinis* (*E. affinis*) by month for three salinity ranges. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.



with *E. affinis* and *P. forbesi* being major prey items downstream in the LSZ with a transition to *S. doerrii* and cyclopoid copepods as major prey items upstream into the Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC) (Fig. 39).

Juvenile Delta Smelt (June-September) rely extensively on calanoid copepods such as *E. affinis* and *P. forbesi*, especially in freshwater (salinity < 1) and CS-SRDWSC but there is great variability among regions (figs. 40-43). Larger fish are also able to take advantage of mysids,

Figure 34. **Density (number/m^3) of adult *Pseudodiaptomus forbesi* (*P. forbesi*) by month for three salinity ranges. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.**



cladocerans, and amphipods (Moyle et al. 1992, Lott 1998, Feyrer et al. 2003, Steven Slater, California Department of Fish and Wildlife, unpublished data) (Figs. 34-37). The presence of several epibenthic species in diets therefore indicates that food sources for this species are not confined to pelagic pathways. Such food sources may be especially important in regions of the estuary where there is extensive shoal habitat such as Liberty Island (Steven Slater, California Department of Fish and Wildlife, unpublished data).

Figure 35. **Density (number/m³) of adult *Acartiella sinensis* (*A. sinensis*) by month. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.**

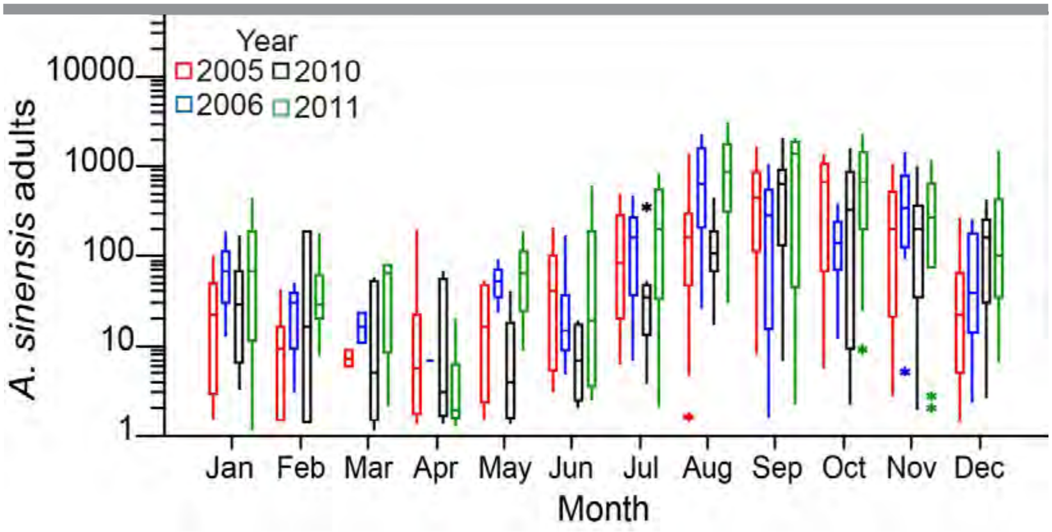
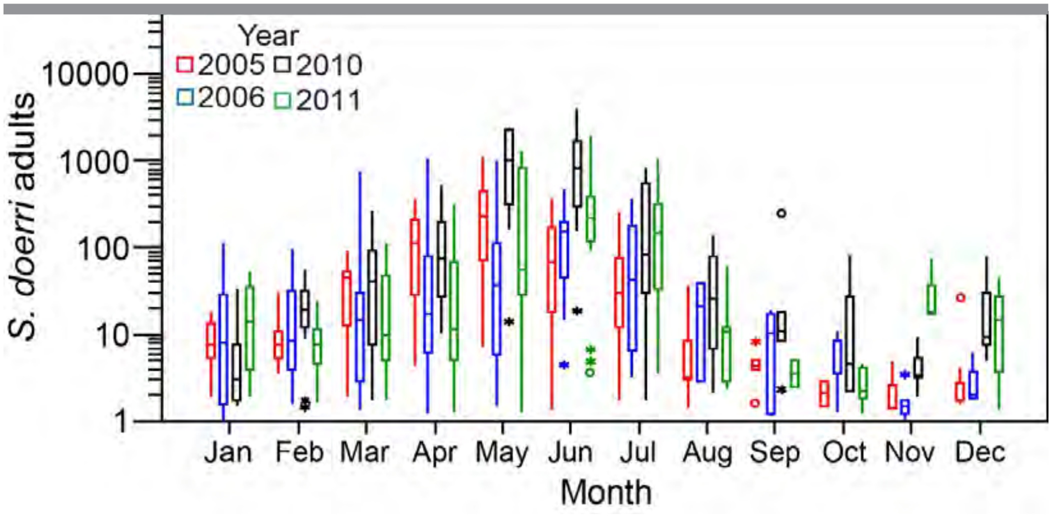


Figure 36. **Density (number/m³) of adult *Sinocalanus doerrii* (*S. doerri*) by month. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.**



Subadult Delta Smelt (September through December) prey items are very similar to those of juvenile Delta Smelt but with increased variability in diet composition (Moyle et al. 1992, Lott 1998, Steven Slater, California Department of Fish and Wildlife, unpublished data) (Figs. 40-43) coinciding with the seasonal decline in pelagic zooplankton, such as *P. forbesi* (Fig. 34) and mysids (Fig. 38). Food habits of adult Delta Smelt during the winter and spring (January-May) have been less well documented (Moyle et al. 1992). In 2012, diet of adults in the LSZ and

Figure 37. Density (number/m³) of all cladoceran taxa by month. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.

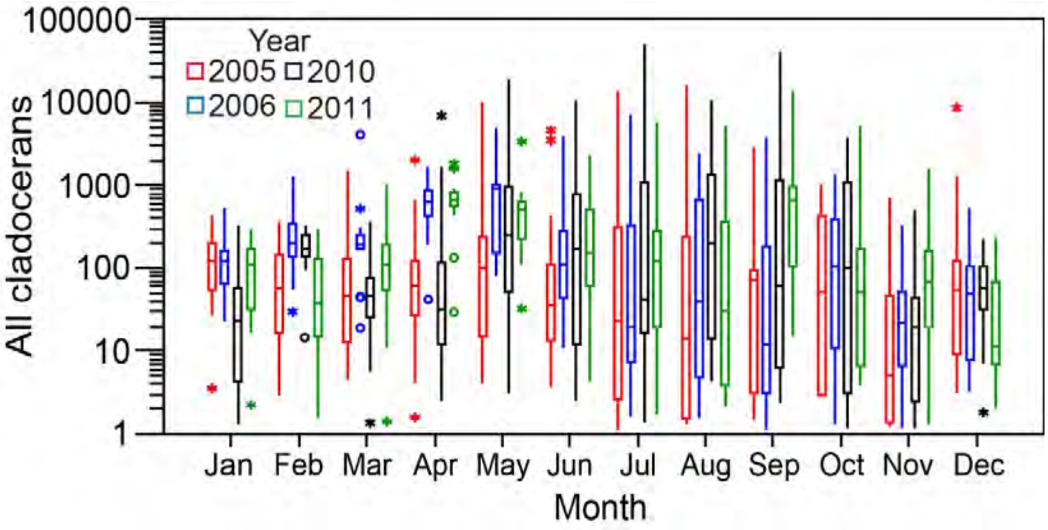
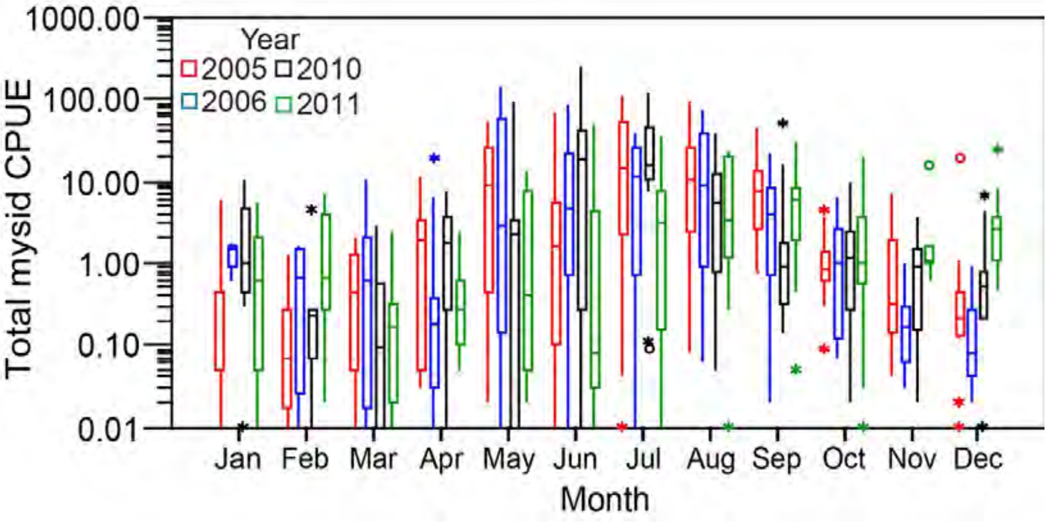


Figure 38. Density (number/m³) of all mysid shrimp taxa by month. Each month 16 stations were sampled across all salinity ranges. Horizontal lines represent single samples within a salinity range and boxes without whiskers indicate 2 samples within a salinity range. Data from the IEP Zooplankton Study index stations. See Chapter 3: Data Analyses for explanation of boxplots.



< 1 ppt were found to include cyclopoid copepods, other than *Limnoithona* spp., with a mix of larger prey types, amphipods, cladocerans, cumaceans, and larval fish and in CS-SRDWSC the calanoid copepod *S. doerrii* continued to be a large portion of the diet (Steven Slater, California Department of Fish and Wildlife, unpublished data) (Fig. 44). Larval fish found in stomachs of Delta Smelt in the higher salinity areas were primarily Pacific Herring (*Clupea pallasii*), with

some Longfin Smelt, and Prickly Sculpin (*Cottus asper*) in the Sacramento River and CS-SRDWSC region; no Delta Smelt larvae were found in the stomachs of adults (Steven Slater, California Department of Fish and Wildlife, unpublished data).

The large proportion of benthic amphipods, cumaceans, and some cladocerans (*Camptocercus* spp.) in the diet is a notable change from Delta Smelt diet in the 1970s. Delta Smelt diets historically did include amphipods, notably *Corophium* spp. (Moyle et al. 1992), yet it was a small fraction of a mostly pelagic based diet. The considerable use of benthic invertebrates for food in recent years is believed to be in large part due to food limitation associated with the long-term decline and changes in composition of the pelagic food web (Slater and Baxter 2014). The quality of benthic invertebrates as food is not currently understood, but amphipods are lower in energy (calories per gram) than copepods (Cummins and Wuychek 1971, Davis 1993) and mysids (Davis 1993).

As noted previously, the changes in phytoplankton production and phytoplankton species abundances observed and the invasion of *P. amurensis* may have had important consequences for consumer species preyed upon by Delta Smelt. For example, there has been a decrease in mean zooplankton size (Winder and Jassby 2011) and a long-term decline in calanoid copepods, including a major step-decline in the abundance of the copepod *E. affinis*. These changes are possibly due to predation by the overbite clam (Kimmerer et al. 1994) or indirect effects of clam grazing on copepod food supply. Predation by *P. amurensis* may also have been important for other zooplankton species (Kimmerer 2008). Northern Anchovy *Engraulis mordax* abandoned the low salinity zone coincident with the *P. amurensis* invasion, presumably because the clam reduced planktonic food abundance to the point that occupation of the low-salinity waters was no longer energetically efficient for this marine fish (Kimmerer 2006). Similarly, Longfin Smelt *Spirinchus thaleichthys* shifted its distribution toward higher salinity in the early 1990s, also presumably because of reduced pelagic food in the upper estuary (Fish et al. 2009). There was also a decline in mysid shrimp (Winder and Jassby 2011), including a major step-decline in 1987–1988, likely due to competition with the overbite clam for phytoplankton (Orsi and Mecum 1996). Mysid shrimp had been an extremely important food item for larger fishes like Longfin Smelt and juvenile Striped Bass (Orsi and Mecum 1996), and may be consumed by larger Delta Smelt (Moyle et al. 1992). The decline in mysids was associated with substantial changes in the diet composition of these and other fishes, including Delta Smelt (Feyrer et al. 2003, Bryant and Arnold 2007). The population responses of Longfin Smelt and juvenile Striped Bass to winter–spring outflows changed after the *P. amurensis* invasion. Longfin Smelt relative abundance was lower per unit outflow after the overbite clam became established (Kimmerer 2002b). Age-0 Striped Bass relative abundance stopped responding to outflow altogether (Sommer et al. 2007). One hypothesis to explain these changes in fish population dynamics is that lower prey abundance reduced the system carrying capacity (Kimmerer et al. 2000, Sommer et al. 2007).

In addition to a long-term decline in calanoid copepods and mysids in the upper Estuary, there have been numerous copepod species introductions (Winder and Jassby 2011). *P. forbesi*, a calanoid copepod that was first observed in the estuary in the late 1980s, has replaced *E. affinis* as the most common Delta Smelt prey during the summer. It may have a competitive advantage over *E. affinis* due to its more selective feeding ability. Selective feeding may allow *P. forbesi* to utilize the remaining high-quality algae in the system while avoiding increasingly more prevalent low-quality and potentially toxic food items such as *M. aeruginosa* (Mueller-Solger et al. 2006, Ger et al. 2010a). After an initial rapid increase in abundance, *P. forbesi* declined somewhat in abundance from the early 1990s in the Suisun Bay and Suisun Marsh regions but maintained its abundance, with some variability, in the central and southern Delta (Winder and Jassby 2011).

Figure 39. **Percentage by weight of prey types found in the digestive tracts of larval and young juvenile Delta Smelt (≤ 20 mm fork length) collected from 1-6 ppt, < 1 ppt, and Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC) in A) 2005, B) 2006, C) 2010, and D) 2011. Number of digestive tracts examined are shown above the columns. Mean fork length (mm) of Delta Smelt is also shown.**

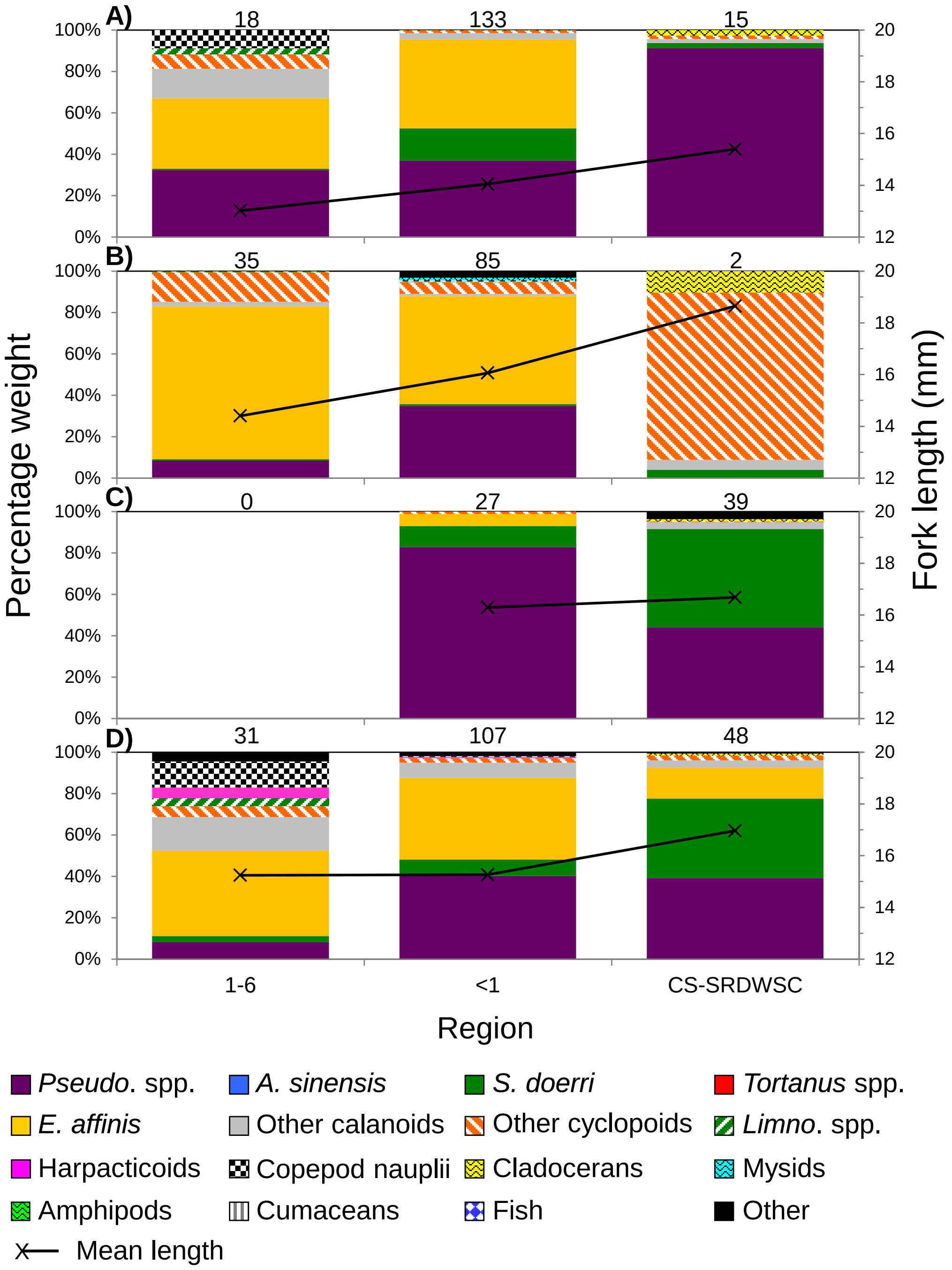


Figure 40. **Percentage by weight of prey types found in stomachs of age-0 Delta Smelt collected from > 6 ppt during April through December in A) 2005, B) 2006, C) 2010, and D) 2011. Number of stomachs examined are shown above the columns. One fish examined in August 2006 had an empty stomach. Mean fork length (mm) of Delta Smelt is also shown.**

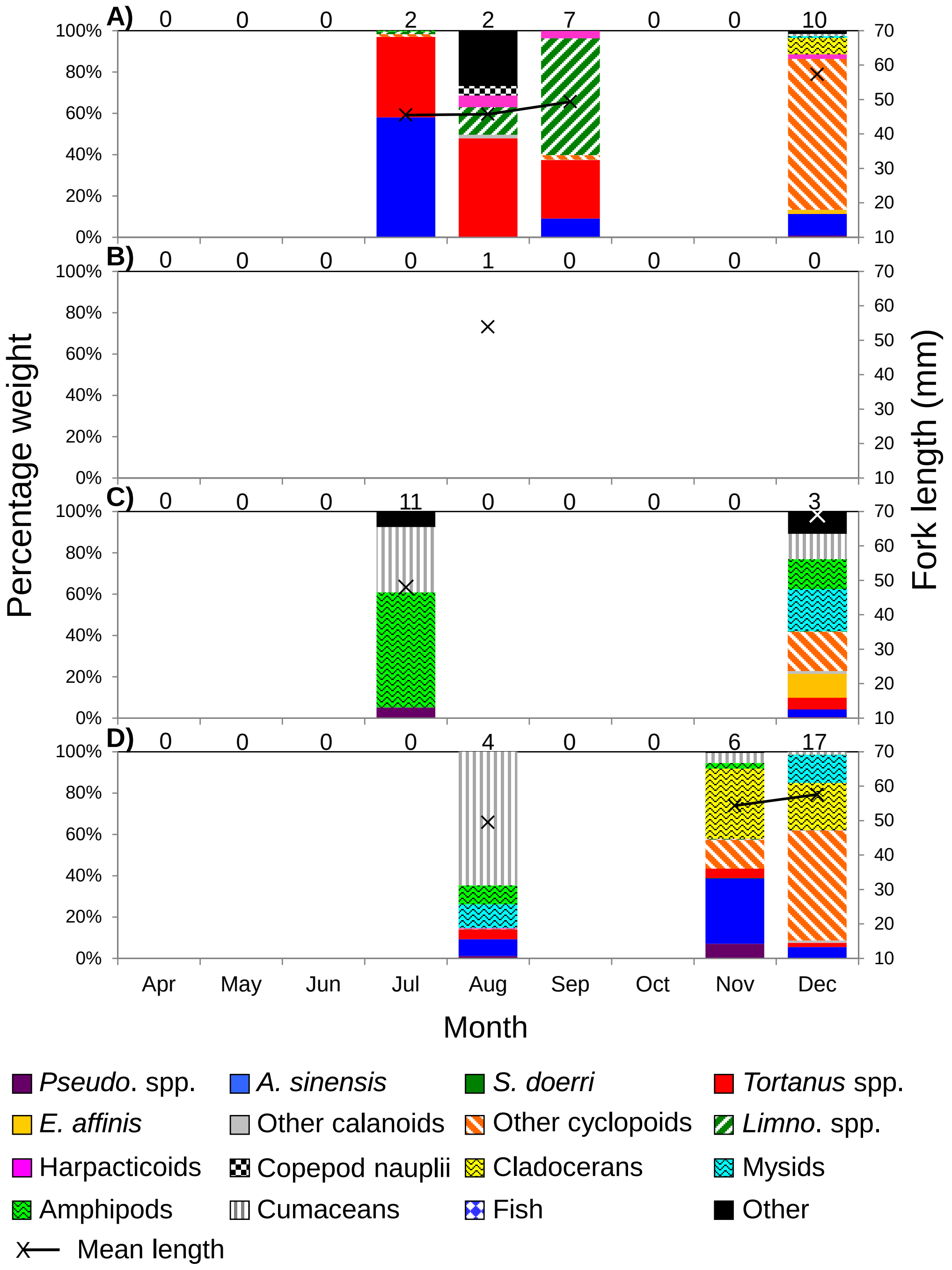


Figure 41. **Percentage by weight of prey types found in stomachs of age-0 Delta Smelt collected from 1-6 ppt during April through December in A) 2005, B) 2006, C) 2010, and D) 2011. Number of stomachs examined are shown above the columns. Mean fork length (mm) of Delta Smelt is also shown.**

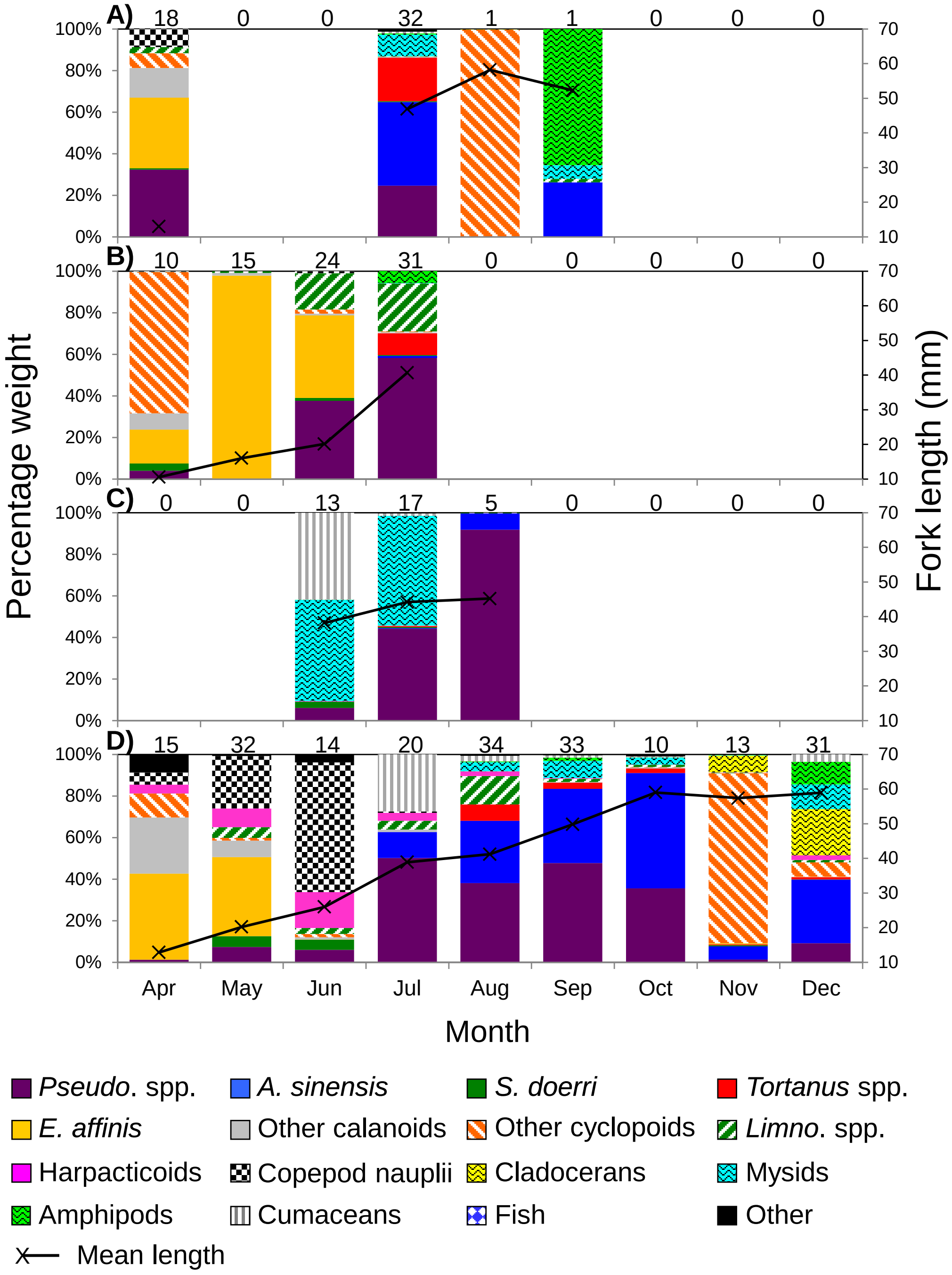


Figure 42. **Percentage by weight of prey types found in stomachs of age-0 Delta Smelt collected from < 1 ppt during April through December in A) 2005, B) 2006, C) 2010, and D) 2011. Number of stomachs examined are shown above the columns. Mean fork length (mm) of Delta Smelt is also shown.**

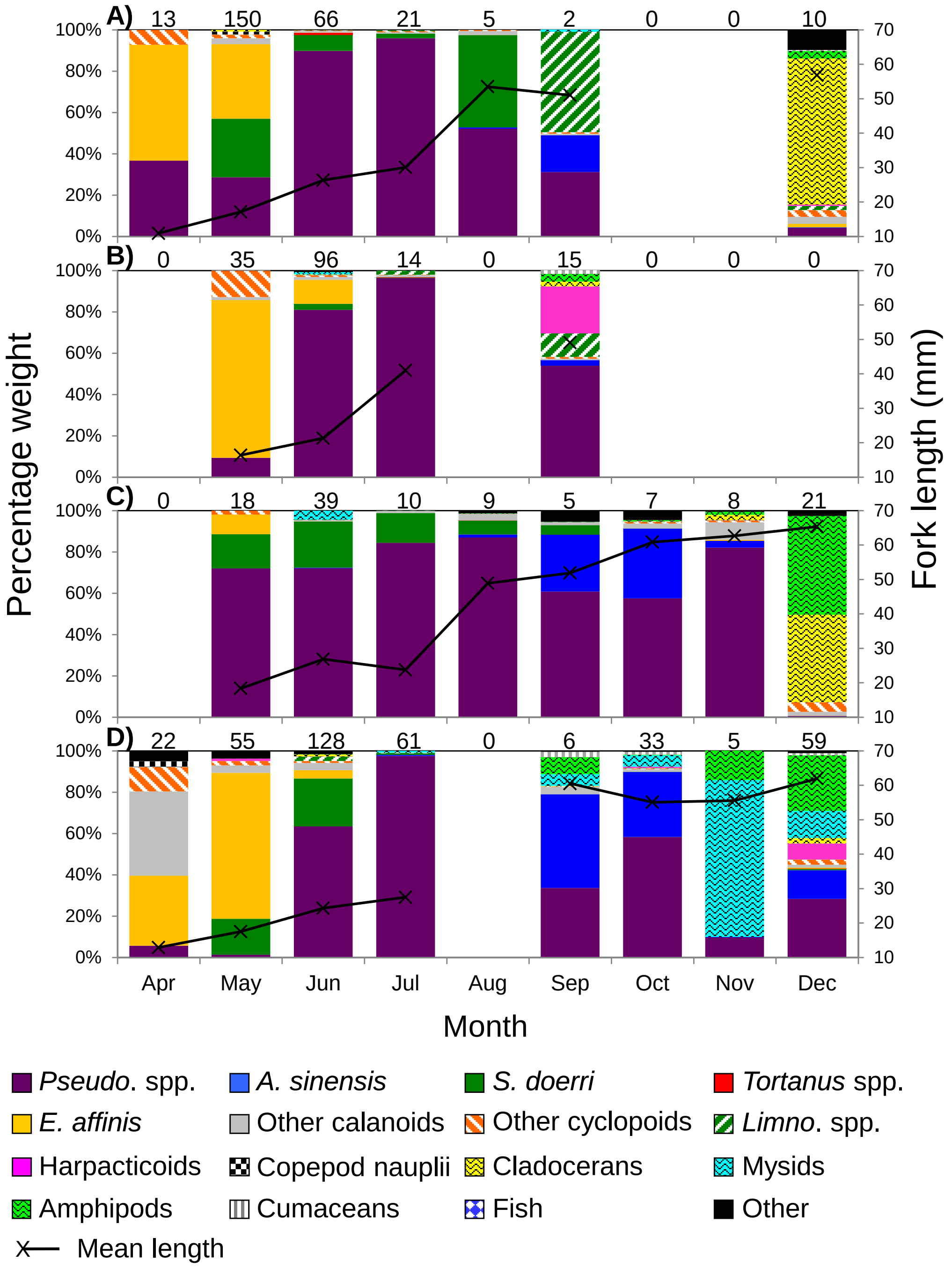


Figure 43. **Percentage by weight of prey types found in stomachs of age-0 Delta Smelt collected from Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC) during April through December in A) 2005, B) 2006, C) 2010, and D) 2011. Number of stomachs examined are shown above the columns. Mean fork length (mm) of Delta Smelt is also shown.**

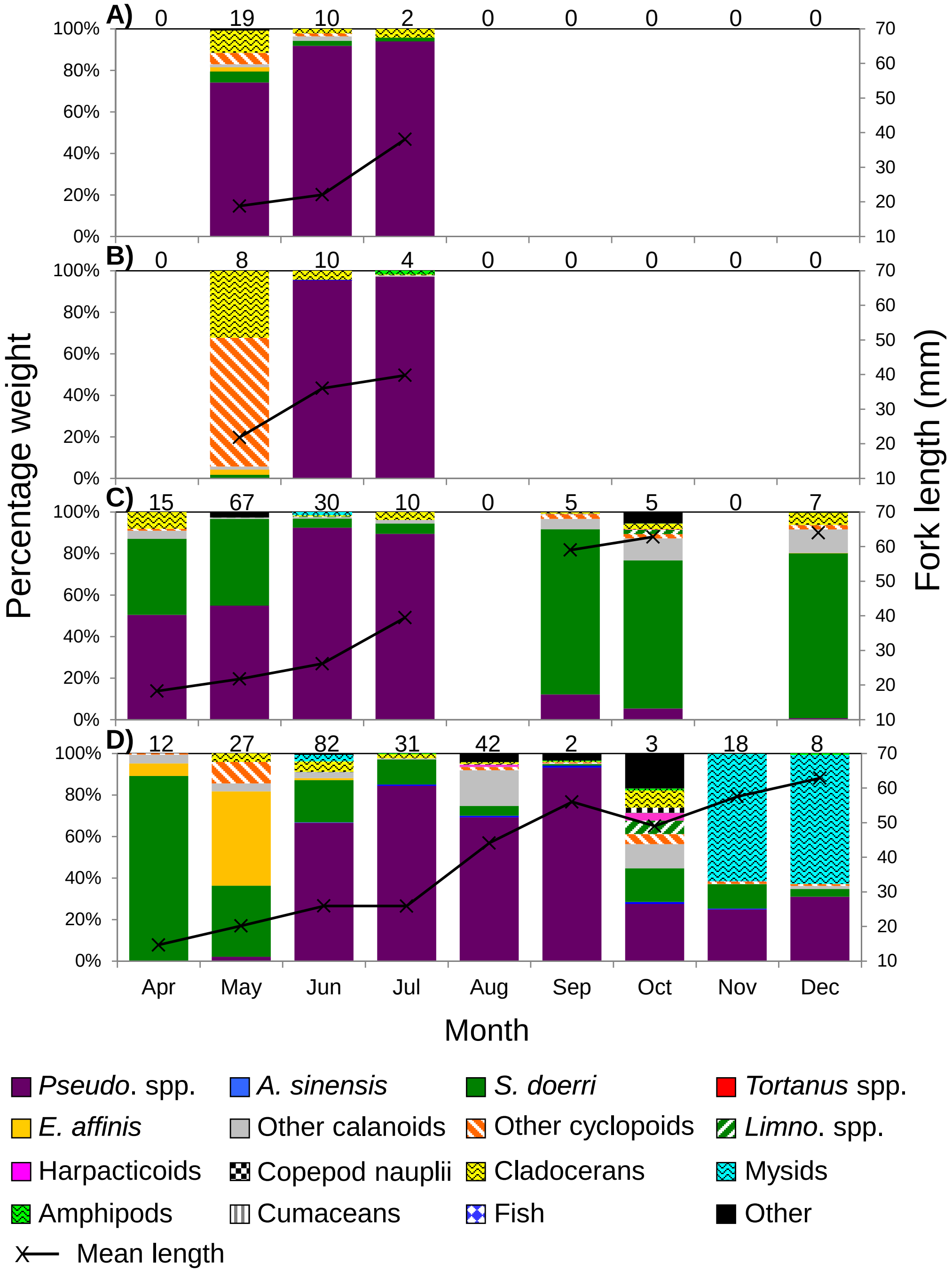
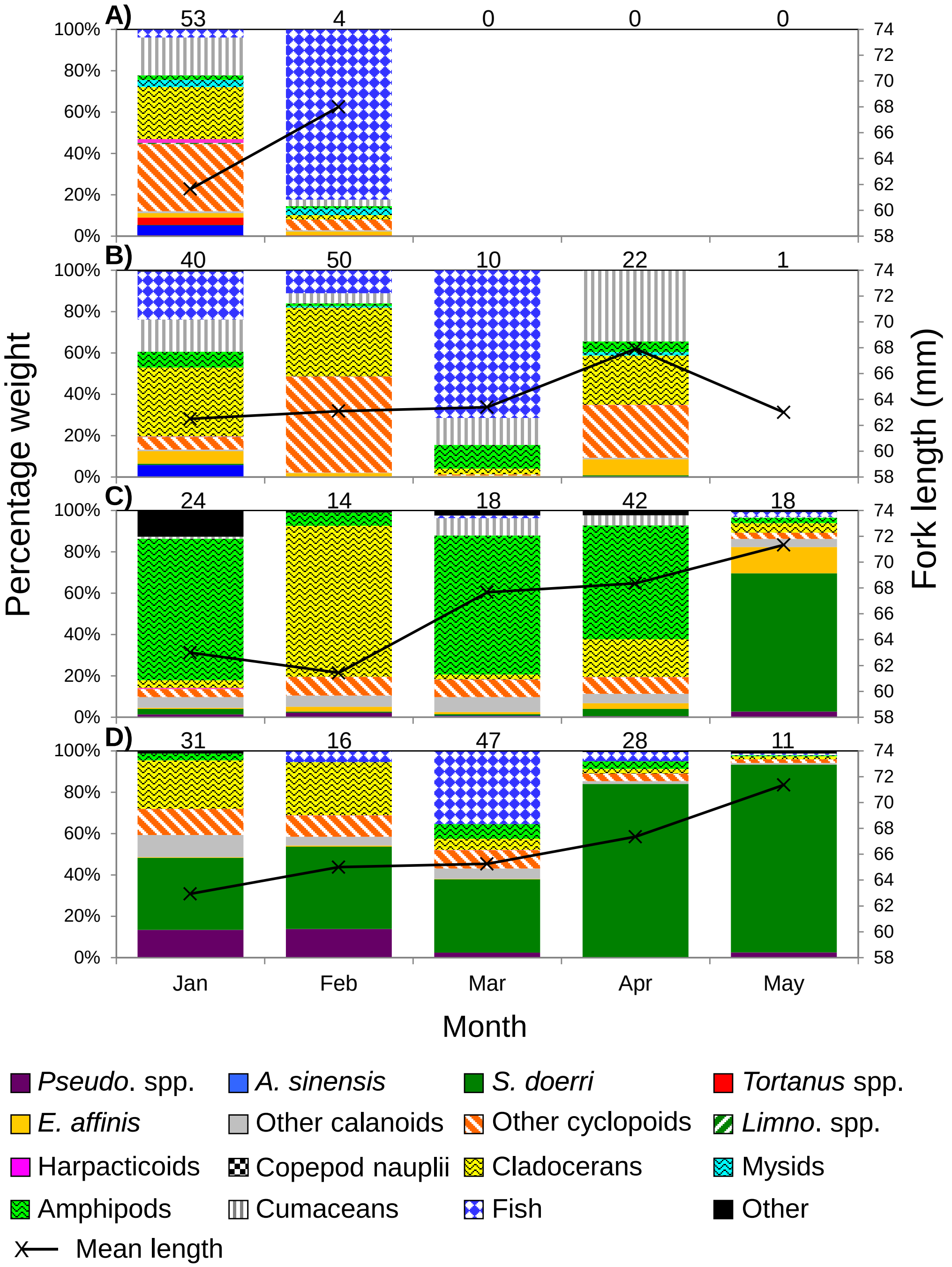


Figure 44. **Percentage by weight of prey types found in stomachs of adult Delta Smelt collected in 2012 during January through May from A) > 6 ppt, B) 1-6 ppt, C) < 1 ppt, and D) Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC). Number of stomachs examined are shown above the columns. One fish examined from 1-6 ppt in May had an empty stomach. Mean fork length (mm) of Delta Smelt is also shown.**



Although substantial uncertainties about mechanisms remain, the decline of *P. forbesi* in the Suisun region may be related to increasing recruitment failure and mortality in this region due to competition and predation by *P. amurensis*, contaminant exposures, and entrainment of source populations in the Delta (Mueller-Solger et al. 2006, Winder and Jassby 2011, Durand 2010).

The abundance of a more recent invader, the cyclopoid copepod *Limnoithona tetraspina*, significantly increased in the Suisun Bay region beginning in the mid-1990s. It is now the most abundant copepod species in the Suisun Bay and confluence region of the estuary (Bouley and Kimmerer 2006, Winder and Jassby 2011). Gould and Kimmerer (2010) found that it grows slowly and has low fecundity. Based on these findings they concluded that the population success of *L. tetraspina* must be due to low mortality and that this small copepod may be able to avoid visual predation to which larger copepods are more susceptible. It has been hypothesized that *L. tetraspina* is an inferior food for pelagic fishes including Delta Smelt because of its small size, generally sedentary behavior, and ability to detect and avoid predators (Bouley and Kimmerer 2006, Gould and Kimmerer 2010). Nevertheless, this copepod has been found in the guts of Delta Smelt when *Limnoithona* spp. occurrs at extremely high densities relative to other zooplankton (Slater and Baxter 2014). Recent experimental studies addressing this issue suggest that larval Delta Smelt will consume and grow on *L. tetraspina*, but growth is slower than with *P. forbesi* (Kimmerer et al. 2011). It remains unclear if consuming this small prey is energetically beneficial for Delta Smelt at all sizes or if there is a breakpoint above which larger Delta Smelt receive little benefit from such prey. *Acartiella sinensis*, a calanoid copepod species that invaded at the same time as *L. tetraspina*, also reached considerable densities in Suisun Bay and the western Delta over the last decade (Hennessy 2010), although its suitability as food for pelagic fish species remains unclear.

Preliminary information from studies on pelagic fish growth, condition, and histology provide additional evidence for food limitation in pelagic fishes in the estuary (IEP 2005). In 1999 and 2004, Delta Smelt growth was low from the Sacramento-San Joaquin confluence through Suisun Bay relative to other parts of the system. Delta Smelt collected in 2005 from the Sacramento-San Joaquin confluence and Suisun Bay also had high incidence of liver glycogen depletion, a possible indicator of food limitation (Bennett et al. 2008). As previously noted, warm water temperatures during the summer period may have exacerbated lack of food by raising the metabolic rate of Delta Smelt. Based on data for histopathology, date of birth from otoliths, and growth rates from otoliths of Delta Smelt in 2005, Bennett et al. (2008) proposed a novel strategy for Delta Smelt survival in 2005. Natural selection appeared to favor individuals with a specific set of characters, including relatively slow larval development, but faster than average juvenile growth in July. Water temperatures in July typically include the annual maximum (Fig. 16). The salinity field can also change rapidly as freshwater flow out of the Delta changes. Many of these fish surviving into the pre-adult stage had also hatched earlier in the spawning season (i.e., before May).

For many fishes, success at first feeding is believed to be critical to larval survival and a major cause of year-class variability (e.g., “critical period hypothesis,” Hjort 1914, Leggett and DeBlois 1994). In Rainbow Smelt *Osmerus mordax* a related smelt species, calculated larva mortality rates were related to feeding conditions at first feeding that varied on a predictable cycle of 15 days associated with tide and photoperiod (Sirois and Dodson 2000b). In feeding experiments, copepod evasion behavior affected capture by larval Striped Bass, and *E. affinis* was among the more easily captured species (Meng and Orsi 1991). There has been a long-term decline in calanoid copepods in the upper estuary, particularly in the Suisun Region (Winder and Jassby 2011), potentially reducing feeding success, growth and thereby survival. Currently, *E. affinis* abundance peaks in spring (Hennessy 2010, 2011) coincident with hatching of Delta Smelt. *E. affinis* abundance has been negatively related to X2 since the overbite clam invasion (Kimmerer 2002b). When X2 is "high" outflow is low and *E. affinis* densities are low. These lines of evidence suggest that the first feeding conditions may improve in springs with higher outflow.

Changes in the quality and quantity of available prey may have contributed to the observed reduction in the mean size of Delta Smelt in fall since the early 1990s (Sweetnam 1999, Bennett 2005); however, mean size subsequently increased. The importance of food resources as a driver is supported by Kimmerer (2008), who showed that Delta Smelt survival from summer to fall is correlated with biomass of copepods in the low salinity zone, the central 50% of the summer Delta Smelt distribution. Other variations of this correlation were shown by Maunder and Deriso (2011) and Miller et al. (2012). Miller et al. (2012) have tested for an explicit influence of prey density during the fall. Miller et al. (2012) found a stronger correlation between Delta Smelt abundance during the fall and prey density during the fall than for prey density during the summer.

Harmful algal blooms

Periodic blooms of the toxic blue-green alga *Microcystis aeruginosa* during late summer, most commonly August and September are an emerging concern for Delta Smelt (Lehman et al. 2005, Lehman et al. 2013). Although this harmful algal bloom (HAB) typically occurs in the San Joaquin River away from the core summer distribution of Delta Smelt, some overlap is apparent during blooms and as cells and toxins are dispersed downstream after blooms (Baxter et al. 2010). Density rankings of *Microcystis* at TNS stations were highest in the south Delta, east Delta and lower San Joaquin River regions; yet *Microcystis* distribution may be expanding north over time (Morris 2013). Moreover, studies by Lehman et al. (2010) suggest that Delta Smelt likely are exposed to microcystins, which may degrade their habitat and perhaps affect the distribution of Delta Smelt (Baxter et al. 2010). For example, these HABs are known to be toxic to another native fish of the region, Sacramento Splittail (Acuña et al. 2012a) and the alien Threadfin Shad (Acuña et al. 2012b). Histopathology evidence from Lehman et al. (2010) suggested the health of two common fish in the estuary, Striped Bass, and Mississippi Silversides, was worse at locations where microcystin concentrations were elevated.

Indirect effects are also likely as *Microcystis* blooms are toxic to copepods that serve as the primary food resources of Delta Smelt (Ger et al. 2009, 2010a,b). Ger et al. (2009) determined toxicity of one form of microcystin (LR) to two species of calanoid copepods, *E. affinis* and *P. forbesi*, which are important as food to Delta Smelt. They found that, although the copepods tested were relatively sensitive to microcystin-LR compared to other types of zooplankton, ambient concentrations in the Delta were unlikely to be acutely toxic. However, chronic effects were not determined and Lehman et al. (2010) found that *Microcystis* may indeed contribute to changes in phytoplankton, zooplankton and fish populations in the Delta.

Factors that are thought to cause more intensive *Microcystis* blooms include warmer temperatures, lower flows, high nitrogen levels, and relatively clear water (Lehman et al. 2005, Baxter et al. 2010, Lehman et al. 2013, Morris 2013). These conditions occur during dry years in the SFE. Both *Microcystis* abundance and microcystin concentrations have been greater in recent years with dry year conditions (Lehman et al. 2013). These factors can also interact. For example, low flows can provide less dilution of ammonium from wastewater treatment plants (Jassby and Van Nieuwenhuyse 2005, Dugdale et al. 2012, Dugdale et al. 2013) and *Microcystis* can readily utilize ammonium as a primary nitrogen source during blooms (Lehman et al. 2013). The intensity and duration of *Microcystis* blooms are expected to increase over the long-term, along with any negative impact on aquatic organisms, due to increased frequency of drought conditions associated with climate change (Lehman et al. 2013).

Chapter 5: Updated Conceptual Models for Delta Smelt

In this Chapter we transfer the information on drivers and Delta Smelt responses reviewed and presented in Chapter 4 into the conceptual model framework established in Chapter 3. The Delta Smelt general life cycle conceptual model recognizes the pervasive, year-round importance of the tier 1 landscape attributes and the seasonal importance of the various tier 2 environmental drivers and tier 3 habitat attributes to the tier 4 life stage transitions of Delta Smelt in the four tier 5 “transition seasons” (Fig. 45). Some habitat attributes – food, toxicity, and predation – affect life stage transitions in all seasons, while other habitat attributes – temperature, entrainment and transport, size and location of the low salinity zone, and harmful algal blooms – affect some life stage transition more than others. Clearly, adequate food must be available at all life stages for Delta Smelt to survive. Toxicity is included during all seasons because we know that contaminants of various types are present throughout the year; however, little is known about the direct or indirect effects of contaminants at ambient concentrations on individual Delta Smelt or the population as a whole. Predation is included in all seasons because we recognize that predation is likely the ultimate cause of mortality for most individual fish; however, responses of Delta Smelt to other habitat attributes and environmental drivers such as food availability and turbidity can modify predation risk.

The mechanistic linkages between landscape attributes, environmental drivers, habitat attributes and Delta Smelt responses in the four life stage seasons are depicted as one-way arrows in four new “life stage transition” conceptual models (Figs. 46-49). As mentioned in Chapter 3, the life stage transition conceptual models are nested components of the general life cycle conceptual model (Fig. 8). Each life stage transition conceptual model (Figs. 46-49) includes the habitat attributes hypothesized to affect the transition of Delta Smelt from one life-stage to the next. Hypotheses selected for detailed consideration in Chapter 7 are indicated by “H” in the diagrams. The models also show the landscape attributes and environmental drivers. While the models include many linkages among individual landscape attributes, environmental drivers, and habitat attributes, they do not include linkages between individual habitat attributes and the specific biological processes (growth, survival, reproduction) underlying the life stage transitions. The primary reason for this simplification is that the available data are generally inadequate to fully describe and differentiate among specific functional relationships and mathematical modeling that could help estimate them is beyond the scope of this report. Instead, the combined effects of all habitat attributes on the life stage transition probability are depicted by one upward arrow in each life stage transition conceptual model. This does not imply, however, that all habitat attributes have an equal role in determining life stage transition probability and population success or that the role of each habitat attribute remains constant from year to year.

In the remainder of this Chapter we briefly describe the linkages and associated hypotheses depicted in each of the life stage transition conceptual model diagrams (figs. 46-49). These

Figure 45. **Delta Smelt general life cycle conceptual model.**

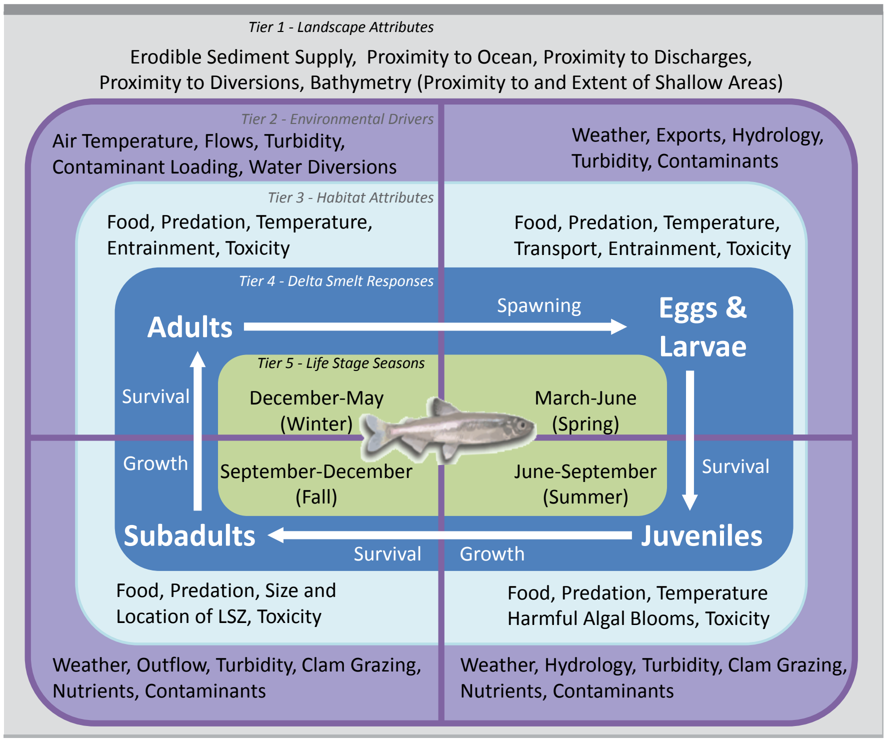


Figure 46. **Conceptual model of drivers affecting the transition from Delta Smelt adults to larvae. Hypotheses addressed in Chapter 7 are indicated by the "H-number" combinations.**

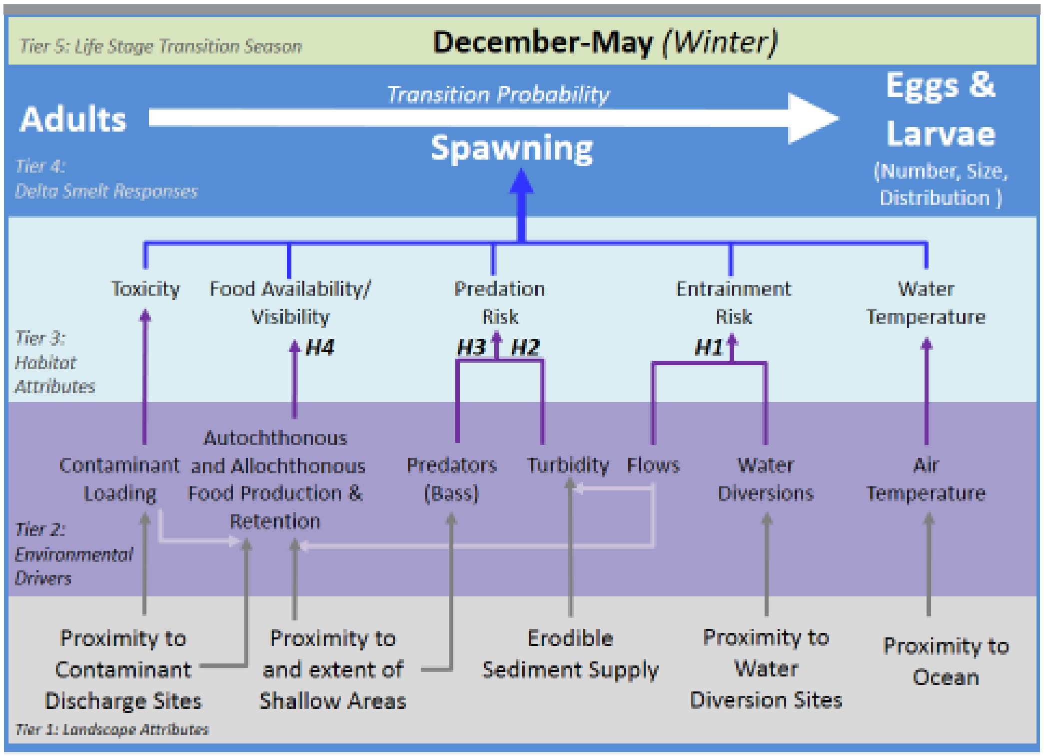


Figure 47. Conceptual model of drivers affecting the transition from Delta Smelt larvae to juveniles. Hypotheses addressed in Chapter 7 are indicated by the “H-number” combinations.

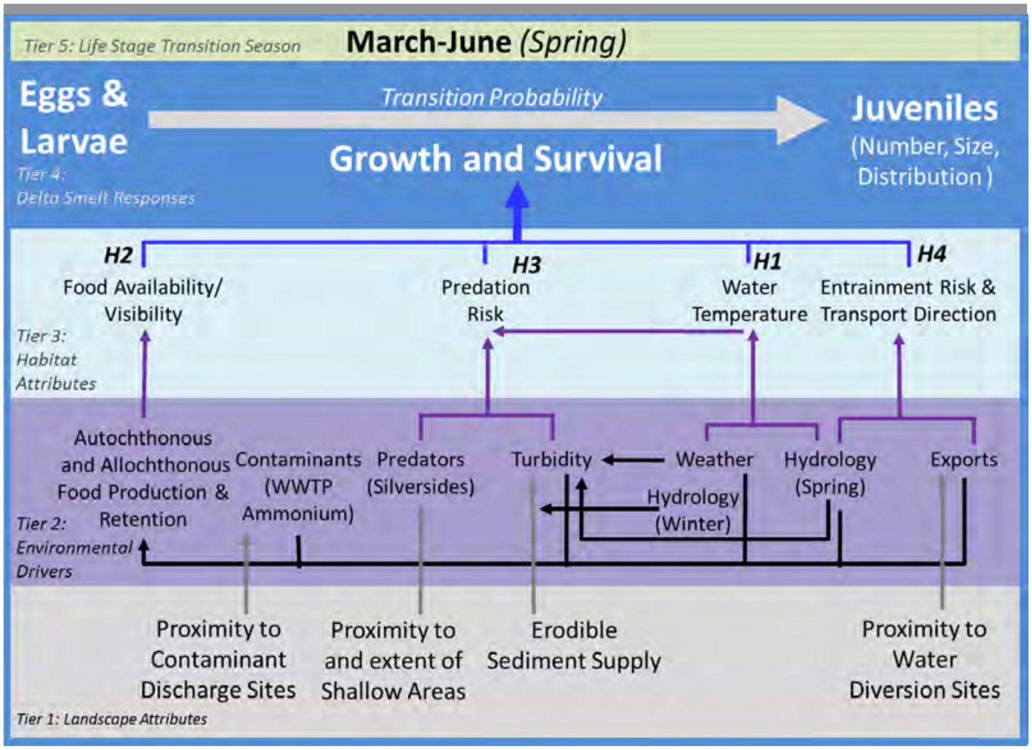


Figure 48. Conceptual model of drivers affecting the transition from Delta Smelt juveniles to subadults. Hypotheses addressed in Chapter 7 are indicated by the “H-number” combinations.

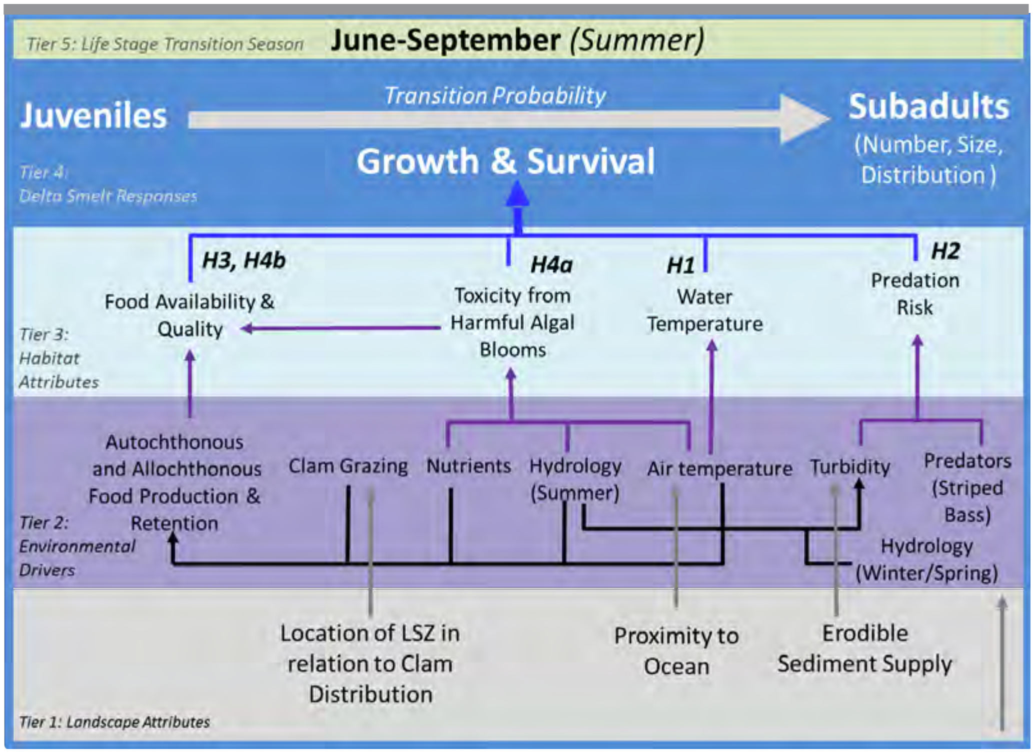
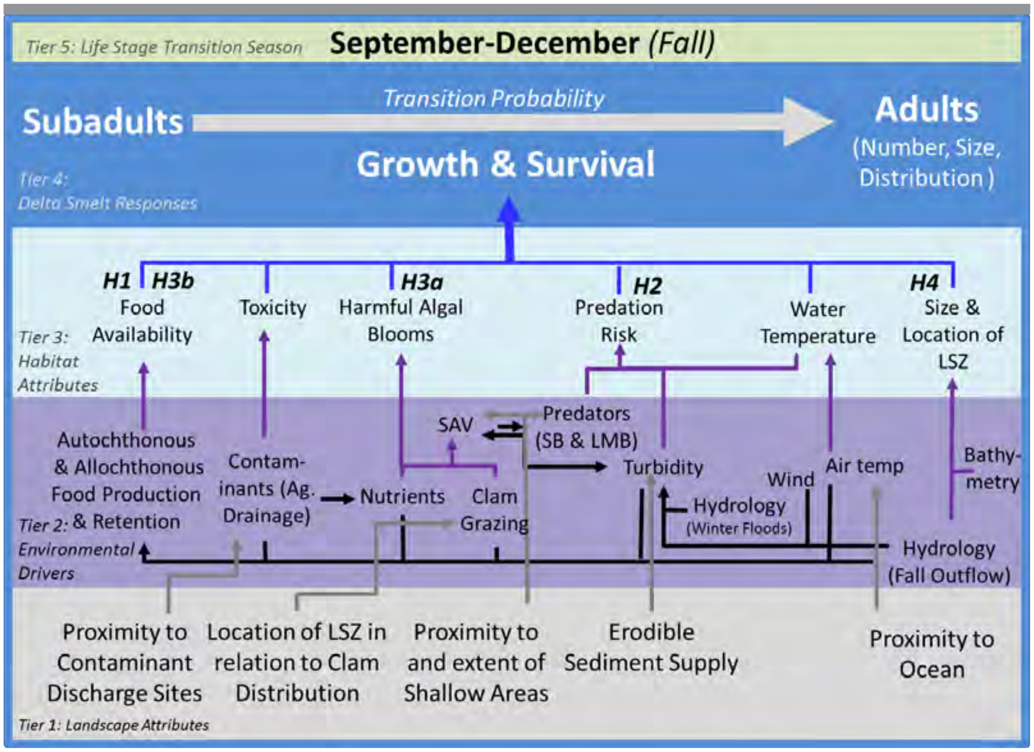


Figure 49. **Conceptual model of drivers affecting the transition from Delta Smelt subadults to adults. Hypotheses addressed in Chapter 7 are indicated by the "H-number" combinations.**



hypotheses are stated and addressed in more detail in Chapter 7. All hypotheses focus on the life stage that is transitioning to (i.e. occurs prior to) the next life stage, for example, adults but not eggs and larvae, larvae and post-larvae but not juveniles, and so on. That said, it is important to remember that all life stages overlap and all transitions except for the transitions from adults to eggs and from eggs to freshly hatched larvae are gradual, not abrupt, and delineations of life stages are somewhat arbitrary (see Chapter 3).

The life stage conceptual model for the transition of adult Delta Smelt to eggs and larvae (Fig. 46) includes 5 habitat attributes. Because of the lack of information about specific contaminant effects on Delta Smelt noted above, there are no specific hypotheses regarding the effects of contaminants and possible direct or indirect toxicity on Delta Smelt, but based on the information discussed in Chapter 4, the model does recognize that effects on Delta Smelt or its food supply may be occurring. Food availability and visibility are hypothesized to be important with respect to providing nutrition that allows Delta Smelt to grow into healthy, large adults that can produce a large numbers of high quality eggs as well as multiple clutches of eggs over the spawning season. The availability of food is considered dependent on both food production and the availability of such food to the fish. There are two hypotheses related to predation risk. The first is that turbidity, created by the interaction of high winter and spring flows with the erodible sediment supply in the watershed and within the Delta, influences the vulnerability of Delta Smelt to predators that co-occur with them. The second is that Delta Smelt behaviors that bring Delta Smelt close to channel edges may increase their vulnerability to Largemouth Bass, which generally occupy nearshore and vegetated habitats such as SAV beds. Entrainment risk in this life stage transition conceptual model is focused on adults. Entrainment of adults would reduce the reproductive potential of the population. Entrainment risk depends on the distribution of the adult Delta Smelt in relation to water diversions, and the magnitudes of water diversions and flows. Delta water temperature determines the beginning and duration of the spawning season (hereafter “spawning window”).

The life stage conceptual model for the transition of Delta Smelt eggs and larvae to juveniles includes 4 habitat attributes (Fig. 47). Food production and availability is important for the survival of larvae to juveniles. Food quantity is dependent on multiple interacting factors. Turbidity is important for early feeding by delta smelt larvae. Predation risk focuses on predation of Mississippi Silversides on Delta Smelt larvae because of recent evidence that such predation occurs. Predation risk is hypothesized to depend on co-occurrence of the two species, with Mississippi Silverside generally being associated with shallower waters, turbidity, which decreases the effectiveness of predators, and water temperature, which affects energy requirements of predators (hunger level). In addition to its effect on predator bioenergetics, water temperature is hypothesized to affect the length of the spawning season (spawning window). If food availability is sufficient, then a longer spawning window may allow the adult population to produce multiple clutches of eggs, resulting in more young. This hypothesis could arguably be included in the previous life stage transition conceptual model, but considering it here allows for consideration of predation on larvae in the context of the time period over which larvae are being produced. Larvae are also at risk of entrainment or transport to unfavorable areas. The magnitude of this risk is hypothesized to depend on an interaction of spring hydrology and water exports. As indicated by numerous arrows, winter and spring hydrology affect Delta Smelt spawning and larval rearing habitat in many ways. We thus also include a more general hypothesis about the hydrological effects on Delta Smelt larval abundance and recruitment.

The life stage conceptual model for the transition of Delta Smelt juveniles to subadults includes 4 habitat attributes (Fig. 48). In addition, there is a stand-alone hypothesis dealing with population dynamics. Juvenile growth and survival is hypothesized to depend on availability and quantity of food. Food production during this summer period is hypothesized to involve complex interactions of clam grazing, nutrients, hydrology and harmful algal blooms. The probability of observing a harmful algal bloom is hypothesized to be a function of the same factors but with temperature playing an important role. Harmful algal blooms may also affect Delta Smelt directly through production of toxic microcystins. Summer water temperatures are hypothesized to have a very direct effect on juvenile Delta Smelt with water temperatures hypothesized to reach stressful levels, affecting their bioenergetics and the area of suitable habitat. The transition probability hypothesis is that at the currently small population sizes, survival from juvenile to subadult is density independent, meaning independent of the number of individuals present (see Chapter 6 for details).

The life stage conceptual model for the transition of Delta Smelt subadults to adults includes 6 habitat attributes (Fig. 49). As for the previous conceptual model, there is a stand-alone hypothesis dealing with population dynamics. As in the previous conceptual model, growth and survival are hypothesized to depend on food availability and food production and availability depends on interactions of a variety of landscape attributes and environmental drivers. Toxicity is recognized as potentially important but no specific hypotheses have been tested. Harmful algal blooms may still be present with hypothesized direct effects on Delta Smelt subadults and indirect effects on their food. Predation risk on subadult Delta Smelt is hypothesized to depend on co-occurrence of Delta Smelt with the two most likely predators, Largemouth Bass and Striped Bass. Largemouth Bass occurrence is linked with that of SAV and the vulnerability of prey to both predators is affected by turbidity and bioenergetics. Water temperature is mainly hypothesized to have an effect through bioenergetics because water temperature becomes less stressful than in the summer. In this conceptual model the size and location of the LSZ is considered both a landscape attribute and a habitat attribute. In the earlier conceptual models, the LSZ was mainly viewed as a landscape attribute that interacted with other landscape attributes and environmental drivers to create habitat attributes. In this conceptual model the size and position of the LSZ is hypothesized to have certain characteristics that directly determine habitat quantity and quality for Delta Smelt. The transition probability hypothesis is that at the currently small population sizes, survival from subadult to adult is density independent, meaning independent of the number of individuals present (see Chapter 6 for details).

Chapter 6: Delta Smelt Population Biology

This Chapter consists of two main parts. In the first part, we introduce general concepts in population biology that are utilized in the following sections of this Chapter and to generally describe Delta Smelt population dynamics. Explaining these concepts and population trends now is intended to reduce repetitive text in the remaining sections and to reduce possible confusion for readers unfamiliar with the concepts. The concepts are discussed specifically in the context of Delta Smelt.

In the second part of this Chapter, we review information about the life history and population trends of each Delta Smelt life stage represented in our conceptual models, starting with adults. While we describe trends over the entire available time series for each life stage, we pay particular attention to differences in Delta Smelt abundance and life stage transitions between the two most recent wet years, 2006 and 2011. Our working assumption is that these differences should be attributable to differing habitat conditions and, in some cases, management actions. Differences in habitat conditions between these two years will be further explored in Chapter 7.

Population Biology

Recruitment is the addition of new individuals to a population through reproduction or immigration. In fisheries science, the term recruitment was first used by Ricker (1954) to describe the addition of fish of a new generation to a fish population, in other words, the number of young surviving to a particular age or life stage. We use the term recruitment to refer to production of larvae, juveniles, subadults, or adults by adults of the previous generation. Relationships between numbers of spawning fish or other measures of potential spawning stock (e.g., numbers of subadult or mature prespawning fish) and the numbers of fish of a given age or life stage in the subsequent generation are known as stock-recruitment relationships.

Stock-recruitment relationships have been described for many species and are a central part of the management of commercially and recreationally fished species (Myers et al. 1995, Touzeau and Gouze 1998). Different forms of stock-recruitment relationships are possible, including density-independent, density-dependent, and density-vague types. The density-independent type occurs when the current size of the population has little or no effect on the number of recruits (except possibly when stock size is extremely low). This type of population growth is rare in fish populations and occurs when environmental factors largely determine the survival and number of recruits (e.g., the Longfin Smelt outflow abundance relationship; see Myers 1998). Density dependence occurs when the current population size affects survival and abundance of recruits and thus population growth. In such populations, within the lower range of stock size, the number of recruits is strongly and positively related to stock size. At some point as stock size increases, competition for food (or some other limiting factor) between the adult population and recruits affects survival and abundance of recruits; cannibalism is another means by which recruitment can be affected by stock size. Thus, the growth and survival of the recruit population strongly depends on the density of the stock population. In reality it's difficult to determine which type of response is occurring (e.g., Myers and Barrowman 1996). Moreover, a predominantly annual fish, such as Delta Smelt, is predicted to conform poorly to models that assume density-dependent recruitment (Winemiller 2005), which appears to be the case (e.g., Rose et al. 2013).

The idea of density dependence is related to the idea of carrying capacity. The carrying capacity of an ecosystem is the number of individuals of all species that can be supported by the available resources. In reality it can be very difficult to apply this idea to a single species in an ecosystem because of the complex relationships among species and the seasonal, annual, and other changes in resource availability. The density vague type of population growth refers to situations where there is not a statistically demonstrable stock-recruitment relationship observable in available data.

In density-dependent stock-recruitment relationships, the factors causing the density dependence can operate at various points in the life cycle of the new generation. For some species, the concept of density dependence is separated into two concepts. In this formulation, density-dependent stock recruitment is limited to the direct effects of the adult stock on recruitment of the next generation, as described above. For example, if a large spawning stock has a limited spawning area, as in the case of salmonids, then successive waves of female spawners are known to re-excavate previous nests while building their own, substantially increasing mortality of the eggs. Density dependence could also occur at the larval or juvenile stage if adults are predatory and feed on young, or if adults are in direct competition for food or space with young. The second concept of density-dependent survival is often inextricably linked to density-dependent stock-recruit relationships because the mechanisms causing declines in recruits at high stock levels are unknown. In density-dependent survival, the abundance of young affects their own survival.

In the case of Delta Smelt, density dependent survival could occur if many of the larvae starved because of insufficient food supplies due to competition with other Delta Smelt larvae, or other species. Because many Delta Smelt die after their first spawning, density-dependent survival is certainly the dominant mechanism for the species and for the remainder of this report the direct effects of adults on survival of eggs and larvae are assumed to be minimal. If resources were sufficient for larvae and juvenile fish to survive in large numbers, the surviving subadults might overwhelm food sources (i.e., surpass carrying capacity), resulting in low survival and poor reproductive output. Thus, it is important to understand species ecology and survival between life stages to understand how density dependence is affecting a population. This is particularly important for fishes in estuaries where environmental factors can create large variation in habitat size and food web productivity from season to season and year to year, thus affecting carrying capacity and the potential for density-dependent survival.

Density-independence is more straightforward. In this case, the population is controlled by factors unrelated to the density of the population. For example, high water temperatures will affect individual fish, whether the population is large or small. In reality, populations can be affected by both density-dependent and density-independent factors at different times. This interaction is the basis for the idea of compensatory density dependence. In this formulation, a population is governed by density independent factors when population size is small. As the population increases and approaches the carrying capacity, density-dependent factors become important and the population growth rate declines. Fluctuations in carrying capacity, as noted above, are an added complication. Again, it is essential to understand the ecology of the species and survival between life stages to understand the relative importance of density dependent and density independent factors.

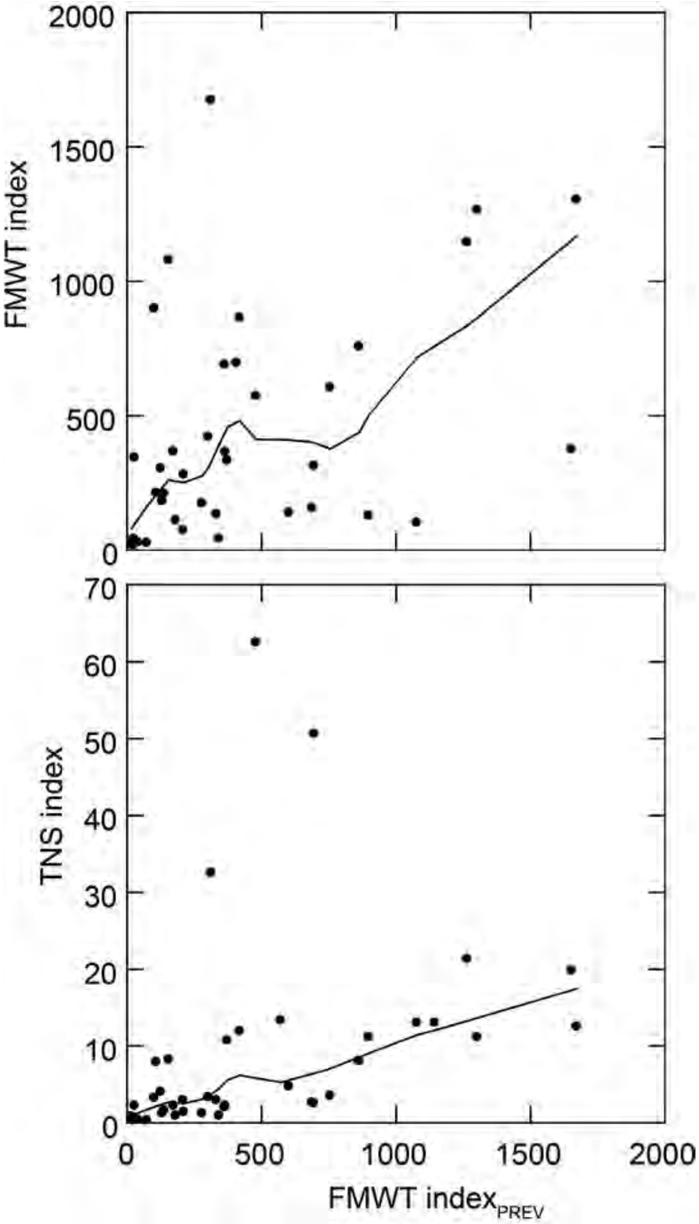
Unfortunately, Delta Smelt were never of sufficient interest as a commercial or recreational species to warrant development of stock-recruitment models until they were listed. Data now used to develop stock-recruitment models for Delta Smelt started becoming available after the initiation of fisheries studies and monitoring surveys in the late 1950s (TNS initiated 1959; FMWT initiated 1967) in association with the planning and operation of the CVP and SWP. These IEP fish monitoring surveys were designed to produce relative abundance indices or catch-per-unit-effort (CPUE, e.g., number per trawl) that could be used to monitor trends in abundance over time. More recently, annual abundance indices based on these surveys have also been incorporated into stock-recruit relationships (e.g., Moyle et al. 1992, Sweetnam and Stevens 1993, Miller 2000, Bennett 2005, Maunder and Deriso 2011). Neither of these early IEP fish monitoring surveys (TNS, FMWT) were specifically designed to monitor Delta Smelt, but instead targeted primarily the commercially and recreationally more important Striped Bass. As researchers began using TNS and FMWT indices for Delta Smelt analyses, they began investigating how the indices performed and means to improve them (see Wadsworth and Sommer 1996, Miller 2000, Newman 2008). This work is ongoing and also includes similar investigations for the newer SKT (initiated in 2002) and 20 mm survey (initiated in 1995) monitoring surveys.

The two stock-recruitment relations based on the longest data records include the relationsip of the FMWT abundance index with the FMWT adundance index in the previous year and the relationship of the TNS abundance index with the FMWT adundance index in the previous year (Fig. 50). Because of the large changes that have occurred in the Delta ecosystem, including the invasion by *P. amurensis* and the POD, these plots can be difficult to interpret because carrying capacity is assumed to have changed (Bennett 2005, Kimmerer et al. 2000, Sommer et al. 2007). It does appear that there is much more variability associated with the FMWT relationship compared to the TNS relationship. This might indicate variable survival between the juvenile and subadult life stage.

In any form of a stock-recruitment model, there is a point at which low adult stock will result in low juvenile abundance and subsequent low recruitment to future adult stocks. This can occur even under favorable environmental conditions while the stock “rebuilds” itself. From a stock-recruitment perspective, the recent low abundance of Delta Smelt is of particular concern. Since about 2002, the current population is smaller than at any time previously in the record, with the exception of the 2011 year class. This strong year class suggests that Delta Smelt have yet to reach low levels where the stock will need years to rebuild, at least to pre-POD levels (Fig. 3).

In addition to their use in exploring stock-recruitment relationships, ratios of annual Delta Smelt abundance indices can also be used to obtain rough estimates of relative annual recruitment and survival rates (figs. 51 and 52). As for the stock-recruitment relationships these recruitment and survival indices should be interpreted with caution given the large changes that have taken place in the Delta and the absence of estimates of variability for the indices. The main utility of these

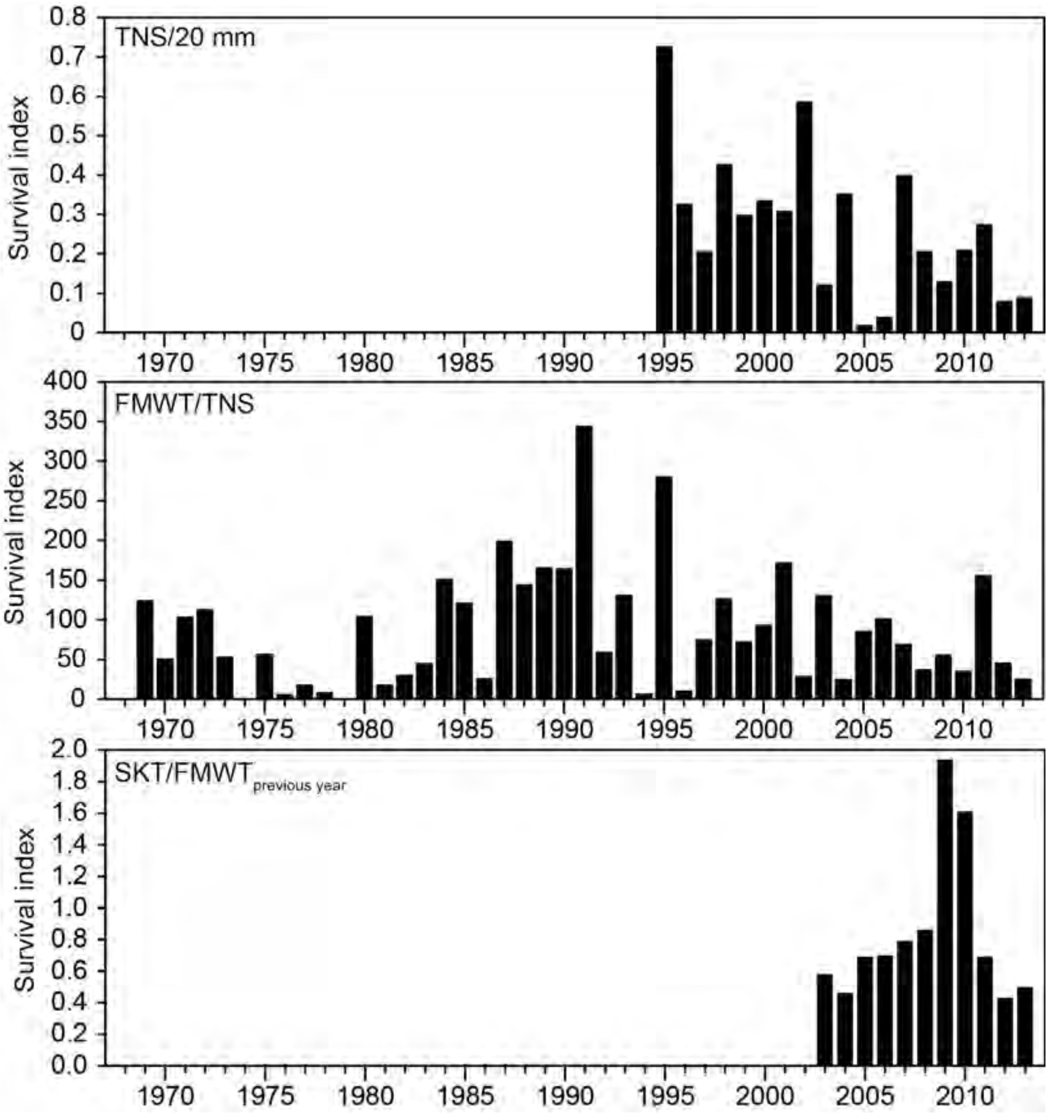
Figure 50. Scatterplots and LOWESS splines depicting the relationship of the Fall Midwater Trawl index of Delta Smelt relative abundance (FMWT) (1968-2012) and Summer Townet Survey (TNS) (1969-2012) with the FMWT in the previous year.



indices is identifying years with relatively high or low survival for a specific life stage transition or life stage transitions with differences in annual variability.

Here, we use the ratios of abundance indices for different life stages of the same generation as indices of survival (survival indices, Fig. 51) and the ratios of current to preceding year abundance indices as indices of recruitment (recruitment indices, Fig. 52). For the density-independent case, recruitment rate is independent of the size of the adult population. The number

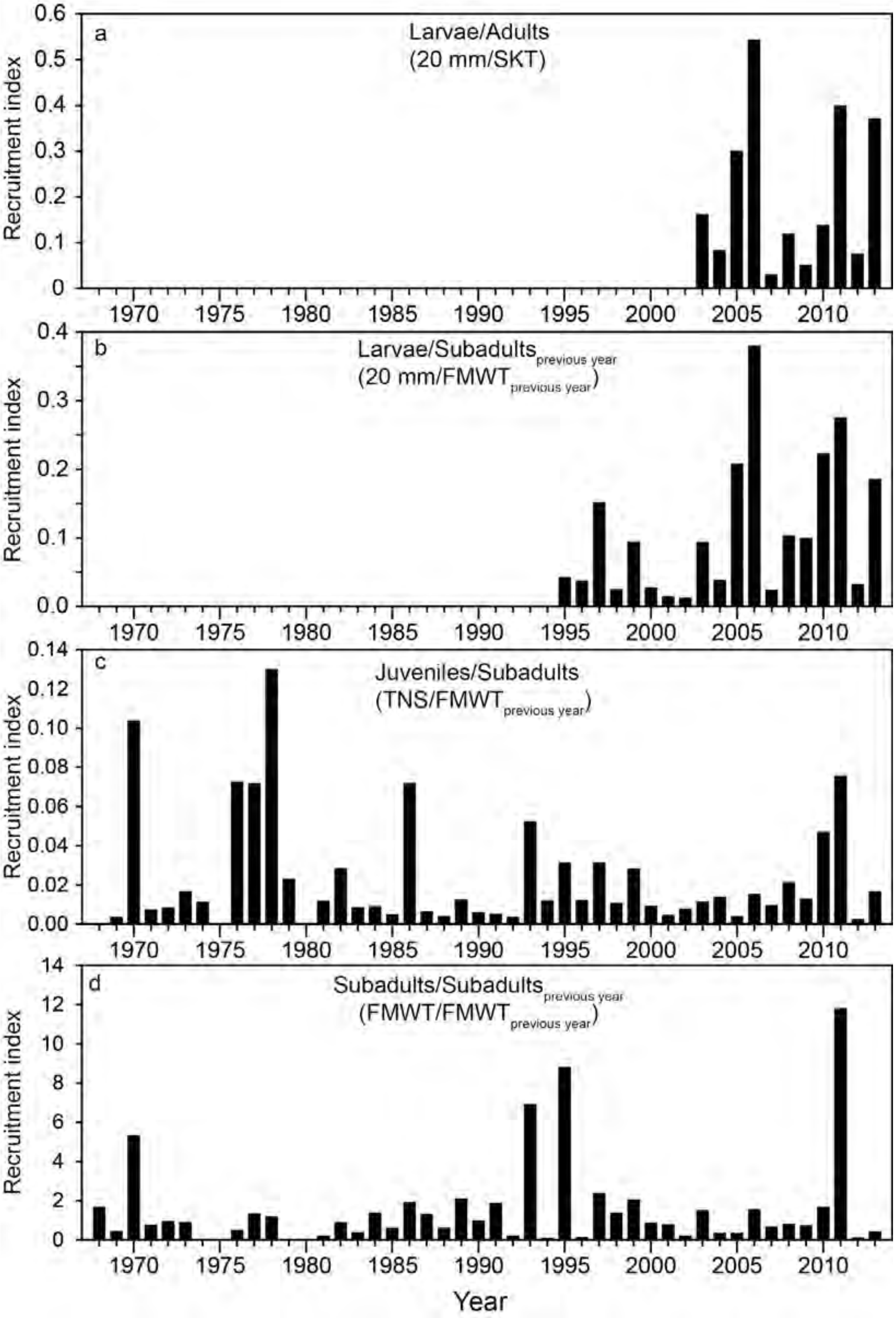
Figure 51. Stage to stage survival indices based on data from Summer Townet Survey (TNS), Fall Midwater Trawl (FMWT), and Spring Kodiak Trawl (SKT).



of recruits produced is the product of recruitment rate and the size of the adult population. For this report, we assume that the estimates have sufficiently low and comparable uncertainty to provide worthwhile interpretations, as long as caution is exercised. It is also important to remember that abundance, survival, and recruitment index values are only meaningful in a relative, not in an absolute sense.

The annual stage to stage survival indices from larvae to juveniles, subadults, and adults are shown in Figure 51. The relative recruitment rates from adults and subadults in one year to larvae, juveniles, and subadults the next year are shown in Figure 52. We recognize that a life cycle model with environmental covariates is needed to fully assess the combined effects of stock-recruitment and stage-to-stage survival indices on Delta Smelt population dynamics. Nevertheless, examination of the recruitment and survival index data sets reveal several interesting patterns for the POD period (2003-2013).

Figure 52. Delta Smelt recruitment indices based on the annual adult, larval, juvenile, and subadult abundance indices provided by the Spring Kodiak Trawl (SKT, adults), 20 mm Survey (20 mm, larvae), Summer Townet Survey (TNS. juveniles), and Fall Midwater Trawl (FMWT, subadults).



First, interannual variability in these stock and survival indices declines from larval recruitment (coefficient of variation (CV): 92%), to subsequent larvae to juvenile survival (CV: 67%), juvenile to subadult survival (CV: 43%), to subadult to adult survival (CV: 38%). This result is consistent with expected highly dynamic patterns of recruitment and survival for an annual opportunistic species such as Delta Smelt. The pattern of reduced variability in survival for larger fish suggests that older fish may no longer be vulnerable to some forms of mortality affecting earlier life stages either because a factor is no longer important when larger fish are present (e.g., effect of summer high water temperatures on juveniles) or that larger fish escape some forms of mortality (e.g., larger fish are no longer eaten by the large variety of predators able to consume larvae).

Second, the patterns of adult and larval abundance (Fig. 3) and adult to larvae recruitment (Fig. 52a) suggest: (1) even a small adult Delta Smelt stock can produce a large number of larvae under the right habitat conditions; but (2) larval recruitment is not a good predictor of juvenile survival and subsequent adult stock size. In other words, good larval recruitment sets the stage for population recovery, but good survival through subsequent life stage transitions is needed to realize its potential.

Third, there are clear contrasts in Delta Smelt responses between the two wet years 2006 and 2011 (the years of particular interest in this report) (Figs. 51 and 52). Since the initiation of the SKT survey for adult Delta Smelt in 2002 (indices calculated beginning in 2003), the recruitment of larvae from adults was greatest in the two wet years 2006 and 2011 (Fig. 52a) compared to the other, drier years in the time series, but in 2006 very strong adult to larvae recruitment was followed by very poor larvae to juvenile survival in the summer (Fig. 51a) and only average survival in the fall (Fig. 51b) and winter (Fig. 51c). This led to low abundance of the subsequent life stages of the 2006 cohort. Survival from larvae to juveniles and subadults was much better in 2011 and, along with good recruitment, led to the highest juvenile and adult abundance indices since the onset of the POD (Fig. 3). In other words, good recruitment set the stage for population recovery in both recent wet years, but a substantial abundance increase was realized only in 2011. Unfortunately the 2011 abundance increase was short-lived; it was immediately followed by poor recruitment and survival in 2012 and abundance indices for the 2012 and 2013 cohorts were once again at the low levels typical for the POD period (Fig. 3). Several consecutive years of good recruitment and survival are likely needed for a more sustained increase of the Delta Smelt population abundance to pre-POD abundance levels. Population declines such as the decline experienced by Delta Smelt do not only reduce the number of individuals, but can also reduce the genetic diversity present in the population. While the 2011-2012 data suggest that recovery of Delta Smelt abundance can still be fairly rapid via high larval recruitment followed by good survival (Figs. 51 and 52) recovery of genetic diversity is a much slower process which is an important conservation concern (Fisch et al. 2011).

Small Delta Smelt population size affects the effective population size (*Ne*), a measure of the genetic properties of a population and the abundance at which significant genetic diversity is lost due to inbreeding (Falconer and Mackay 1996, Schwartz et al. 2007, Antao et al. 2010). In many species *Ne* may be orders of magnitude smaller than the census population size (*N*) and low *Ne*/*N* ratios indicate the population may be in danger of losing genetic variability, potentially resulting in reduced adaptability, population persistence, and productivity (Hauser et al. 2002). For Delta Smelt, Fisch et al. (2011) detected a genetic bottleneck in each of four sampling years (2003, 2005, 2007 and 2009) and observed a significant decline in effective population size between sampling years 2003 and 2007 (Fisch et at. 2011). The genetic signal of the decline in *Ne* is corroborated by the observed abundance index declines and support the hypothesis that decreases in *Ne* and allelic richness have likely occurred over the last few decades (Fisch et al. 2011). Genetic changes within the Delta Smelt population deserve continued evaluation with respect to changes in population size.

In addition, Delta Smelt recruitment and the fecundity of adult Delta Smelt likely vary substantially from year to year (Rose et al. 2013b). Delta Smelt fecundity is a function of female size (Bennett 2005, Lindberg et al. 2013). The mean size of adult Delta Smelt declined in the early 1990s (Sweetnam 1999), possibly due to changes in the food web (see Chapter 4), but substantially recovered in the late 2000s. Another possible reason is that in some recent years, there may have been selection for smaller, late-spawned larvae as a result of export pumping schedules (Bennnett 2011). For example, Bennett (2011) proposed that high export pumping in late winter may have resulted in high entrainment mortality of offspring from larger, fitter, early spawning females, which produced larger, fitter offspring (Bennett 2011). Further, Bennett et al. (2008) and Bennett (2011) posited that curtailment of export pumping in mid-April related to the Vernalis Adaptive Management Program (VAMP), allowed for greater survival of later-spawned, smaller larvae. The major concern is that these smaller later-spawned larvae have less opportunity to grow to large adult size, especially when food is scarce. If correct, the combined effects of export pumping and food supply on Delta Smelt growth and size could have a nonlinear impact on overall fecundity and population success. This is corroborated by the results from individual-based modeling which showed that growth in fall-winter and the subsequent number of eggs produced per adult were the most important factor determining the success of the next generation (Rose et al. 2013b). Moreover, repeated losses of early-spawned larvae could potentially have a negative effect on expression of this important phenotype and result in eventual loss of genetic variability in the population, and contribute to the genetic bottlenecks reported by Fisch et al. (2011).

Given the unprecedented low abundance of Delta Smelt since 2002 (Fig. 3, summer and fall), serious consideration should be given to evaluation of Allee effects. Allee effects occur when reproductive output per fish declines at low population levels (Berec et al. 2006). In other words, below a certain threshold the individuals in a population can no longer reproduce rapidly enough to replace themselves and the population, exhibiting inverse density dependence, spirals to extinction. For Delta Smelt, possible mechanisms for Allee effects include processes directly related to reproduction and genetic fitness such as difficulty finding mates, genetic drift, and inbreeding (Gascoigne et al. 2009), although none of these effects have been documented yet in Delta Smelt (Fisch et al. 2011). Other mechanisms related to survival such as increased vulnerability to predation (Gascoigne and Lipcius 2004) are also possible. While theoretical work suggests that Allee effects might be common in nature, empirical evidence for Allee effects in natural populations of fishes remains relatively sparse (Myers et al. 1995, Liermann and Hillborn 1997), possibly because they are often masked by measurement errors (Gregory et al. 2010). Recent meta-analytical work by Keith and Hutchings (2012) suggests that Allee effects in marine fish species might be more common than previously thought. But even in the absence of "true" Allee mechanisms, small population size (Hutchings 2013) can produce an emergent Allee effect and prevent recovery of collapsed fish populations even when threats are reduced (Kuparinen et al. 2012). This may be one of the reasons why recovery of many collapsed fish populations remains slow despite large reductions in fishing (Pauly et al. 1998, Hutchings et al. 2010). This finding challenges the traditional fisheries management view that depleted populations will grow and recover rapidly when fishing pressure is relaxed (Hilborn and Walters 1992). In addition, the interactive effects of multiple Allee effects may have important implications for species conservation, but have not yet been well explored in ecology (Berec et al. 2006).

Compensatory density dependence predicts that a fish's population growth or survival rates can increase when abundance is low and decrease if abundance increases beyond a carrying capacity (Rose et al. 2001). If compensatory density dependence occurred in 2011, Delta Smelt survival would be expected to increase as long as the carrying capacity of the environment was not exceeded. Therefore, the sudden increase in subadult abundance in 2011 is consistent with the higher survival predicted by compensatory density dependence at low population abundance coupled with widespread availability of good habitat conditions throughout the year. Among the remaining comparison years, both 2005 and 2006 show evidence of compensatory recruitment to larvae (Fig. 52a). Adult abundance was moderately high in 2005, but low in 2006 and 2010 (Fig. 3). As predicted by compensatory density dependence processes, the recruitment index to larvae was higher in 2006 than in 2005. However, low adult abundance in 2010 did not give way to a similarly high recruitment index (Fig. 52a). In addition, the relatively high recruitment index in 2006 did not result in a higher larval abundance index compared to 2005 (Fig. 3). These inconsistences, combined with a small number of comparison years, prevent any firm conclusion regarding compensatory recruitment or survival.

Similarly, if compensatory density-dependent survival was important we might expect larva to juvenile survival to be lower when larva production per adult was higher assuming similar adult populations. This was not the case for 2006, 2010, and 2011, which had relatively similar values for the SKT abundance index (figs. 3). In 2006, larval survival was low with high larval production per adult, and 2010 and 2011 had very similar larval survivals with similar adult abundances. Finally, in 2011, the highest population of juveniles led to the highest population of subadults and adults (2012 SKT), which argues against compensatory density-dependent survival. These comparisons argue against strict compensatory density dependence operating within the POD years. It seems more likely that population dynamics are driven by density independent relationships with factors such as summer water temperatures and resource availability (fluctuations in carrying capacity); however, the evidence is not conclusive. In particular, we do not understand how carrying capacity fluctuates over seasons and years or how other factors, such as predation, affect carrying capacity (Walters and Juanes 1993; Walters and Korman 1999).

Adults

Life History

The Delta Smelt is generally considered a diadromous seasonal reproductive migrant, and in the winter, many adult Delta Smelt move upstream into fresh water for spawning (Moyle et al. 1992, Bennett 2005, Sommer et al. 2011). These movements may be a specific change in behavior in response to one or more environmental cues, for example, to the rapid and often dramatic environmental changes during winter first flush periods (Sommer et al. 2011, Bennett and Burau 2014). Focused, fixed-station sampling in the winters of 2009-10 and 2010-11 revealed higher catch of Delta Smelt at higher turbidity levels, as well as an asymmetry in probability of catch with respect to tidal phase; catch was highest in the channels during flood tide, but highest near the shoreline during ebb tides (Bennett and Burau 2014). This change in horizontal channel position with respect to tidal direction has recently been confirmed by a second study in the fall of 2012 that used the "SmeltCam," an underwater video camera attached to the cod-end of the FMWT net to detect Delta Smelt (Feyrer et al. 2013). This study demonstrated that during flood tides, Delta Smelt were relatively abundant throughout the water column, but less abundant during ebb tides, and found only in the lower portion of the water column and closer to shorelines. This asymmetry in catch supports the idea of a “tidal surfing” behavior during migration that may minimize energetic costs of upstream movement and allow Delta Smelt to follow favorable conditions with respect to turbidity and salinity (Feyrer et al. 2013). Variations of this behavior would allow fish to maintain position in the channel (stay on the edge during flood or ebb tide) or move downstream (move into the channel on ebb tide).

It is also possible that Delta Smelt movements do not represent a change in behavior; rather, fish are simply expanding their foraging or refuge distribution to habitat upstream when it becomes turbid or otherwise more suitable during and after the first flush period (Murphy and Hamilton 2013). The specific mechanism for the seasonal change in distribution, however, may be more a matter of terminology than of ecological relevance for a fish with as small a home range as Delta Smelt. Here, we acknowledge the existence of both possibilities, but will use the term “spawning migration” to simply refer to a directed movement upstream or downstream occurring prior to and during the spawning season. Using this definition, this seasonal change counts as a migration since it represents a relatively predictable and substantial change in distribution that has adaptive value including potential spawning, foraging and refuge functions (Lucas and Bara 2001).

The Delta Smelt spawning migration from their low-salinity rearing habitat into freshwater usually occurs between late December and late February, typically during first flush periods when inflow and turbidity increase on the Sacramento and San Joaquin Rivers (Grimaldo et al. 2009, Sommer et al. 2011a). Increased catches of Delta Smelt in the Delta Juvenile Fish Monitoring Program’s Chipps Island Trawl Survey and at the south Delta salvage facilities are unimodal in most years and occur within a couple of weeks of first flush events, suggesting that adult Delta Smelt are responding to environmental changes and migrating rapidly upstream once the first flush occurs (Grimaldo et al. 2009, Sommer et al. 2011a). However, spawning migrations are not always upstream. During occasional periods of very high river flows that spread freshwater habitat throughout much of the estuary, some Delta Smelt “migrate downstream” from rearing habitats in Suisun Bay and the Delta to freshwater spawning habitats as far west as the Napa River (Hobbs et al. 2007). Also under high flow conditions, it is possible that some Delta Smelt may not migrate in any direction; if their brackish-water rearing habitat becomes fresh, they can presumably spawn in suitable areas nearby. In addition, there is a small subset of the population that appears to remain in the Cache Slough complex year around; these fish presumably stay in the region for spawning (Sommer et al. 2011).

Osmerids generally spawn in shallow waters (Moulton 1974, Murawski et al. 1980, Hirose and Kawaguchi 1998, Martin and Swiderski 2001, Bennett 2005). It is believed that Delta Smelt spawn over sandy substrates in shallow areas based on the observation that first hatch larvae are collected in high concentrations in areas near expansive sandy shoals (Bennett 2005, L. Grimaldo, U.S. Bureau of Reclamation, unpublished data); confirmation of this hypothesis has not been verified through egg collections or observations of spawning adults, except in mesocosm studies (J. Lindberg, U.C. Davis, unpublished data). Pilot studies to identify egg deposition areas have been conducted by the IEP but these efforts were unsuccessful; it is unknown whether it was due to the method used, locations selected, or because of the low probability of detecting eggs from a relatively rare species.

The Delta Smelt is an opportunistic strategist (Nobriga et al. 2005). Opportunistic strategists are characterized by their short life spans, but high intrinsic rates of population increase driven by rapid maturation and repeat spawns over a protracted spawning season (Winemiller and Rose 1992). The importance of per capita fecundity to the success of the Delta Smelt population was recently highlighted in an individual-based modeling study (Rose et al. 2013a,b). In culture, Delta Smelt can spawn up to four times per year depending on water temperature (J. Lindberg, U.C. Davis, unpublished data). Recent evidence indicates that Delta Smelt can spawn multiple times in the wild if water temperatures stay cool in the later winter and early spring (Wang 2007, L. Damon, CDFW, written comm. 2013). The ability of Delta Smelt to spawn multiple times in the wild could substantially increase per capita fecundity over previous estimates for individuals of a specific size. It could also be a contributing factor to the large interannual variability in adult to larvae recruitment (Fig. 52a).

Population Trends

Adult Delta Smelt are monitored by the Spring Kodiak Trawl (SKT) survey which was initiated by CDFW (then CDFG) in 2002 and runs from January to May each year (Honey et al 2004). An indexing method was recently developed by CDFW for the SKT survey, allowing for year to year comparisons as well as comparisons with the abundance indices for other life stages (Fig. 3). The SKT index time series used in this report comprises 11 annual indices, from 2003 to 2013; no index is available for 2002. Each index represents the abundance of adult fish hatched in the previous calendar year that survive to spawn at the beginning of the next calendar year. The highest SKT index on record occurred in 2012 (147), as a result of the high 2011 abundance of younger fish, and the lowest in 2006 (18). Of the four comparison years, 2005 had the highest SKT index (51), followed by 2010 (27) and 2011 (20) and then 2006 (18). While the SKT index was thus lower in the two wet years than in the two drier years, the SKT index increased substantially in each of the years following the two wet years; however it increased only 2-fold from 2006 to 2007 while it increased 7-fold from 2011 to 2012 (Fig. 3). It is also possible that the SKT is less effective during very high flow events. Delta outflow at times exceeded 200,000 cfs in winter 2011 and 300,000 cfs in winter 2006. These high flow events might have contributed to the low SKT indices in these two wet years, if Delta Smelt remained near shore to avoid displacement or moved into San Pablo Bay with the LSZ. In both cases they would be outside of SKT sampling range. Further evaluations are needed, however, to investigate and quantify this hypothesized effect.

The annual adult Delta Smelt abundance indices track the annual abundance indices of sub-adults calculated from the previous years' FMWT survey closely (Fig. 53; see also Kimmerer 2008). The relationship is particularly strong at higher fall abundance indices (FMWT index > 50), with more variability at lower abundance indices. Before the POD decline in 2002, all Delta Smelt FMWT indices were greater than 50 (Fig. 3). Thus, the FMWT might provide a useful surrogate for estimating long-term abundance trends in the adult Delta Smelt population prior to the initiation of the SKT survey in 2002, but great caution is warranted with the approach because this hindcasting would rest on only four data points with high leverage (2003-2005, 2012) and assume stable subadult to adult survival relationships and habitat conditions, neither of which is likely true. Moreover, the Kodiak trawl more efficiently captures Delta Smelt than the FMWT net. The SKT survey was set up to target Delta Smelt, while the FMWT survey was designed to monitor young Striped Bass, which tend to be larger than Delta Smelt during fall; however, there is no reason to expect the difference in capture efficiency to affect the relationship, unless such differences were a function of population size (i.e., efficiency was different above and below FMWT = 50). The utility of the FMWT as a descriptor of long-term adult population trends in the absence of long-term data from the SKT will benefit from ongoing IEP efforts to quantitatively estimate the efficiency of the FMWT and to compare efficiencies of different trawling gear and protocols. While survival from subadults in the fall (FMWT) to adults in the winter and spring (SKT) (Fig. 53) has been more stable than adult to larvae recruitment and survival between other life stages (Figs. 51 and 52), it nevertheless shows some variability, especially when abundance is low. These data suggest that at least in the POD decade, adult numbers appear largely driven by juvenile abundance and the influence of changes in winter-time habitat attributes is less important and relatively stable from year to year.

The number of adult spawners affects population dynamics through production of eggs. Potential reproductive output is proportional to the number of adult female spawners, the clutch size for females of a specific size, and the number of egg clutches produced by each female. Although egg production in the wild has not yet been documented, we can evaluate the relationship of the SKT adult population index to the 20 mm Survey abundance index (Fig. 54). This relationship does not appear to be strong during the POD period (linear regression, $P > 0.05$). This suggests that egg production or subsequent hatching of eggs and survival of larvae and thus overall recruitment of larvae from the previous generation's adults is affected by other factors than adult population size. Hypotheses about the effects of habitat attributes in our conceptual model on adult growth and fecundity and recruitment of young are explored in Chapter 7.

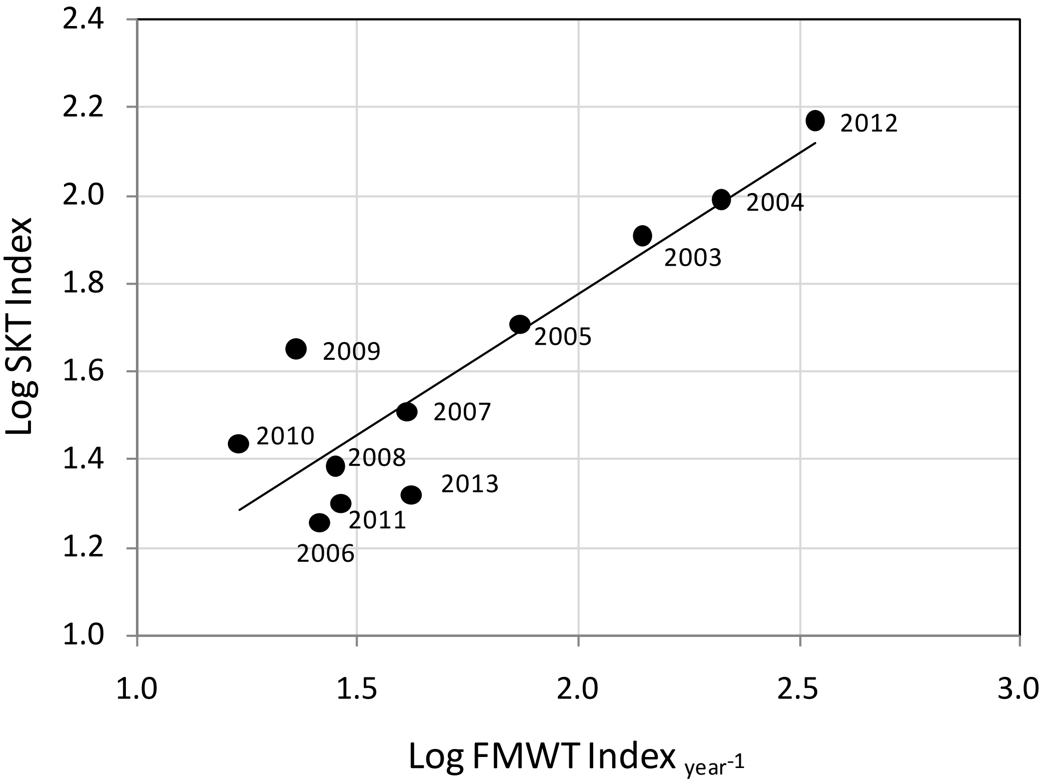
Clutch sizes of fish collected in the SKT were not measured, but annual fork lengths of Delta Smelt collected in the SKT did not vary greatly (Fig. 55). It does not appear that clutch size should have varied much in the POD years, including the four comparison years 2005-6 and 2010-11, with 2003 as the exception where the median length was greater than 70 mm standard length (Fig. 55). For Delta Smelt, which are now considered seasonal indeterminant spawners (i.e., they spawn multiple times), total reproductive output of an individual female should vary with: 1) size at the onset of the spawning window because batch fecundity is a function of size (Bennett 2005, CDFW unpublished data), 2) length of the spawning window, which is the number of days with suitable water temperatures for spawning (see larvae section below) and determines the number of batches possible; and 3) growth during the spawning window, which can potentially improve batch fecundity over time (see larval section below). Obviously, reproductive output will be higher in years when adult females are larger, abundances are higher, and the spawning window is prolonged such that multiple clutches are produced. Note that maximum reproductive output of the adult population at the beginning of spawning is not often realized due to mortality arising from density-dependent (e.g., food limitation or predation) or density-independent (e.g., entrainment, contaminants) mechanisms. According to Bennett (2011), larvae from bigger, early-spawning females may be disproportionally lost to CVP and SWP entrainment. In this report, we consider years when there are bigger females and/or a higher spawning stock size to be better in terms of reproductive potential than years when adult female size and spawning stock are smaller.

Larvae

Life History

Adult Delta Smelt, through their selection of spawning sites and spawn timing, largely determine the early rearing habitat and environmental conditions encountered by larvae. Given the Delta Smelt's annual life cycle, small size at maturity, relatively low fecundity, and small egg size compared to other fishes, life history theory suggests that parental care, here limited to selection of spawning sites and spawn timing, should be an important factor in reproductive success (Winemiller and Rose 1992). Since eggs have not been detected routinely in the wild, spawning and early rearing habitat locations are inferred from collection of ripe adults and early stage

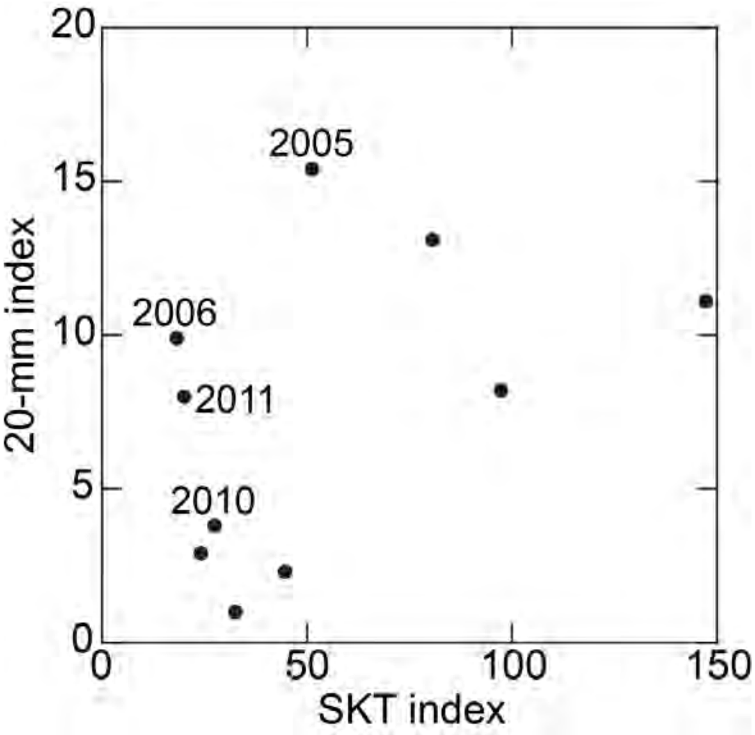
Figure 53. Relationship of annual indices of Delta Smelt abundance from the Spring Kodiak Trawl (SKT) and Fall Widwater Trawl (FMWT) from the previous year. Year labels correspond to the year of the SKT. The linear regression with all index values log-transformed to address non-normal distributions in the raw data is: Log SKT Index = 0.4997 + 0.6381(Log FMWT Index Year^{-1}), n = 11, p < 0.001, R^2 = 0.79.



larvae, which occur from the Delta margins through eastern Suisun Bay (see: http://www.dfg.ca.gov/delta/projects.asp?ProjectID=SKT; Wang 1986, 1991, 2007). In culture, Delta Smelt begin spawning as water temperatures increase to 10-12 °C, at which time individual females accompanied by several males select appropriate water velocities and release gametes close to the substrate from dusk to dawn (Baskerville-Bridges et al. 2004b). In lab experiments, females deposited significantly more eggs on sand and gravel substrates as compared to other substrates offered for egg deposition (J. Lindberg, U.C. Davis, unpublished data). Based on periodicity in egg deposition in culture, Bennett (2005) proposed that spawning likely coincides with peak tidal currents (i.e., spring tides), which would result in hatching near neap tides. Such a strategy would limit the initial tidal dispersal of larvae.

In culture, larvae hatch after an 11-13 day incubation period at 14.8-16.0 °C and begin a short period of buoyancy (or positive phototaxis; Baskerville-Bridges et al. 2004b) prior to slowly settling to the bottom (Mager et al. 2004). After this buoyant period, Mager et al. (2004) found that larvae were demersal unless actively swimming to feed, which occurred only during daylight hours. Exogenous feeding begins at 5-6 days post-hatch as the last of the yolk sac is absorbed; the lipid globule is absorbed at 10 days (Mager et al. 2004) providing some nutritional reserve if feeding conditions are poor. Larvae probably remain somewhat bottom oriented until swim

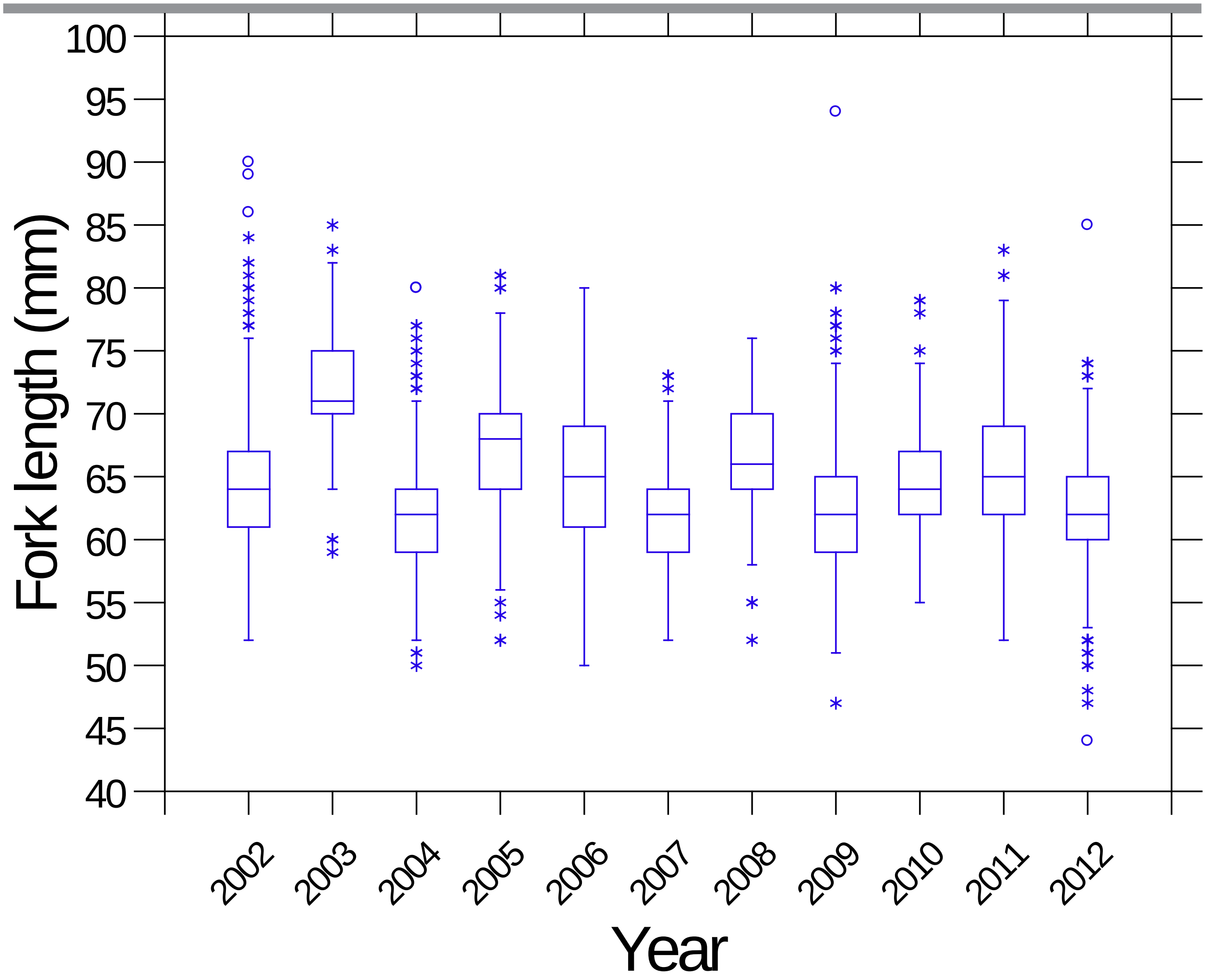
Figure 54. **Plot of the Spring Kodiak Trawl (SKT) adult abundance index against the 20 mm Survey larval abundance index 2003-2012. The comparison years of 2005, 2006, 2010, and 2011 are labeled.**



bladder and fin development are complete at about 65 days of age and about 20 mm TL (Mager et al. 2004, Baskerville-Bridges et al. 2004b), at which time they can fully control their buoyancy and efficiently use tidal and river currents to migrate. The center of distribution for Delta Smelt larvae and young juveniles is generally downstream of the spawning habitat, but upstream of and varying in association with X2 during spring (Dege and Brown 2004).

Early larval stages of Delta Smelt (4-15 mm) tended to be poorly collected by gear previously used in historical SFE egg and larval surveys (Striped Bass Egg and Larva Survey; sled-mounted 500 micron mesh net with 0.38 m^2 mouth area), but with growth and development greater proportions of the population become vulnerable. This observation led to a sampling gear change in the mid-1990s from the historical egg and larval gear to new gear targeting more vulnerable post-larvae and early juvenile Delta Smelt (i.e., 20 mm Survey). The improved catch and distribution information resulting from this change has since proven valuable to the management of Delta Smelt, and the 20 mm Survey results are now considered essential information (USFWS 2008). In the mid-2000s, an abundance index was developed from 20 mm data (Gleason and Adib-Samii 2007) that has since been used to index abundance trends of larvae in spring (e.g., Hieb et al. 2005, Contreras et al. 2011). We use 20 mm Survey abundance indices as one Delta Smelt end-point to evaluate the support for our hypotheses concerning the environmental drivers and habitat attributes responsible for abundance and survival of larvae.

Figure 55. **Median fork length (mm) of Delta Smelt collected in January and February by the Spring Kodiak Trawl by year, 2002-2012. See Chapter 3: Data Analyses for explanation of boxplots.**



Population Trends

The highest larval abundance indices on record occurred in the late 1990s, shortly after the initiation of the 20 mm survey in 1995. The lowest larval abundances were observed in 2007-2010 (Fig. 3). In 2011, larval abundance improved substantially from the recent minimum in 2007, and achieved levels comparable to those earlier in the 2000s (Fig. 3). Although 2011 larval abundance compared favorably to that of 2010, it remained below levels of 2005 and 2006. Thus, the modest larva abundance in 2011 did not appear sufficient to explain the high FMWT index observed in 2011 (Fig. 3). As explained above, larval abundance does not track the abundance of the parent generation very well (Fig. 54). In contrast, subsequent life stages of the same cohort track larval abundance and abundance relationships of larvae (log 20 mm index) with juveniles (log TNS index) and subadults (log FMWT index) in the same year are statistically significant (Fig. 56). However, the linear regression based on the FMWT explains less variance than the linear regression based on the TNS suggesting more variability in the abundance of the older life stages. This suggests that factors affecting juvenile mortality rates also play an important role in eventual recruitment.

Juveniles

Life History

During summer, juvenile Delta Smelt primarily rear in the west Delta, Suisun Bay, and Cache Slough complex (Moyle 2002, Bennett 2005, Merz et al. 2011, Sommer and Mejia 2013). As in late spring and fall, the center of distribution of the fish occurs in the low salinity zone, with the exception of the Cache Slough complex. The degree to which the fish use particular geographic areas depends on salinity, temperature, and turbidity (Nobriga et al. 2008); other factors that may affect their summer distribution include *Microcystis* distribution, and possibly prey density, bathymetric features, or other water quality constituents. As noted previously, Delta Smelt used to be common in the central and south Delta during the summer months, but this is no longer the case (Nobriga et al. 2008).

Population Trends

Relative abundance of juvenile Delta Smelt is presently indexed by the Summer Townet Survey (TNS). The survey was not designed specifically to measure Delta Smelt abundance and catches are low (Honey et al. 2004). Nonetheless, patterns in the annual abundance index provide a useful basic measure of population trends.

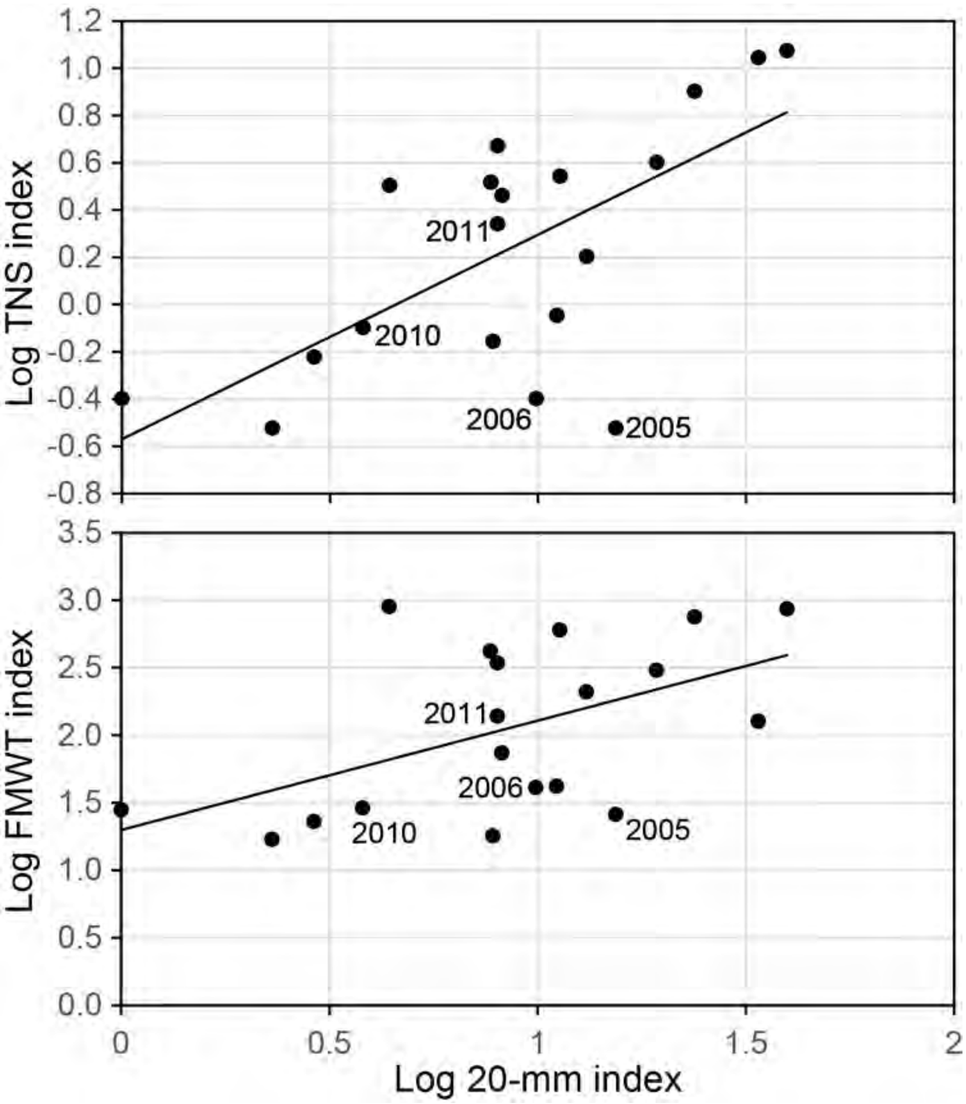
The TNS index rebounded substantially in 2011, but declined to a value consistent with low recent year indices in 2012 (Fig. 3). This pattern of persistently low abundance is consistent with the POD, which began over a decade ago (Sommer et al. 2007, Thomson et al. 2010). During the last decade, TNS abundance indices were especially low from 2005-2009 (Fig. 3). The onset of the 2005-2009 period of low juvenile abundance was characterized by extremely low larvae to juvenile survival in 2005 and 2006 (Fig. 51). Larval survival to juveniles recovered somewhat in the following years, but TNS indices stayed low (Fig. 3). Historically (e.g., early 1970s), high levels of Delta Smelt abundance during summer apparently allowed density dependent effects to occur between summer and fall in some years; this conclusion was still supported after the species declined in the early 1980s, but the apparent carrying capacity was lower (Bennett 2005). The available trawl data suggest that this trend of declining carrying capacity has continued as suggested by the very low Fall Midwater Trawl indices produced by a range of juvenile TNS abundance levels, during the POD years (Fig. 57).

Subadults

Life History

During fall, subadult Delta Smelt primarily rear in the western Delta, Suisun Bay, and Cache Slough complex (Moyle 2002, Bennett 2005, Sommer and Mejia 2013). The center of distribution is in the low-salinity zone (Sommer et al. 2011), with the exception of the Cache Slough complex. The degree to which the fish use particular geographic areas depends on salinity and turbidity (Feyrer et al. 2007). Other factors that may affect their distribution during the fall include *Microcystis* distribution and water temperature in the early fall (September-October), and possibly prey density.

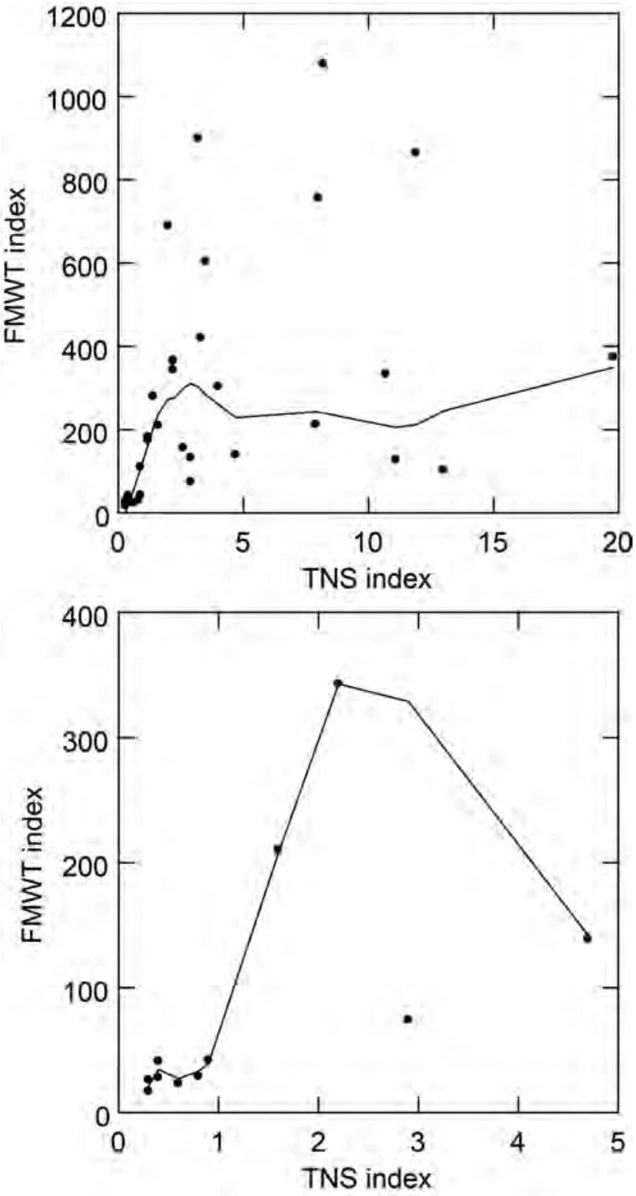
Figure 56. **Relationship of annual index of Delta Smelt abundance from the 20 mm survey (20 mm) with the annual indices from the summer townet survey (TNS) and fall midwater trawl survey (FMWT). Year labels correspond to the comparison years of interest. The linear regressions with all index values log-transformed to address non-normal distributions in the raw data are: Log 20 mm index = 0.57 + 0.87(Log TNS index), n = 19, $p < 0.05$, $R^2 = 0.44$ and Log 20 mm index = 1.30 + 0.81(Log FMWT index), n = 19, $p < 0.05$, $R^2 = 0.27$.**



Population Trends

Population trends for subadult Delta Smelt are presently indexed by the FMWT. Like the TNS, the FMWT was not designed specifically to measure Delta Smelt relative abundance and catches are low (Honey et al. 2004, Newman 2008). The data are nonetheless a useful basic measure of population trends, except perhaps at very low abundance (i.e., FMWT index values less than about 50; Fig. 53). However, the general agreement between the FMWT and subsequent Spring Kodiak Trawl (SKT) sampling (Fig. 53), suggests that FMWT results are a reasonable indicator

Figure 57. Plots of fall midwater trawl (FMWT) abundance index as a function of summer townet survey (TNS) abundance index for 1982-2013 and 2003-2013. Note the very different scales for both axes. Lines are LOWESS smooths.



of general trends in abundance of adult Delta Smelt.

The FMWT index rebounded substantially in 2011, but declined to a value consistent with low recent-year indices in 2012 (Fig. 3). During the last decade, FMWT indices were especially low from 2005-2010 (Fig. 3). After the rebound in 2011, the index went back to a lower level similar to the 2005-2010 period. Since 2003, the juvenile to subadult survival index was lowest in 2004. During the four comparison years, the juvenile to subadult survival index was lowest in 2010, but relatively high in the other three years and highest in 2011 (Fig. 51).

Historically, high levels of Delta Smelt abundance during summer apparently resulted in density-dependent mortality between summer and fall in some years (Bennett 2005). This conclusion was still supported after the species declined in the early 1980s, but the apparent carrying capacity, meaning the magnitude of the FMWT index relative to the TNS index, was lower (Fig. 57). The available FMWT data suggest that these trends of density-dependent mortality during the summer-fall and declining carrying capacity have continued (Fig. 57). The close correlation of the FMWT and SKT (Fig. 53) indicates that the factors likely affecting survival of Delta Smelt to the adult spawning population operate earlier in the life cycle (i.e., between the egg and subadult life stages). Additional mortality certainly occurs between the FMWT and SKT but the lack of variability around the regression line suggests there is not a lot of variability in the rate of that mortality. Thus, the relative annual spawning stock appears to be largely determined by fall of the birth year.

Chapter 7: Using the Conceptual Model–Why did Delta Smelt abundance increase in 2011?

In this Chapter, we further explore Delta Smelt responses and habitat attributes as depicted in the driver and life stage transition conceptual model diagrams presented in Chapter 5. The purpose is to demonstrate the utility of our conceptual model framework for generating hypotheses about the factors that may have contributed to the 2011 increase in Delta Smelt abundance. For each life stage transition, we explore a series of hypothesized linkages among ecosystem drivers, habitat attributes, and Delta Smelt responses. We evaluate these hypotheses by comparing habitat conditions and Delta Smelt responses in the wet year 2011 to those in the prior wet year 2006 and in the drier years 2005 and 2010.

In this Chapter we briefly describe the comparative approach and the hydrological conditions during the four years that are the focus of our comparisons. We then state and explore each hypothesis for the adult, larval, juvenile, and subadult life stages of Delta Smelt using data sources described in Chapter 3. Key points from these evaluations, as well as previous report Chapters, along with benefits and limitations of the comparative approach are summarized and discussed in Chapter 8. In several cases, we lacked suitable data or other necessary information to evaluate our hypotheses; these data and information gaps are described in Chapter 9. Chapter 9 also includes a brief review of some of the more complex mathematical analyses used in recent peer-reviewed publications, such approaches currently being used by others, and three examples of additional mathematical modeling approaches that can be used to further explore some of the linkages and interactions in our conceptual model and complement previously published and other ongoing mathematical modeling efforts for Delta Smelt.

Comparative Approach

The comparative approach used for evaluating the hypotheses stated in this Chapter is similar to the approach taken in the FLaSH investigation (Brown et al. 2014, see also http://deltacouncil.ca.gov/science-program/fall-low-salinity-habitat-flash-studies-and-adaptive-management-plan-review-0). This allowed us to place the results of the FLaSH investigation in a year-round, life cycle context as recommended by the FLaSH Panel (FLaSH Panel 2012). Specifically, we compared data from the two most recent wet years, 2006 and 2011, and the two years that immediately preceded them, 2005 and 2010. To conduct our comparisons, we determined how Delta Smelt responses or habitat attributes would be expected to respond in the different years and then compared the expected response to the observed response. If the expected and observed responses were similar, the hypothesis was considered to be supported.

Moderate to wet hydrological conditions tend to benefit many estuarine organisms, including Delta Smelt (Sommer et al. 2007). But low recruitment or low survival at any point in the predominantly annual Delta Smelt life cycle can lead to low abundance even in a wet year. Identifying the reason(s) for low abundance in a wet year may give important insights into key habitat attributes and environmental drivers that could be managed in a way that would improve the likelihood of abundance increases in all wet years.

The two wettest years after the onset of the POD were 2006 and 2011 (Fig. 58). Delta Smelt abundance increased substantially in 2011, but not in 2006 (Fig. 3). The failure of the Delta Smelt population to increase in the wet year 2006 and the increase of Delta Smelt in the wet year 2011 provides an opportunity to compare and contrast habitat attributes in these two years and possibly identify new options for management actions. As stated in Chapter 3, our working assumption is that different Delta Smelt abundances in 2006 and 2011 should be attributable to differing environmental conditions, in some cases attributable to management actions, and subsequent ecological processes influencing the Delta Smelt population.

Preceding habitat conditions may have important implications for the response of a population to the environmental conditions present during a wet year; therefore, we also consider data from 2005 and 2010. Further, we also consider adult and larval abundance in 2012 following the wet year of 2011. We did not include any years predating the POD period in this analysis. This was done to prevent the possibly more subtle, but management-relevant, environmental changes occurring during the POD period from being overwhelmed by effects of the strong POD step changes in the early 2000s as well as similarly strong changes that occurred before the POD (e.g., after the invasion of the clam *Potamocorbula amurensis*).

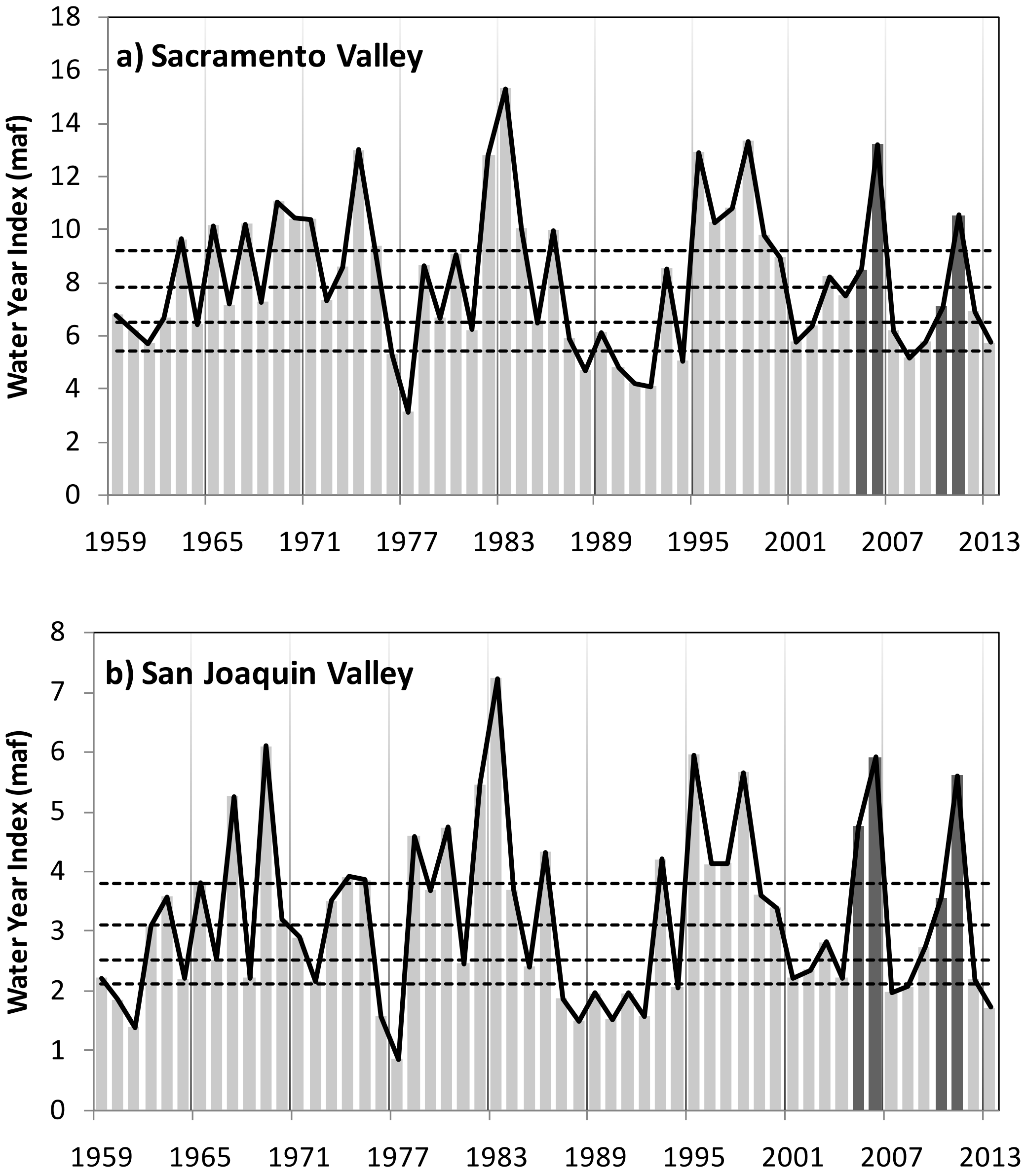
For the purpose of this report, we call 2005, 2006, 2010, and 2011 our "study years." We use "year" rather loosely because the Delta Smelt life cycle does not follow the calendar year. As already explained, life stages can overlap and can be observed during different months in different years. Mature adults of a cohort produced in one year are generally not observed until the following year. Similarly, the life cycle does not strictly follow the water year type. We do our best to explain these mismatches when they occur and keep the presentation focused on the life cycle and the conceptual models.

Note that we do not examine the complex interactions that may occur when more than one hypothesis is true (or false), nor do we rule out that a hypothesis may be true in some years and false in others. Therefore, it is important to recognize that data contrary to a hypothesis may indicate that the habitat attribute was not controlling in the selected years, or that complex interactions among multiple habitat attributes (and corresponding hypotheses) contributed to the observed effects. Addressing such complexities is more appropriate for quantitative models as discussed in Chapter 9.

Hydrological Conditions

According to annual water year indices and classifications for overall hydrological conditions in the Sacramento and San Joaquin Valleys that provide the freshwater inflow into the Delta, 2005, 2006 and 2011 were the wettest years of the POD period (Fig. 58, see also http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). In the San Joaquin Valley, 2010 was the fourth wettest year of this period. In the Sacramento Valley, 2003 and 2004 were wetter than 2010. Specifically, water year 2010 was classified as "below normal" in the Sacramento Valley and "above normal" in the San Joaquin Valley and 2011 was classified as wet in both areas, according to the water year index classifications. Water year 2005 was classified as "above normal" in the Sacramento Valley and "wet" in the San Joaquin Valley and 2006 was classified as wet in both areas. (Fig. 58). Water year 2012 was classified as "below normal" in the Sacramento Valley and "dry" in the San Joaquin Valley.

Figure 58. Annual water year indices for the a) Sacramento and b) San Joaquin Valleys since the initiation of the Summer Townet Survey in 1959. Horizontal dashed lines: threshold levels for water year type classifications as wet (W), above normal (AN), below normal (BN), dry (D) and critically dry (C). Darker grey bars indicate the four study years (2005, 2006, 2010, 2011) examined in Chapter 7 of this report. (Data are from http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST).



The overall wet hydrological conditions in the Sacramento and San Joaquin Valleys in 2005-6 and 2010-11 resulted in relatively prolonged periods of high Delta inflow and outflow and low X2 values in the winter and spring months of the four study years (Fig. 59). In the first half of the year, 2006 had the highest outflow and lowest X2 values followed by 2011, 2005, and 2010. In the second half of 2011, outflow was higher and X2 values were lower than in the second half of 2006 and of all other years during the POD period. In spite of having the lowest spring X2, 2006 had the highest fall X2 (September to October) of all study years, followed by 2005, 2010, and 2011 (Fig. 60).

The overall high flows during these four years allowed for periods of very high fresh water exports from the Delta (Fig. 59). This led to record high volumes of fresh water exported in water year 2011 (6.7 maf) and in water year 2005 (6.5 maf) and a somewhat lower export volume in water year 2006 (6.3 maf). The total water export volume was substantially lower in water year 2010 (4.8 maf) because 2010 immediately followed a three-year drought and the below normal hydrological conditions in the Sacramento Valley (Fig. 58) were not sufficient to rapidly replenish reservoirs and allow for greater exports.

Hypotheses

Individual hypotheses are indicated in the life stage transition conceptual model diagrams next to the arrows depicting each hypothesized linkage or outcome (figs. 46-49). While all linkages are considered important, we only developed hypotheses for selected linkages. We developed hypotheses for linkages with sufficient data for quantitative assessments and where there is disagreement or uncertainty regarding the outcome resulting from a driver. We also developed hypotheses for linkages considered important but where we found critical information was missing; thus, highlighting topics where new work is needed. For each of these hypotheses, we then considered the available data to examine whether the Delta Smelt response expected under the hypothesis was consistent with the observed trends in habitat attributes or population dynamics. While we would have liked to test hypotheses about the linkages between habitat attributes and the specific life stage transition processes shown in the life stage transition conceptual model diagrams, the available data often only allowed us to test “lower tier” hypotheses about the linkages between ecosystem drivers and habitat attributes.

Note that we have not examined the complex interactions that may have occurred when more than one hypothesis was true (or false), nor have we ruled out that a hypothesis may be true in some years and false in others. Therefore, it is important to recognize that data contrary to a hypothesis may indicate that the habitat attribute was not controlling in the selected years, or that complex interactions among multiple habitat attributes (and corresponding hypotheses) contributed to the observed effects. Addressing such complexities is likely more appropriate for quantitative models as discussed in Chapter 9. Our overall objective in this Chapter is to provide a demonstration of how the conceptual model can be used to generate and test hypotheses and highlight data gaps while addressing a specific topic of management interest—the increased Delta Smelt abundance index in 2011.

Adult Hypotheses

Hypothesis 1: Hydrology and water exports interact to **influence entrainment risk for adult Delta Smelt.**

As discussed earlier, we do not currently have a reliable measure of actual entrainment of fishes by the SWP and CVP export pumps. We also do not have actual population abundance estimates for Delta Smelt. As discussed by Kimmerer (2008, 2011) and Miller (2011), it is thus difficult to estimate proportional population losses due to entrainment. We consider the published

Figure 59. Net daily flows in cubic feet per second for a) Delta inflow from all tributaries, b) Delta outflow into Suisun Bay, and d) total freshwater exports from the Delta. Also shown are daily values for c) X2 (see Chapter 4 for explanation). Flow data are from Dayflow (http://www.water.ca.gov/dayflow/). X2 values are calculated from daily Delta outflow with the equation in Jassby et al. (1995.)

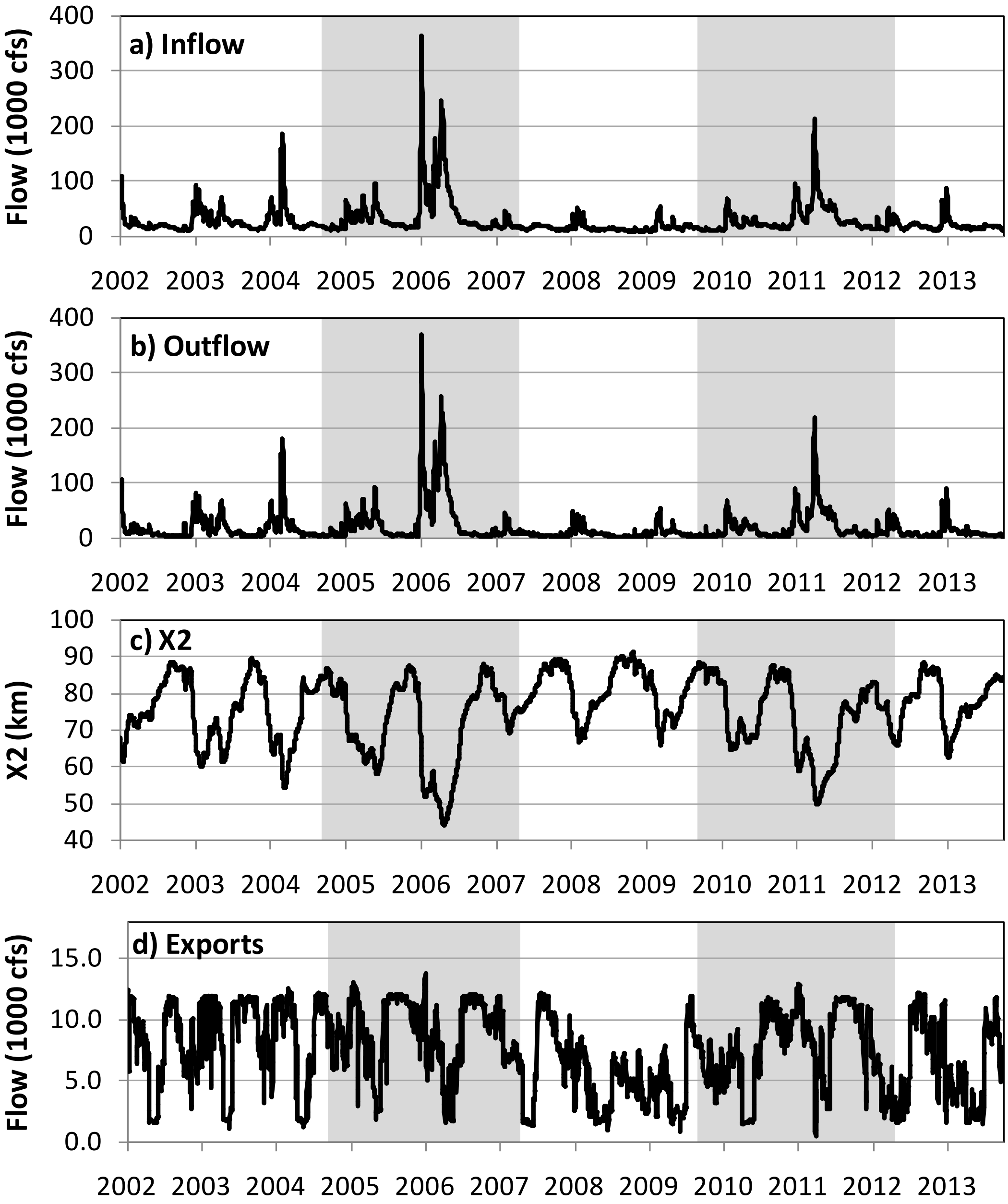
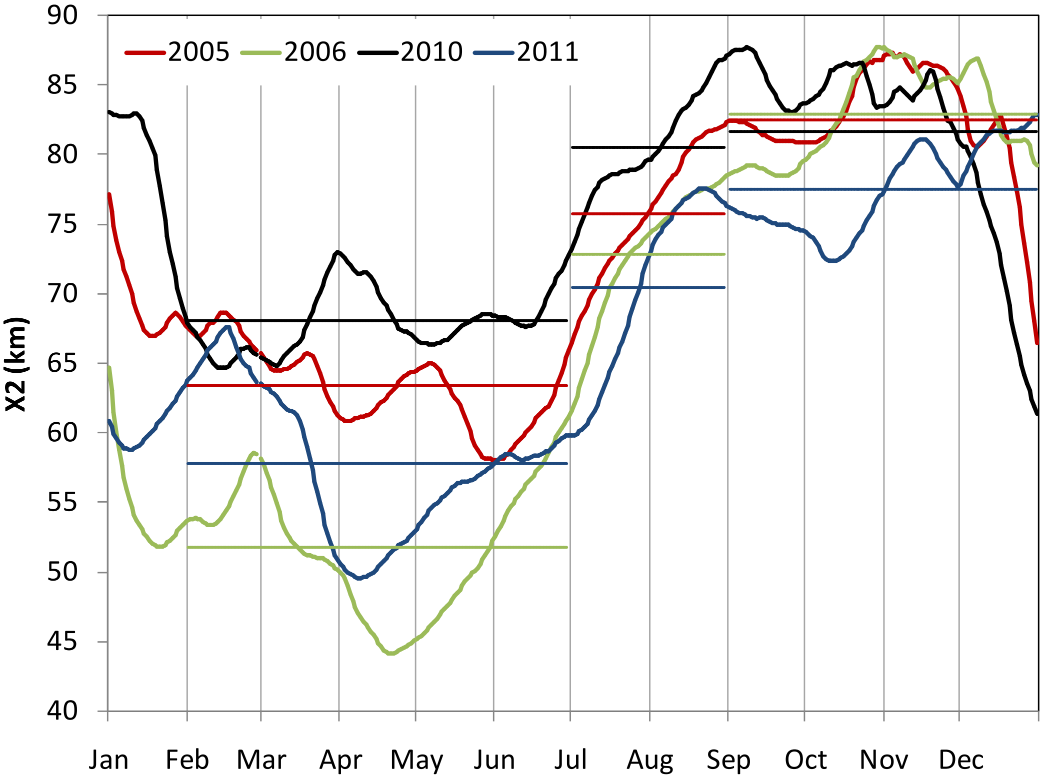


Figure 60. **Daily X2 values in January to December for each of the four study years. Seasonal X2 averages are indicated by horizontal lines for spring X2 (February to June), summer X2 (July and August), and fall X2 (September to December). See Fig. 15 for seasonal X2 in other years.**



proportional loss estimates for adult Delta Smelt entrainment losses for the two years for which they are available (2005 and 2006; Kimmerer 2008). However, we otherwise restrict our analysis – and this hypothesis – to an assessment of entrainment risk based on salvage and OMR flow data. Note that high entrainment risk for an individual fish does not automatically lead to a high proportion of the population lost to entrainment mortality. For example, in wetter years when large numbers of fish are present but most of the population is distributed farther away from the pumps, a large number of fish can be entrained but only a small percentage of the entire population.

Adult (December-March) Delta Smelt salvage was highest in 2005 followed by 2006 and 2010 and lowest in 2011 (Fig. 61). In 2005, most salvage occurred in January, while in the other three years it occurred in February and March (Fig. 62). Overall, adult Delta Smelt salvage in the four comparison years was on the very low end of the historical time series starting in 1980 (Fig. 26). On the other hand, the ratio of adult salvage divided by the previous year's FMWT index was high in 2005 (6th highest on record since 1979), but much lower in 2006 and 2010, and lowest in 2011 (Fig. 26).

Low salvage levels in these years and especially in 2010 and 2011 were not particularly surprising due to the low FMWT levels of the POD years along with more active management of OMR flows for Delta Smelt and salmonid protection after 2008 in accordance with the USFWS (2008) and NMFS (2009) BioOps. For management purposes, the onset of increased adult Delta Smelt entrainment risk is inferred from distributional patterns of Delta Smelt detected by the SKT survey, Delta Smelt salvage and, more recently, consideration of Delta conditions, including turbidity patterns. Since 2009, net OMR flows during periods of increased adult Delta Smelt entrainment risk are now always less negative than they were in years prior to the BioOps. Prior to 2008, net OMR flows often reached -8,000 to -10,000 cfs (see Fig. 31, Kimmerer 2008, Grimaldo et al. 2009), when outflow was low. An exception to these strongly negative flows occurred during April-May export curtailments associated with the Vernalis Adaptive Management Program (VAMP, 2000-2012). These curtailments were especially pronounced in the first half of the VAMP period (2000-2005). During the four comparison years, winter (December-March) net OMR flows were least negative in 2006 followed by 2011 and 2010 with the most negative net OMR flows in 2005 (Fig. 63). High inflows particularly from the San Joaquin River during 2005, 2006 and 2011 moderated effects of negative OMR flows, while export pumping generally remained high. In 2010 at the end of a three-year drought, there was little water in storage to provide for Delta exports prior to the first substantial inflows in mid-January. Subsequently, export levels had to be curtailed to achieve the desired OMR flows. Average winter-time net flows past Jersey Point on the San Joaquin River were positive in all four study years and greatest in 2006 followed by 2011, 2005, and 2010 (Fig. 63).

Kimmerer (2008) used salvage, OMR flows, and fish survey data to estimate proportional population losses due to entrainment for the years 1995-2006. The years 2005 and 2006 represent some of the lower loss estimates in the years examined by Kimmerer (2008); mean population losses reached up to 22% of the adult population in some years when OMR flows were more negative than -5000 cfs (Kimmerer 2008). Even if Kimmerer's estimation method provides a potential overestimate of loss (Miller 2011), proportional losses of the adult population were less than 10% in the two years that coincide with our comparison years (2005 ≈ 3% , 2006 ≈ 9%; from Fig. 12 in Kimmerer 2008). These types of proportional loss estimates are not available for

Figure 61. **Annual adult (December-March) Delta Smelt salvage at the CVP (blue bars) and SWP (green bars) fish protection facilities for 2005-2012.**

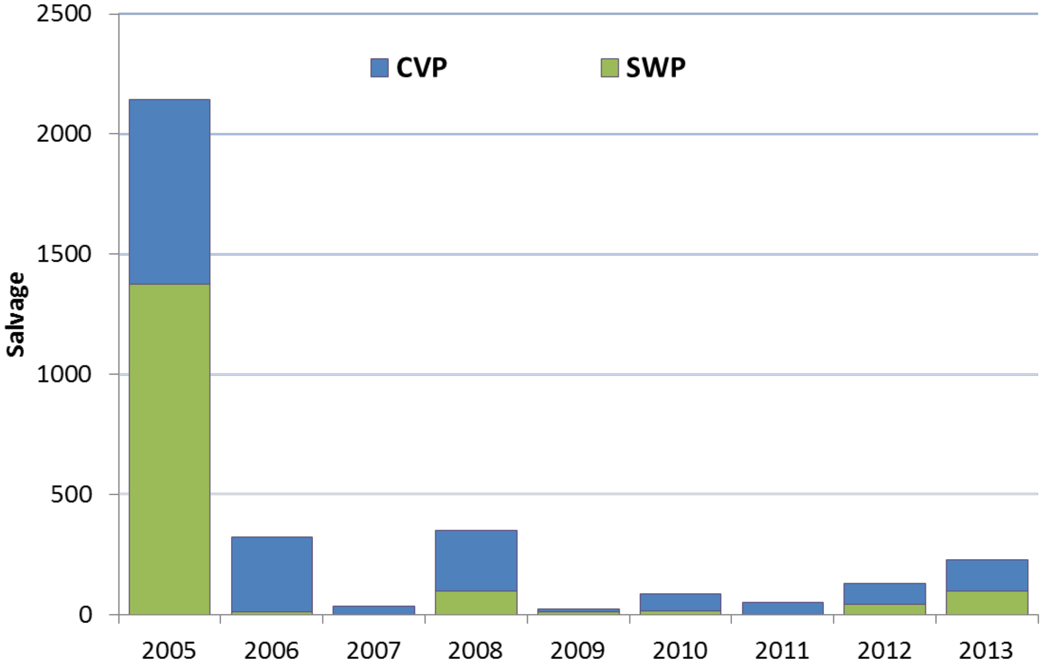
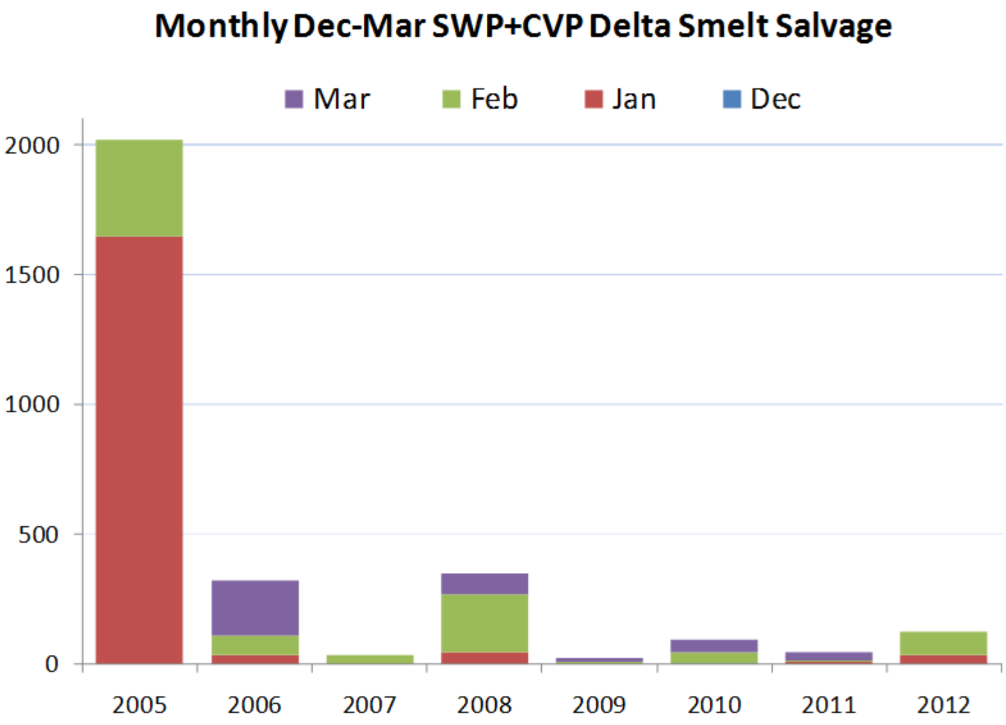


Figure 62. Annual combined adult (December-March) Delta Smelt salvage at the CVP and SWP fish protection facilities by month for 2005-2012.



2010 and 2011, but would likely be even smaller than for 2005 due to less negative OMR flows and fish distributions away from the CVP and SWP pumps. Salvage was also lower in these two years than in 2005 and 2006.

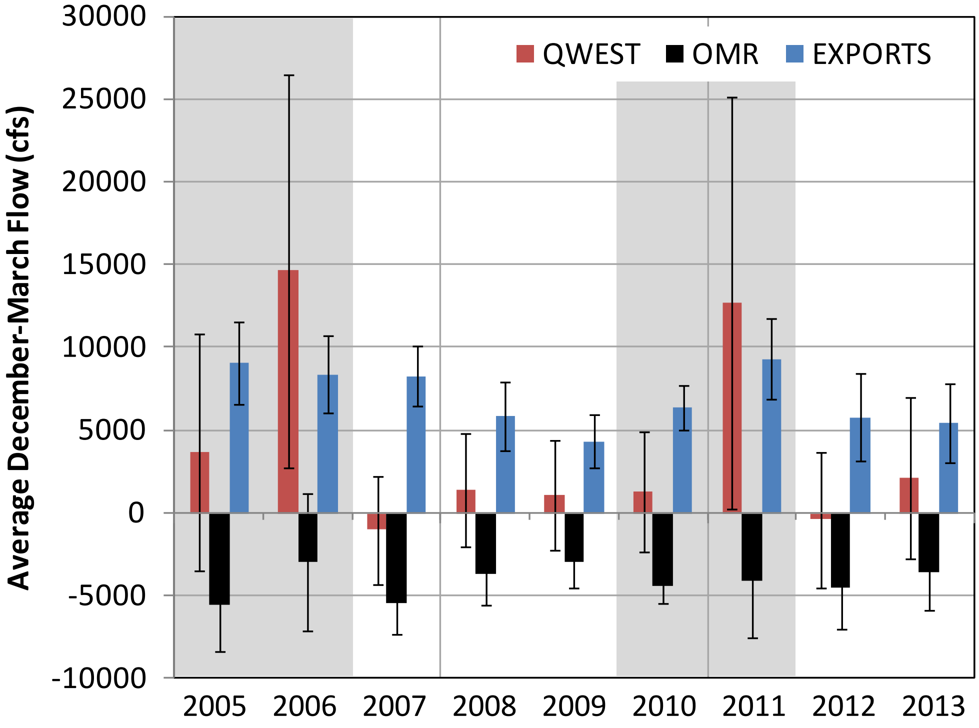
In summary, we conclude that hydrology and water exports do interact to influence entrainment risk for adult Delta Smelt and that adult Delta Smelt entrainment risk during the four comparison years was perhaps higher in 2005 than in the other years, but was low relative to historical levels in all four years.

Hypothesis 2: Hydrology interacting with turbidity affects predation risk for adult Delta Smelt.

At present, we do not have information about differences in actual predation mortality between the comparison years. As with entrainment, we thus limit this hypothesis and our analysis to to a general discussion of predation risk. Fully characterizing predation risk is exceptionally complicated, making it difficult to generate simple hypotheses that describe associated losses of all life stages of Delta Smelt. We thus limit our hypotheses about predation risk to a few factors for each life stage. For adults, we consider hydrology and turbidity as well as overlap with predators (next hypothesis).

Because Delta Smelt migrate during higher flow conditions when the water is generally turbid, it is assumed that losses to visual predators are lower or at least not substantially higher during the migration period than during other periods. First flush studies led by the USGS and UC Davis

Figure 63. **Annual average daily net flows for December through March in cubic feet per second (cfs) in Old and Middle River (OMR), past Jersey Point on the lower San Joaquin River (QWEST) and total exports in millions of acre feet (MAF), 2005-2013. Error bars are 1 standard deviation.**



suggest that Delta Smelt aggregate in the water column away from channel edges during daytime flood tides during upstream migration events (Bennett and Burau 2014), but it is not known if Striped Bass or Sacramento Pikeminnow *Ptychocheilus grandis*, the most likely predators of Delta Smelt in the water column, can detect and exploit these aggregations.

In the winters of 2005, 2006, 2010, and 2011 the highest Secchi depths (lowest turbidity) were found in the freshwater regions of the estuary (< 1 salinity), except for the Cache Slough region in the north Delta which was as turbid as the saltier regions of the estuary (Fig. 64). Winter-time Secchi depths in the freshwater region recorded during the SKT surveys (Fig. 64) were often higher (water clearer) than the average Secchi depths across all IEP EMP monitoring sites during these months since 2003 (about 60 cm) and especially when compared to pre-POD winter Secchi depths (around 50 cm on average) recorded by the EMP (Fig. 25). Winter-time Secchi depths in the other salinity regions were generally lower (water more turbid) than the EMP Secchi depth averages for the POD years and more similar to historical averages. In all four comparison years, predation risk associated with turbidity levels was thus likely not different from the historical risk in the more saline regions and the Cache Slough complex, but possibly higher in the freshwater regions, except for the Cache Slough region.

The salinity region differences were much more pronounced than the interannual differences between the four comparison years. Based on these data, it is not clear that higher flows in 2006 and 2011 contributed to higher turbidity in the winter months. The exception might be near the end of the Delta Smelt spawning season in early April when Secchi depths in the freshwater region were often substantially lower in the two wetter years 2006 and 2011 than in the two drier years 2005 and 2010 (Fig. 64). This will be discussed further in the report section about larval Delta Smelt. For adults, we conclude that interannual differences in turbidity between the wetter and drier of the four comparsion years did not likely contribute substantially to reduced predation risk and increased survival in the two wetter years.

Hypothesis 3: Predator distribution affects predation risk of adult Delta Smelt

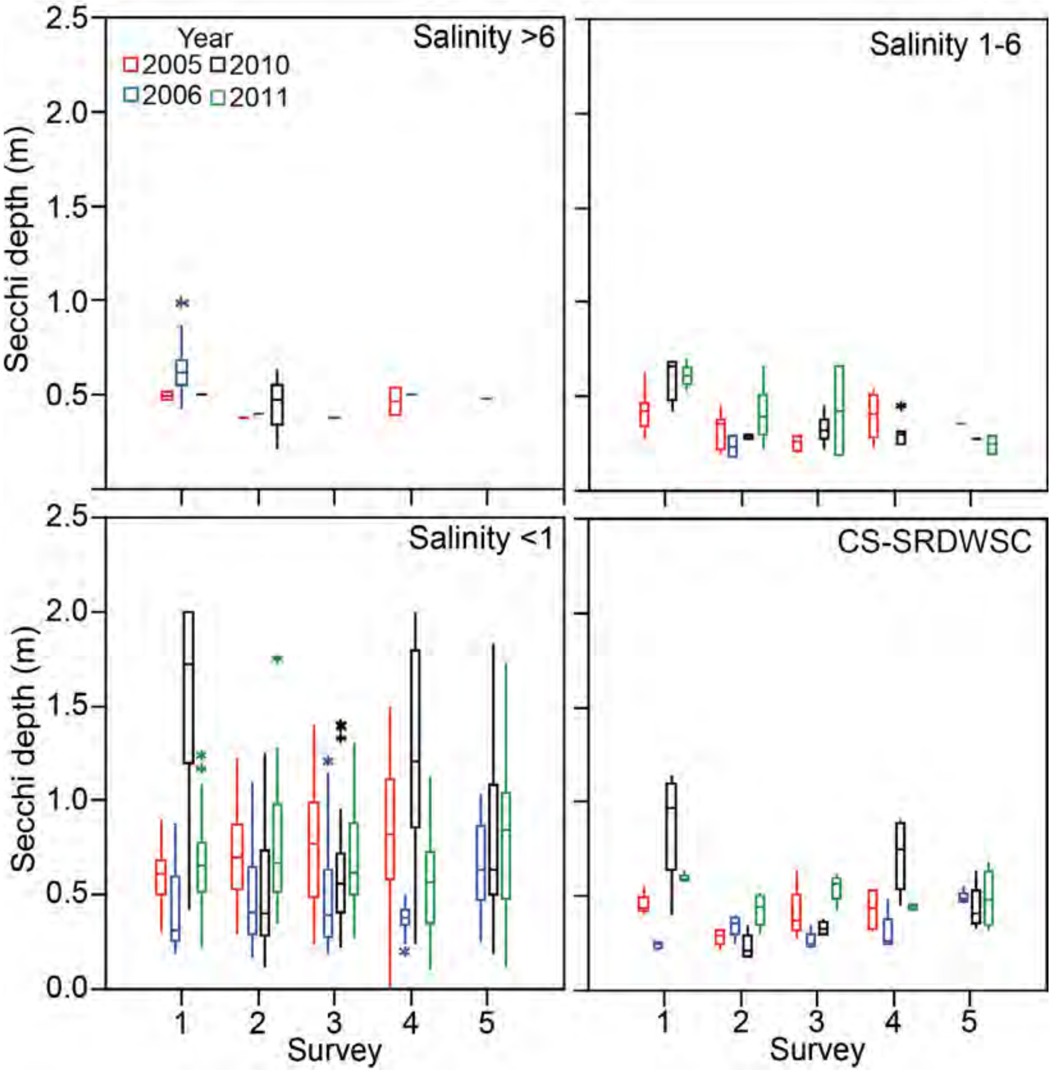
Spatial and temporal overlap with predators is a likely factor contributing to predation risk for all life stages. At present, we do not have information about how predator distribution varied between our comparison years but it is recognized that adult Delta Smelt could be vulnerable to predation if the distributions of predators and Delta Smelt populations overlapped. As already mentioned, Striped Bass and Sacramento Pikeminnow are the most likely open-water predators of adult Delta Smelt. If Delta Smelt utilize littoral habitats to a greater extent than presently assumed, then increased overlap with the distributions of Largemouth Bass and other centrarchid populations is possible. Results of field studies (Feyrer et al. 2013, Bennett and Burau 2014), described for Adult Hypothesis 2, found that adult Delta Smelt did move nearshore on a tidal basis to avoid displacement or move upstream during the “first flush.” Such movements would increase proximity to shoreline predators like Largemouth Bass, albeit during periods of increased turbidity when such visual predators would be at a disadvantage. Clearly, Hypothesis 2 and Hypothesis 3 are closely linked because predation risk is a function of predator presence and prey vulnerability. More information about predator presence is needed to evaluate this aspect of predation risk.

Hypothesis 4: Variability in prey availability during winter and spring affects growth and fecundity (eggs per clutch **and number of clutches) of female Delta Smelt.**

The hypothesis is that increased food availability leads to not only increased adult survivorship, but also growth, which in turn increases reproductive output (number of eggs per female increases with size; Bennett 2005). In addition, with cooler temperatures and lower metabolic rates, sufficient food resources during winter can contribute to energetically demanding multiple spawning events (three spawns possible in wild fish; L. Damon, CDFW, written communication 2012).

For adult females, the ability to meet the bioenergetic demands of reproductive development with sufficient food consumption may be particularly important for fish that spawn multiple times in a year. Preliminary findings from January through April 2012 indicated that adult Delta Smelt are indeed consuming large prey items, such as amphipods, mysids, and larval fish during their spawning period (Fig. 44) with feeding incidence near 98% for the period (Table 2). For this report, we cannot address whether food limitation is a relevant factor during the late winter-spring spawning period because we do not have sufficient data about adult Delta Smelt feeding, but we hypothesize that it may be a critical issue for spawners that need energy for multiple egg clutches. Evidence in support of this hypothesis comes from the modeling simulation experiment by Rose et al. (2013b) who found that food availability along with water temperature affected fall and winter growth and egg production prior to spawning and ultimately population success.

Figure 64. Secchi depth data collected during the Spring Kodiak Trawl Survey. Surveys are conducted monthly January-May. See Chapter 3: Data Analyses for explanation of boxplots.



Based on trajectories in adult fork lengths, it appears that adult growth may have been somewhat higher in 2005 and 2011 than in 2006 and 2010, although differences were not pronounced (Fig. 17) and as noted in Chapter 6, annual fork lengths of Delta Smelt collected in the SKT were similar in the four study years (Fig. 55). From these data we infer that environmental conditions were generally good, supporting both continued growth in length and maturation of eggs, except perhaps in 2010. In 2011, only 13 mature females were collected, so growth estimates are uncertain. In general, the number of mature females collected each year reflected year-class strength as measured by the SKT (Fig. 3), except in 2011 when only 13 ripe or ripening females were collected. Adults may use more energy for egg production than for continued somatic growth, but we do not have data on clutch sizes to evaluate this for the four study years.

Data on prey availability for current IEP sampling locations is also limited. Adult Delta Smelt diet is varied (Fig. 44) and includes pelagic and demersal invertebrates, as well as larval fish. Current mesozooplankton (copepod and cladoceran) and mysid sampling by the EMP

Table 2. **Percent of age-1 Delta Smelt captured during the Spring Kodiak Trawl Survey with food present in the stomach collected January through May 2012 for three salinity regions and the freshwater Cache Slough-Sacraramento River Deepwater Ship Channel (CS-SRDWSC).**

		Month					
YEAR	**REGION**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**GRAND TOTAL**
2012	> 6	100%	100%				100%
	1 - 6	100%	100%	100%	100%	0%	99%
	< 1	100%	93%	100%	90%	89%	94%
	CS-SRDWSC	100%	100%	100%	96%	100%	99%
GRAND TOTAL	**100%**	**99%**	**100%**	**95%**	**90%**	**98%**	

Zooplankton Study and invertebrate sampling by the EMP Benthic Monitoring Study does not sample the full geographic range occupied by adult Delta Smelt, including Cache Slough and the Sacramento River Deep Water Ship Channel. In addition, epibenthic cumaceans and amphipods consumed by Delta Smelt might not be effectively sampled with current methods (substrate grabs using a Ponar dredge), which are more suited to sampling organisms in or attached to the substrate. Amphipods found in stomachs of adult Delta Smelt collected January 2012-May 2012 (Fig. 44) were 95% *Corophium* spp., and of those, 90% were juveniles ranging 0.8 to 1.3 mm in body length. These amphipods are believed to be mostly juvenile *Americorophium spinicorne* and *A. stimpsoni*, which as adults are tube building amphipods (Hazel and Kelley 1966). Dirt, substrate debris, and tube pieces were not found in Delta Smelt stomachs with the amphipods, so it is possible these juveniles amphipods are epibenthic or pelagic prior to settling and building tubes. Size distribution of amphipods collected by the DWR EMP Benthic Monitoring Study is not currently available. The IEP Smelt Larva Survey does collect larval fish data during winter (January-March) over a wide section of the estuary, but comparisons with larval fish consumption by adult Delta Smelt are limited because this survey is still new; it was initiated in 2009.

Data were insufficient to conclusively test the hypothesis that variability in prey availability affects growth and fecundity of adult Delta Smelt. More data are needed on growth, clutch number and size, and prey availability.

Larval Hypotheses

Hypothesis 1: Delta Smelt larvae numbers are positively affected by increased duration of the temperature spawning window

To evaluate this hypothesis, we developed two water temperature measures. The first is the number of days in the temperature spawning window as indexed by mean daily water temperatures at Rio Vista between 12 and 20 °C. This temperature range was selected as representing a reasonable balance between the various temperature ranges observed in laboratory and field studies (Wang 1986, Baskerville-Bridges et al. 2004b, Bennett 2005) and reviewed in earlier sections of this report. Presumably, a longer duration spawning window would result in more repeat spawning for individual females and greater total fecundity. The second water temperature measure is the number of days in the optimal temperature for egg survival to hatch. We referred to Fig. 10a in Bennett (2005) and selected the temperature range of 12-17 °C as optimal for egg survival. As explained in previous sections, adult abundance, based on SKT sampling, peaked in 2012 as the 2011 year-class of Delta Smelt reached maturity (Fig. 3). In contrast, the spawning stock (i.e., 2011 SKT) that produced the 2011 year-class ranked second lowest to 2006 (Fig. 3, Adults). Despite this low level, the 2011 spawning stock produced the highest adult abundance observed to date in 2012. This suggests that adult stock size has not limited subsequent adult recruitment from rebounding to levels comparable to those of immediate pre-POD years (see Fig. 3, Subadult). As mentioned in Chapter 6, this suggests that even a severely depleted adult stock can still produce a substantial number of larvae and a rebound in the Delta Smelt population, albeit with potentially lower genetic variability than before (Fisch et al. 2011). It also suggests that factors acting on the survival of larval, juvenile and later stages have a substantial effect on recruitment of adults, because relatively low larval abundance in 2011, was associated with the high 2012 adult abundance (Fig. 3).

As mentioned in the adult section, mature adult female Delta Smelt appeared to grow throughout the spawning seasons of the years compared, except 2010 (Fig. 17). We used water temperatures at the Rio Vista Bridge as a surrogate for temperatures experienced by spawning Delta Smelt (Fig. 65) and calculated the duration of the spawning window and of optimal temperatures to hatch. We calculated each as the number of days between the date of first achieving the lower temperature and the date of first achieving the upper temperature. The onset of the spawning window occurred earliest in 2010, followed by 2005 and 2011 (Fig. 65; Table 3). The spawning window occurred latest in 2006 (Fig. 65; Table 3). The spawning window was broad in both 2005 and 2010 at 128-129 days, intermediate in 2011 at 113 days (20 °C not achieved until July 4, not shown), and was shortest in 2006 at 85 days (Fig. 65; Table 3). Assuming that female Delta Smelt undergo a 35-day refractory period, based on a 4-5 week refractory period (J. Lindberg, U.C. Davis, personal communication, 2013) between each spawning, even in 2006 three spawning events were possible, assuming fish were mature and ready to spawn at the initiation of the spawning window. In all other years, four spawning events were possible, so this measure does not discriminate among years well. The duration of optimal hatch temperature was also lowest in 2006, but other durations ranked differently across years than did spawning window duration (Table 3).

The data for the four study years do not provide conclusive support for the hypothesis that the duration of the spawning window or duration of optimal hatching temperature affected larval production. Relatively high larval abundance in 2005 was consistent with a long spawning window and moderate duration of optimal hatch temperatures (129 days and 68 days, respectively; not shown). However, 2006 with the shortest spawning window (85 days) and shortest optimal hatch duration among the 4 study years also had relatively good larva abundance (Fig. 3). In contrast, larval abundance was low in 2010 although the spawning window and optimal hatch duration were both relatively long. Other factors likely contributed to poor larval abundance in 2010, because ripening and ripe females were not detected after early April 2010 and female growth through the winter was poor (Fig. 17). Finally, both the spawning window and optimal hatch duration were fairly long in 2011 as compared to 2006, so slightly lower larval production in 2011 is inconsistent with these durations. This hypothesis was not supported.

Figure 65. Mean daily temperatures (°C) at Rio Vista from February 1 through June 30, 2005, 2006, 2010, 2011. The green lines enclose the spawning window, which represents temperatures at which successful spawning is expected to occur.

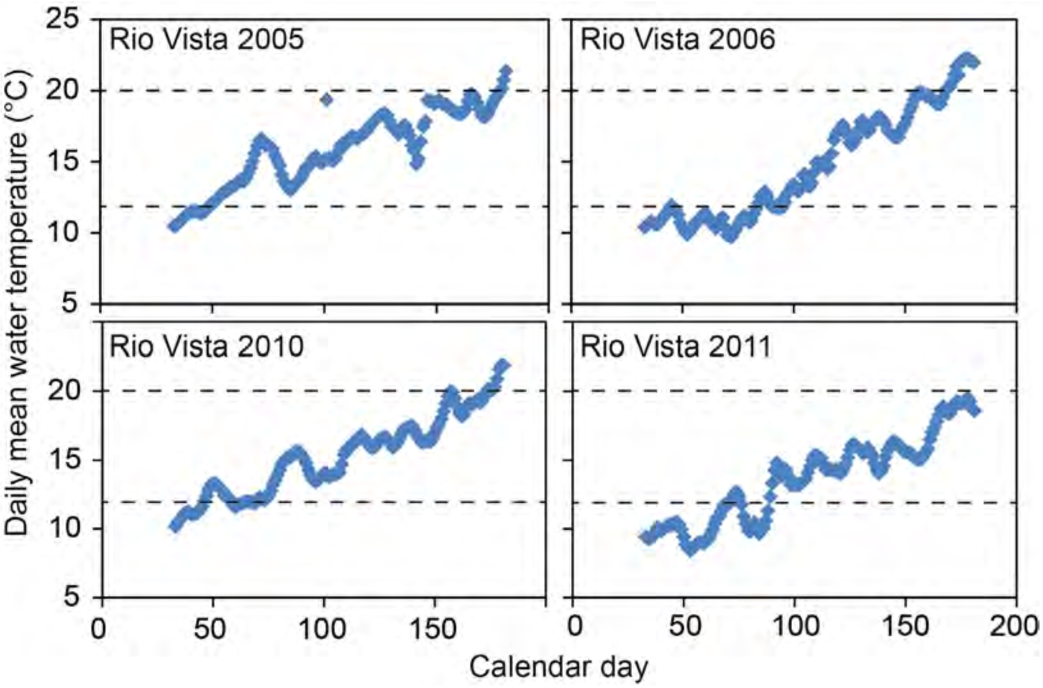


Table 3. Delta Smelt spawning window (12 to 20 °C inclusive) and optimal hatching period (12 to 17 °C inclusive) for 2005, 2006, 2010, and 2011, defined as number of days of water temperatures, based on mean daily water temperatures measured at Rio Vista. Data are calendar day when water temperature achieved 12, 17, and 20 °C and the duration (days) between those calendar days. The upper limit in 2011 was not reached until July 4, outside the spring season.

Year	Day 12 °C Achieved	Day 17 °C Achieved	Day 20 °C Surpassed	Duration 12-20	Duration 12-17	Duration 17-20
2005	50	118	179	129	68	61
2006	84	120	169	85	36	49
2010	46	136	174	128	90	38
2011	72	163	185	113	91	22

Hypothesis 2: Increased food availability results **in increased larval abundance and survival.**

This hypothesis focuses on seasonal changes in phytoplankton biomass and the zooplankton community and resulting changes in abundances of food items most often consumed by Delta Smelt larvae. Phytoplankton biomass data (chlorophyll-*a*) collected at 10 stations by the IEP

EMP show that the highest spring biomass levels were observed in May of 2010 and 2011 (Fig. 66). Median biomass levels were lower in April and May of 2005 and 2006 than in April and May of 2010 and 2011. This suggests that more food was available for zooplankton growth in the spring of 2010 and 2011 than in 2005 and 2006. In all four years, however, chlorophyll concentrations were lower than 10 ug/L at almost all stations, suggesting that zooplankton may have generally been food limited in these years (see Chapter 4). Nevertheless, greater phytoplankton biomass in late spring of 2010 and 2011 may have contributed to overall greater food availability and better survival of late larvae and early juveniles in these years.

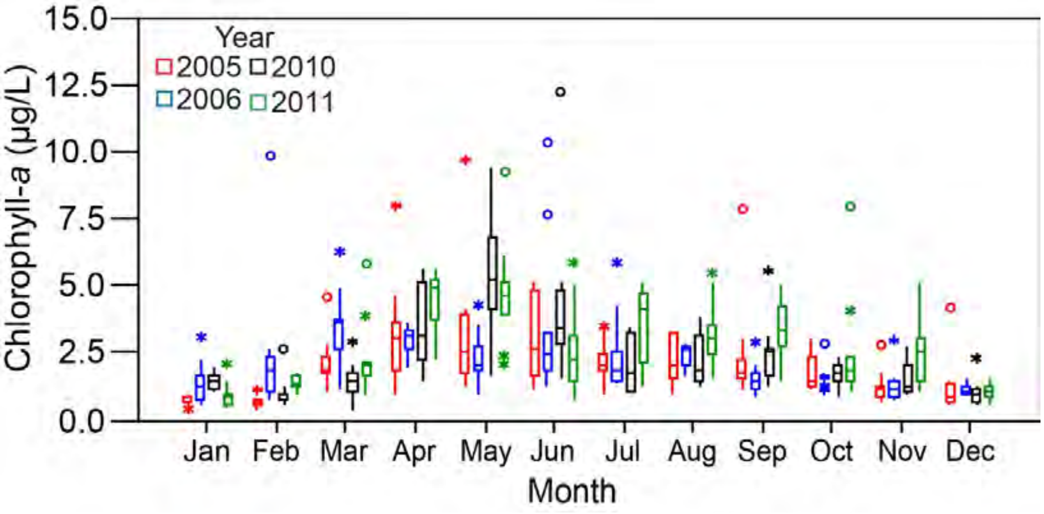
Juvenile and adult calanoid copepods, particularly *E. affinis* and *P. forbesi*, comprise most of the larval diet through June (Nobriga 2002, Slater and Baxter 2014). *E. affinis* is moderately abundant only during winter and spring and rare in summer and fall, whereas *P. forbesi* is abundant only in summer and fall (Durand 2010, Hennessy 2010, 2011, Winder and Jassby 2011). It is not clear whether the seasonal decline in abundance of *E. affinis* is related to temperature, potential competitive interactions with *P. forbesi*, differences between the species in vulnerability to consumption by *P. amurensis* (Miller and Stillman 2013), or a combination of such factors. The transition between high abundances of the two species, may create a seasonal "food gap" during late spring or early summer. This food gap has been hypothesized to be an important period for Delta Smelt larval survival (Bennett 2005, Miller et al. 2012).

To assess whether a gap in prey availability existed between periods of high abundance of *E. affinis* and *P. forbesi*, we evaluated abundance patterns in 20 mm Survey copepod data for stations with and without Delta Smelt. The food gap hypothesis was only weakly supported by the data. The density of *E. affinis* (in the presence of Delta Smelt larvae) typically reached 100 m^3 by week 16 (Figs. 67 and 68). Assuming 100 m^3 as a baseline density for *E. affinis*, this baseline was generally maintained until about week 22, when they declined at about the same time that *P. forbesi* densities increased to 100 m^3 (Figs. 67 and 68). After combining the densities of both *E. affinis* and *P. forbesi* and tracking them through time, we detected a gap in food during week 22 (late May – early June) of 2005 (Fig. 67), which is inconsistent with 2005 exhibiting the highest larva abundance among our comparison years (Fig. 3). Such density gaps were not observed in the other three comparison years (Figs. 67 and 68), which exhibited lower abundance than 2005 (Fig. 3). Survival of larvae to juveniles was very low in 2005, but was also low in 2006 (Fig. 51) with no evidence for a food gap in 2006. Survival of larvae to juveniles was relatively high in 2010 and 2011 (Fig. 51). This analysis does not support the hypothesis that differences in zooplankton availability affected larval abundance and survival in the four study years, but higher phytoplankton biomass in April and May of 2010 and 2011 could have contributed to overall greater food availability and better survival of late larvae and early juveniles in these years.

Hypothesis 3: Distributional overlap of Mississippi Silverside with Delta Smelt and high abundance of Mississippi Silverside increases predation risk/rate on larval Delta Smelt, whereas, increased turbidity, **decreases predation risk/rate on larval Delta Smelt.**

Silversides are ubiquitous within the Delta (Brown and May 2006) and have long been proposed (Bennett 1995) and more recently confirmed as a predator of Delta Smelt larvae (Baerwald et al. 2012). We do not have estimates of predation losses to Silversides during the four study years and thus focus on assessing predation risk by evaluating fish distributions, predator and prey sizes, and prey growth, which is related to temperature.

Figure 66. Trends in chlorophyll-*a* concentrations (µg/L) in samples collected by the IEP Environmental Monitoring Program during each the four study years (2005, 2006, 2010, and 2011). Sample site locations shown in figure 15. See Chapter 3: Data Analyses for explanation of boxplots.

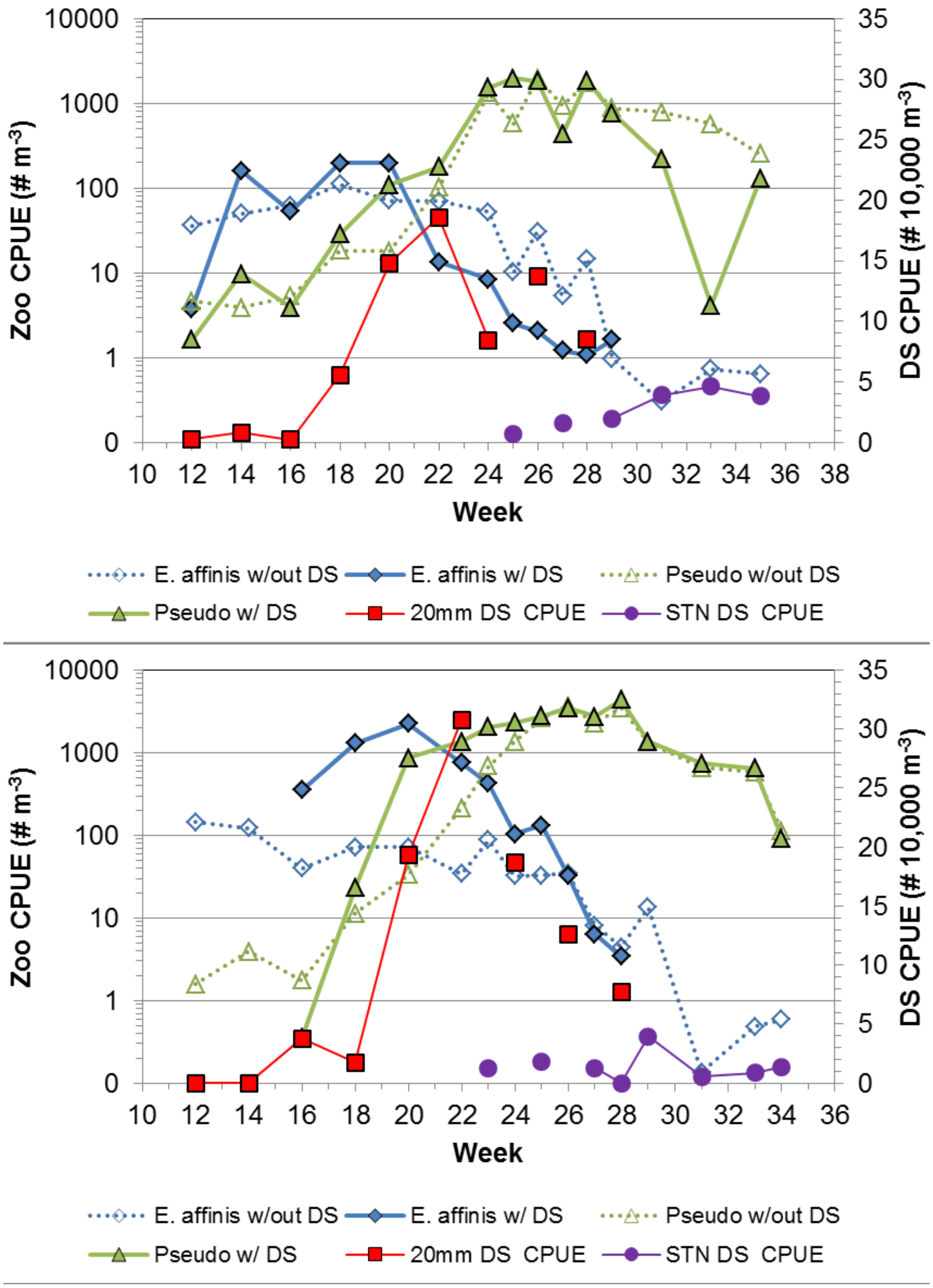


Silversides large enough to consume fish larvae are present in the Delta during spring and are likely to prey upon Delta Smelt larvae. Silverside habitat has been characterized as open water shoals and shoreline (Brown and May 2006, Grimaldo et al. 2012); however, the species also occurs in low density in deep open water primarily in summer (Grimaldo et al. 2012). Catches in the SKT confirm silverside presence in open water in spring as well, though catches tended to be low. However, SKT sampling does not occur at night when offshore Silverside densities may be higher, if foraging patterns follow those observed in Clear Lake, California (see Wurtsbaugh and Li 1985). Compared to the open embayments, SKT Silverside catches were higher in channels such as Montezuma Slough, Cache Slough, the San Joaquin River, and especially the Sacramento Deepwater Ship Channel (Table 4). This Silverside distribution matched higher March through May regional catches of Delta Smelt larvae (Table 4, see http://www.dfg.ca.gov/delta/data/20mm/CPUE_map.asp), except that larvae catches in Suisun Bay and the lower Sacramento River were occasionally high and Silversides catches were usually low. Delta Smelt larvae were found in significantly higher densities in offshore-open water habitats (Grimaldo et al. 2004), which corresponds to the habitat where Silversides consuming Delta Smelt larvae were captured (Baerwald et al. 2012). As discussed above, the relatively large-sized silversides present in the Spring Kodiak Trawl indicates some offshore movement and overlap of predator-sized foraging silversides with Delta Smelt larval habitat.

The frequency and magnitude of Silverside catches by the Spring Kodiak Trawl increased as Secchi depths approached and dropped below 50 cm (Fig. 69), suggesting that Silversides may venture offshore more frequently and in higher numbers in turbid water. This might also represent a displacement effect resulting from high flows, but high catches were most common in Montezuma Slough and the Sacramento Deepwater Ship Channel (Table 4) where displacement by flow should not have been a factor.

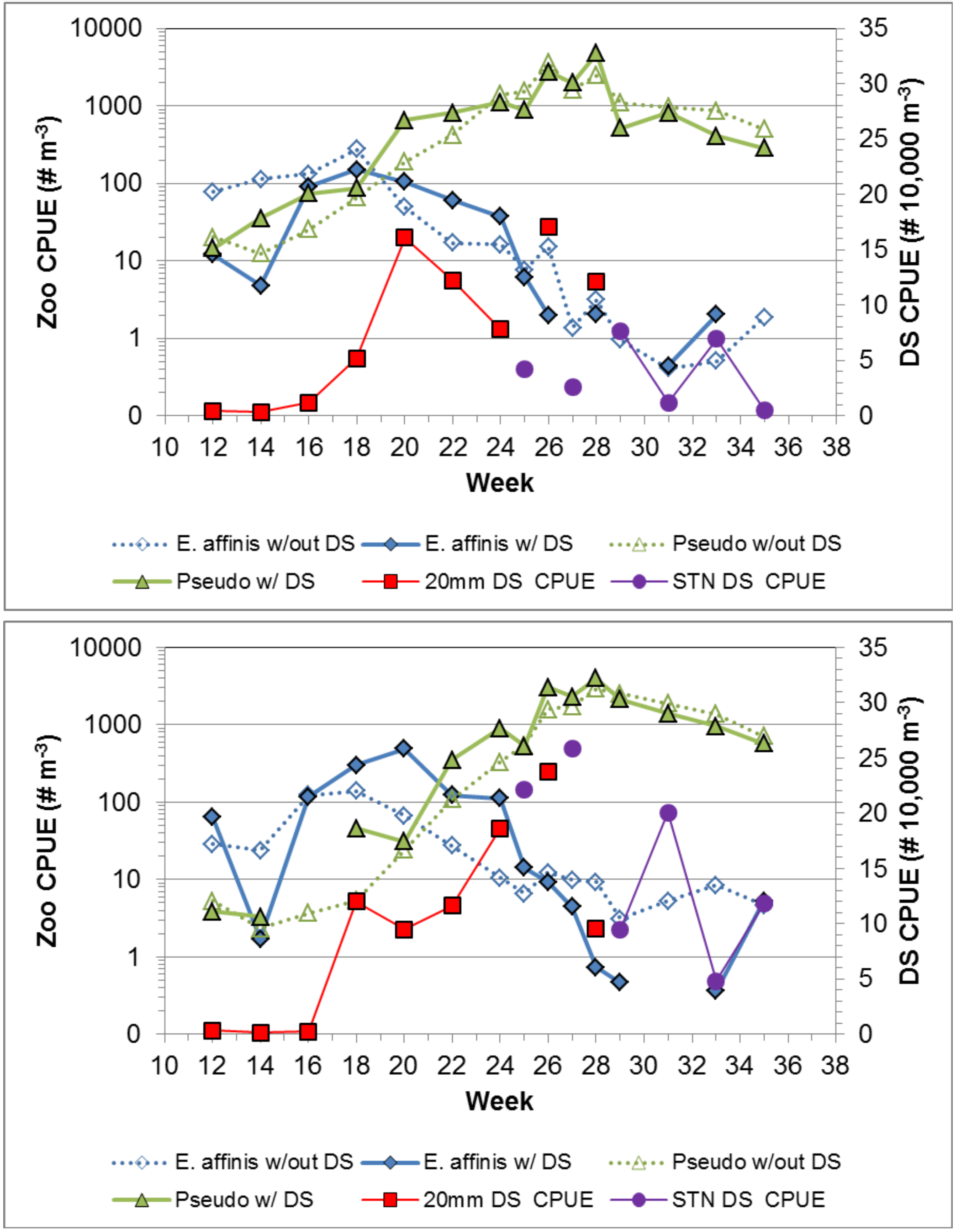
The hypothesis is somewhat supported in that: 1) Silversides are captured in Spring Kodiak Trawl in March and April (Fig. 70), when early stage Delta Smelt larvae are common; 2) Silverside

Figure 67. **Catch per unit effort (CPUE) of adult *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Zoo; number individuals/m^3 sampled) and Delta Smelt (DS; number individuals/10,000 m^3 sampled) by calendar week from mesozooplankton sampling and Delta Smelt catch by the 20 mm and Summer Townet surveys, 2005 (top) and 2006 (bottom)**



catches offshore increase with increased turbidity (i.e., declining Secchi depth; Fig. 69), and 3) there is regional overlap in Cache Slough and the Sacramento Deepwater Ship Channel, and some in Montezuma Slough (cf. Table 4 and http://www.dfg.ca.gov/delta/data/20mm/CPUE_

Figure 68. Catch per unit effort (CPUE) of adult *Eurytemora affinis* and *Pseudodiaptomus forbesi* (Zoo; number individuals/m^3 sampled) and Delta Smelt (DS; number individuals/10,000 m^3 sampled) by calendar week from mesozooplankton sampling and Delta Smelt catch by the 20 mm and Summer Townet surveys, 2010 (top) and 2011 (bottom).



map.asp), known larval rearing regions. It is also possible the nighttime offshore foraging by silversides is a more common strategy (Wurtsbaugh and Li 1985), but one that goes undetected by current sampling. Silverside catch per trawl (Table 4) indicates low offshore densities and the same turbidity that facilitates offshore movement may also inhibit predation effectiveness.

Table 4. Mississippi Silverside catch by region (monthly sample number in parentheses) and year by the Spring Kodiak Trawl Survey sampling monthly March through May (months when Delta Smelt larvae are present), 2005, 2006, 2010 and 2011; distribution survey data only. Annual sampling effort summarized consisted of 3 surveys and 37 stations. Tow volume varied substantially, but averaged 6,300 m^3 per tow for the 4 years.

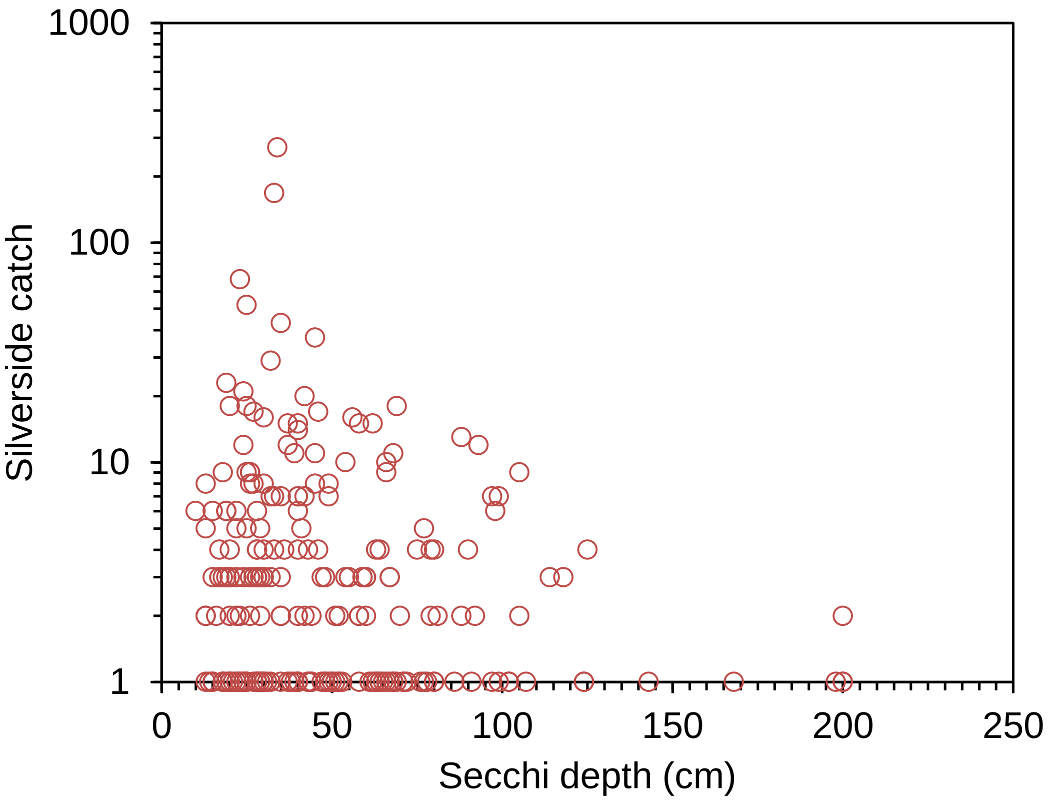
Region	2005	2006	2010	2011	Total Catch	Total Catch per Trawl
SUISUN BAY (N=10)	1	1	2	1	5	0.04
MONTEZUMA SL (N=3)	51	4	17	22	94	2.61
LOWER SACRAMENTO R (N=4)	10	1	1	3	15	0.31
CACHE SL (N=3)	9	2	4	2	17	0.47
SAC DEEPWATER SHIP CHANNEL (N=1)	14	20	45	22	101	8.42
SAN JOAQUIN R (N=8)	39	9	11	14	73	0.76
MOKLEMNE R. (N=5)	1	1	1	8	11	0.18
SOUTH DELTA (N=3)	1	0	1	1	3	0.08
ANNUAL TOTAL FOR REGIONS	126	38	82	73	319	

Overall, the conclusion regarding the effects of species distributions and abundances on predation risk is unclear. If there is an effect, it is most likely to occur in smaller channels, such as Montezuma Slough and those in the Cache Slough and the Sacramento Deepwater Ship Channel where Silversides are present in high numbers along the shoreline and larval Delta Smelt occur offshore.

Hypothesis 4: Hydrology and water exports interact with one another to influence direction of transport and risk of entrainment for larval Delta Smelt.

As for adults, we do not have proportional entrainment estimates for all four study years, so the entrainment portion of this hypothesis cannot be directly evaluated. Also, larvae (< 20 mm fork length) entrained in the State and federal water export systems are generally not quantified. To test this hypothesis we use data for the distribution and density of larvae (≥ 20 mm fork length)

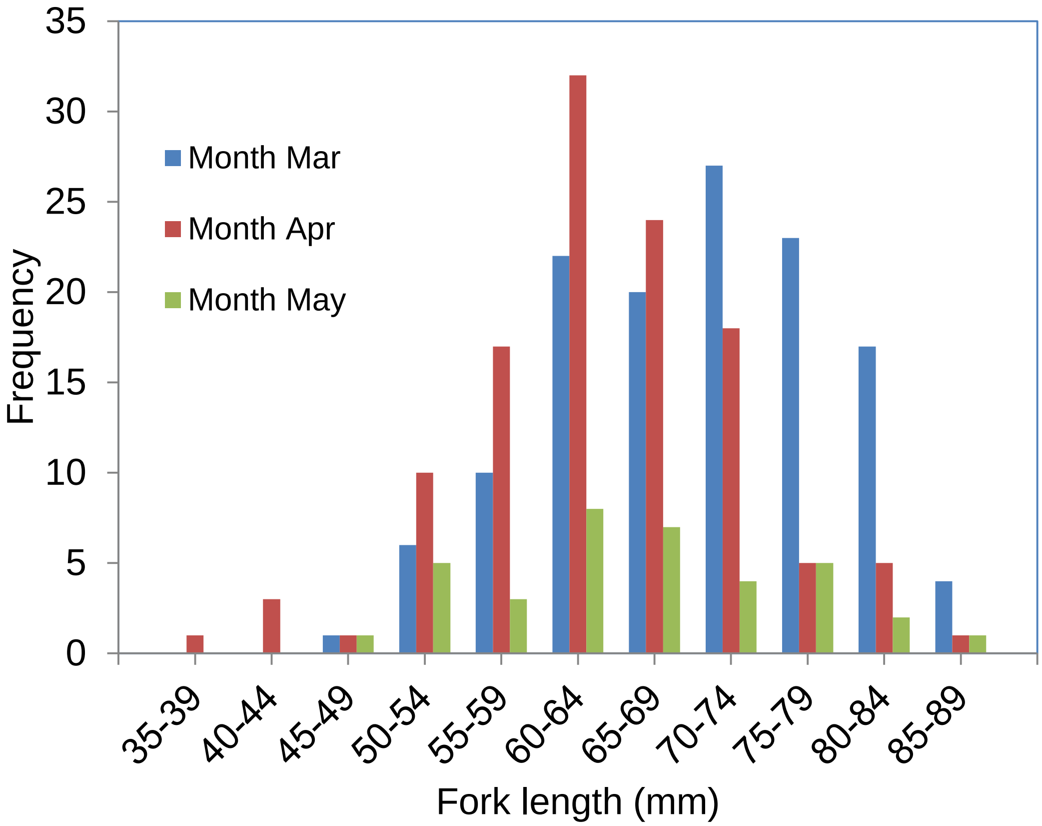
Figure 69. **Scatter plot of Mississippi Silverside catch plotted on Secchi depth (cm) at location of capture from the Spring Kodiak Trawl Survey, 2005, 2006, 2010 and 2011.**



in the central and south Delta and estimates of channel flows to infer risk of entrainment. Among the study years only 2005 larval entrainment was estimated by Kimmerer (2008), and loss to the population was relatively low. However, Delta Smelt density and distribution in the central and south Delta were greater in 2005 than in the three other study years (Table 5). This simple analysis suggests that in our 4-year comparison, entrainment risk for larval Delta Smelt may have been highest in 2005. Hardly any larval Delta Smelt were caught in this region in the two wet years, 2006 and 2011.

As for adults, we also used OMR flows (Fig. 31) to assess larval entrainment risk. Mean March through May OMR flows were positive during the two wet years 2006 and 2011 (8,221 cfs and 3,560 cfs respectively) and negative during the two dry years 2005 and 2010 (-417 cfs and -1,302 cfs, respectively). These OMR values suggest little if any risk during 2006 and 2011, and at most moderate risk in 2005 and 2010. Grimaldo et al. (2009) found that juvenile salvage was a function of abundance in the 20 mm Survey (positive) and OMR flows (negative). Looking more closely at various net daily flows from March to June of 2005, we find that OMR flows were moderately negative (i.e., toward the export pumps) only in March, and were zero to weakly positive in April and May, except for a brief period in mid-April (Fig. 31); also in 2005, Qwest was strongly positive from late March through early June, promoting downstream transport in the San Joaquin River, and exports were low from late April through late May (Fig. 31). The other dry year, 2010 exhibited a similar pattern, but lower inflows resulted in the magnitude of exports more directly influencing OMR flows (Fig. 31), and leading to moderately negative OMR flows

Figure 70. Monthly length frequency of Mississippi Silversides captured by the Spring Kodiak Trawl during distribution sampling March – May in the Sacramento River and Cache Slough sampling stations only, 2002-2012. The months and geographic range were selected to overlap with that of Delta Smelt larvae as they hatch and begin to grow.



in March and again in June, but only weakly negative flows in April and most of May coincident with positive Qwest. In the high outflow years 2006 and 2011, few larvae were detected in the central or south Delta (Table 5) and Qwest flows were strongly positive from March through at least early June, while OMR flows were near zero or weakly negative in March and positive to strongly positive by April and continuing to early June of both years (Fig. 31). Thus, for our comparison years, it appears that the available data generally support our hypothesis, but entrainment of larvae was unlikely to be an important factor during either wet year and was probably not a substantial factor in either dry year.

Table 5. Mean monthly catch of Delta Smelt per 10,000 m^3 by station for stations in the south and central Delta for the 20 mm Survey, 2005, 2006, 2010, 2011. Non-zero values are bolded.

Year = 2005	Months				
STATION	MARCH	APRIL	MAY	JUNE	JULY
809	0.00	0.00	**3.14**	**5.17**	0.00
812	0.00	0.00	**3.14**	**6.66**	0.00
815	0.00	**3.06**	**3.39**	0.00	0.00
901	0.00	0.00	**3.21**	0.00	**3.61**
902	0.00	0.00	0.00	0.00	0.00
906	**1.65**	**2.93**	**3.22**	0.00	0.00
910	0.00	0.00	0.00	0.00	0.00
912	0.00	0.00	0.00	0.00	0.00
914	**3.18**	**1.49**	**1.56**	0.00	0.00
915	0.00	0.00	0.00	0.00	0.00
918	**1.52**	**1.41**	0.00	0.00	0.00
919	0.00	0.00	0.00	0.00	0.00
Year = 2006	Months				
STATION	MARCH	APRIL	MAY	JUNE	JULY
809	0.00	0.00	0.00	0.00	0.00
812	0.00	0.00	0.00	0.00	0.00
815	0.00	0.00	**1.24**	0.00	0.00
901	0.00	0.00	0.00	0.00	0.00
902	0.00	0.00	0.00	0.00	0.00
906	0.00	0.00	0.00	0.00	0.00
910	0.00	0.00	0.00	0.00	0.00
912	0.00	0.00	0.00	0.00	0.00
914	0.00	0.00	0.00	0.00	0.00
915	0.00	0.00	0.00	0.00	0.00
918	0.00	0.00	0.00	0.00	0.00
919		0.00	0.00	0.00	0.00

Year = 2010	Months				
STATION	MARCH	APRIL	MAY	JUNE	JULY
809	0.00	0.00	**1.62**	0.00	0.00
812	0.00	0.00	0.00	0.00	0.00
815	0.00	**1.77**	**1.72**	0.00	0.00
901	0.00	0.00	0.00	0.00	0.00
902	0.00	0.00	0.00	0.00	0.00
906	0.00	**3.36**	0.00	**1.64**	0.00
910	0.00	**5.24**	0.00	0.00	0.00
912	0.00	0.00	0.00	0.00	0.00
914	0.00	0.00	0.00	0.00	0.00
915	0.00	0.00	0.00	0.00	0.00
918	0.00	0.00	0.00	0.00	0.00
919	0.00	0.00	0.00	0.00	0.00

Year = 2011	Months				
STATION	MARCH	APRIL	MAY	JUNE	JULY
809	0.00	0.00	0.00	**1.73**	0.00
812	0.00	0.00	0.00	0.00	0.00
815	0.00	0.00	0.00	0.00	0.00
901	0.00	0.00	**3.69**	0.00	0.00
902	0.00	0.00	0.00	0.00	0.00
906	0.00	0.00	0.00	0.00	0.00
910	0.00	0.00	0.00	0.00	0.00
912	0.00	0.00	0.00	0.00	0.00
914	0.00	0.00	0.00	0.00	0.00
915	0.00	0.00	0.00	0.00	0.00
918	0.00	0.00	0.00	0.00	0.00
919	0.00	0.00	0.00	0.00	0.00

Juvenile Hypotheses

Hypothesis 1: High water temperatures reduce juvenile Delta Smelt growth and survival through lethal and sublethal (bioenergetic stress; reduced distribution) effects.

High water temperatures have a strong effect on juvenile Delta Smelt survival (Swanson et al. 2000, Komoroske et al. 2014). In addition to the obvious potential for lethal effects, temperature can have sub-lethal effects such as reduced habitat area, higher food requirements, increased susceptibility to disease and contaminants, and increased predation. The potential for increased prey requirements and increased predation is described below for other hypotheses.

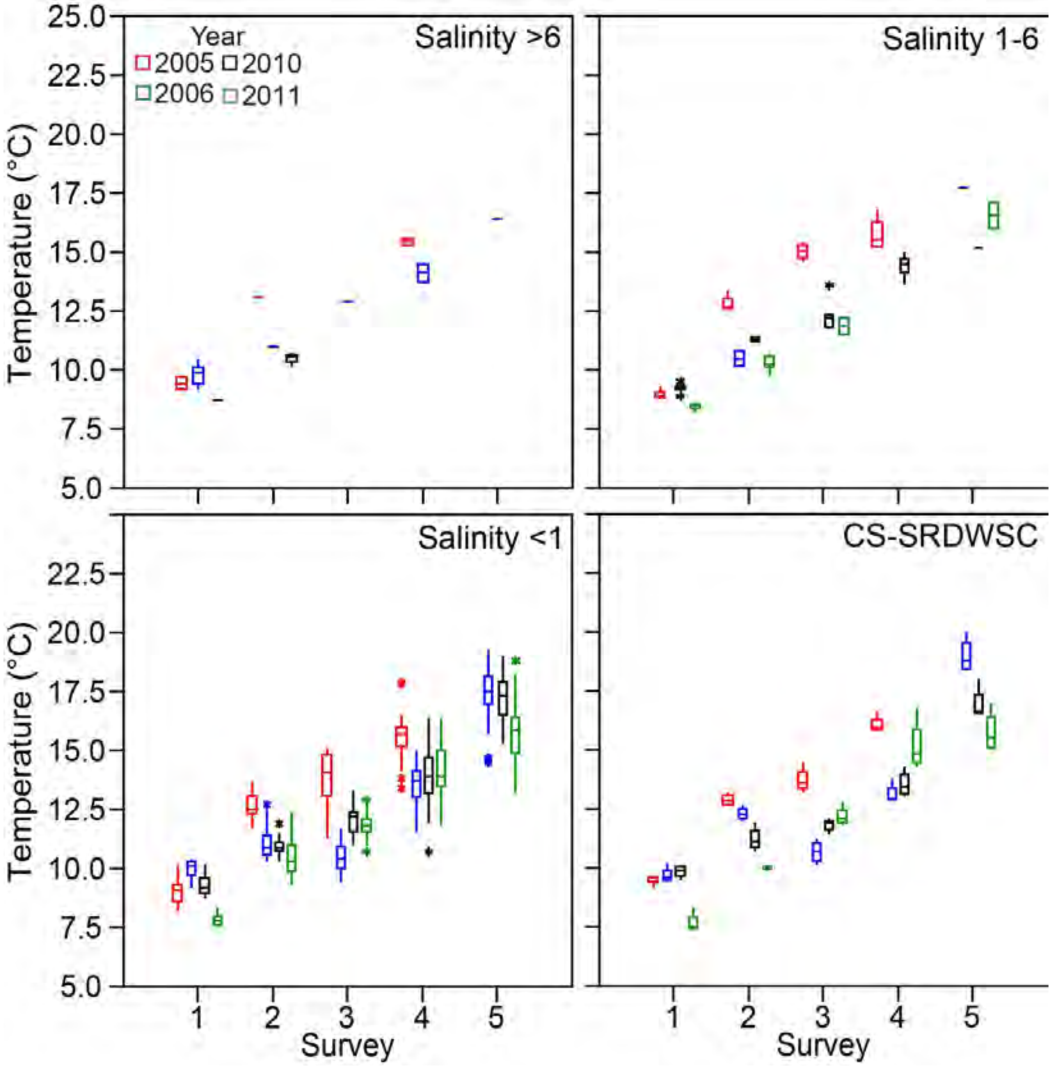
As noted in the adult section, spring water temperature was generally coolest in 2006 and 2011, but warmed up more rapidly toward the end of spring 2006 (May) than in spring 2011. Spring water temperature was overall warmest in 2005 (Fig. 71). Following the high late-spring water temperatures in 2005 and 2006, summer temperatures in 2005 and 2006 tended to be higher than in 2010 and 2011 during July and August (e.g. TNS surveys 3-5; Fig. 72). Temperatures during surveys 4 and 5 may have been particularly important as they exceeded lethal levels in freshwater at some sites, suggesting the potential for mortality. Note that this does not mean that temperatures were universally cooler in 2010 and 2011 than in 2005 and 2006; for example the region around Cache Slough had relatively high temperatures in August 2011. Larval to juvenile survival (ratio of TNS index to 20 mm index) was highest in 2011 followed by 2010, 2006, and 2005, suggesting that the cooler late spring and summer temperatures in 2011 and 2010 may have been beneficial for Delta Smelt. However, juvenile to subadult survival (ratio of FMWT index to TNS index) was highest in 2011 and lowest in 2010 (Fig. 51). While relatively high water temperature in late spring and early to mid summer of of 2005 and 2006 may thus have contributed to low survival of late-stage larvae and early juveniles, water temperature may have been less important to survival in the late summer and early fall. Overall, the results of this analysis of temperature and survival data support our hypothesis that high water temperatures reduce juvenile Delta Smelt growth and survival.

At this point, our data and analyses are inadequate to address temperature effects on juvenile Delta Smelt growth. Although there are some data for Delta Smelt growth during several of the target years, it is difficult to separate the relative effects of improved bioenergetics (see below) versus simple ontogenetic changes in fish size. Juvenile fish growth rates are typically not constant and change with size ("allometric effects;" Fuiman 1983). Specifically, daily growth rates (e.g., mm/day) are often faster for smaller fish and slower for older fish. Hence, cooler years may delay Delta Smelt transitions from faster to slower growth phases, yielding a relatively fast measured growth rate at a specific point in time (e.g., September) because at that specific time the fish are still relatively young and still on the "steepest" part of an idealized growth curve.

Hypothesis 2. Distribution and abundance of Striped Bass, temperature, and turbidity influence predation risk/rate on juvenile Delta Smelt

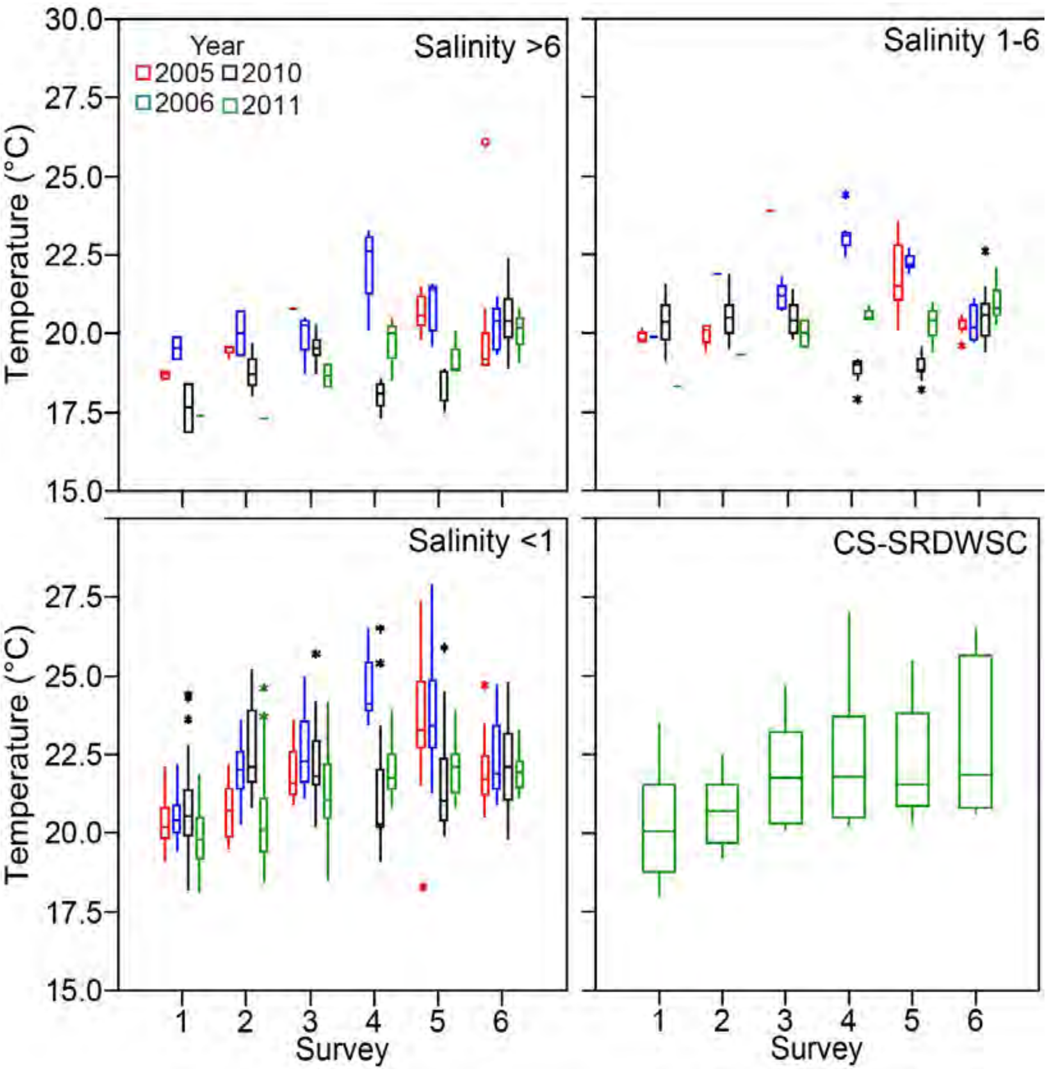
We hypothesize that subadult (age 1-3) Striped Bass are the major predator on juvenile Delta Smelt and that losses are likely affected by temperature and turbidity patterns. However, other factors likely affect predation risk (e.g., other predators such as centrarchids) and several factors

Figure 71. Water surface temperature data collected during the Spring Kodiak Trawl Survey for three salinity regions and the Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC). Surveys are conducted monthly January-May. See Chapter 3: Data Analyses for explanation of boxplots.



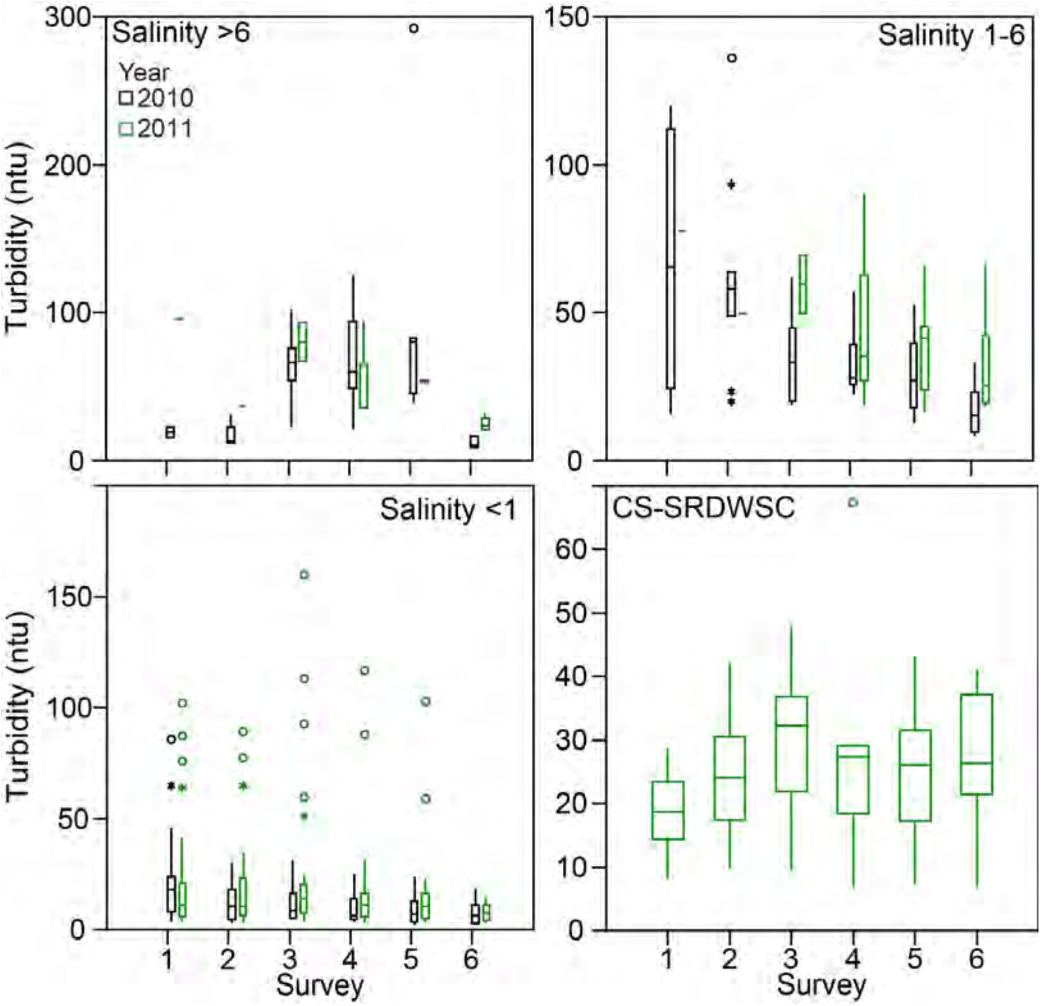
may interact. As noted above for temperature and below for food, high temperatures and low prey density likely lead to bioenergetics problems and increased foraging activity, which might reduce predator avoidance behavior (e.g., Marine and Cech 2004) in Delta Smelt. These effects may be compounded by low turbidity, which makes Delta Smelt more visible to predators in their habitat. Although higher Striped Bass abundance could theoretically result in greater consumption of prey including Delta Smelt (Loboschefsky et al. 2012), changes in habitat variables for both species such as food, temperature, and turbidity mean that predation rates on Delta Smelt periodically may be independent of predator abundance. Although there has been substantial progress in modeling (Lobschefsky et al. 2012, Nobriga et al. 2013) and genetic methods (Baerwald et al. 2012), there is not yet a standardized way to assess the effects of predation on Delta Smelt. Moreover, there are no effective surveys to assess age 1-3 Striped Bass abundance or distribution. Therefore, we are unable to directly evaluate this hypothesis. Lacking this information, we can

Figure 72. Water temperature data collected during the Summer Townet Survey for three salinity regions and the Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC). Surveys are conducted biweekly June-August. See Chapter 3: Data Analyses for explanation of boxplots.



at least examine turbidity and temperature patterns for the four years. Temperature responses were described for Hypothesis 2. In general, summer 2005 and 2006 temperatures were relatively higher than 2010 and 2011 during key summer months (e.g. TNS surveys 3-5; Fig. 72). We expect that cooler temperatures in 2010 and 2011 may have contributed to reduced predation on Delta Smelt. Turbidity data are limited to 2010 and 2011 (Fig. 73). There were no consistent differences between the two years. Secchi depth data did not suggest major differences among the 4 years except at salinities > 6 when 2005-2006 had higher values in some months (Fig. 74).

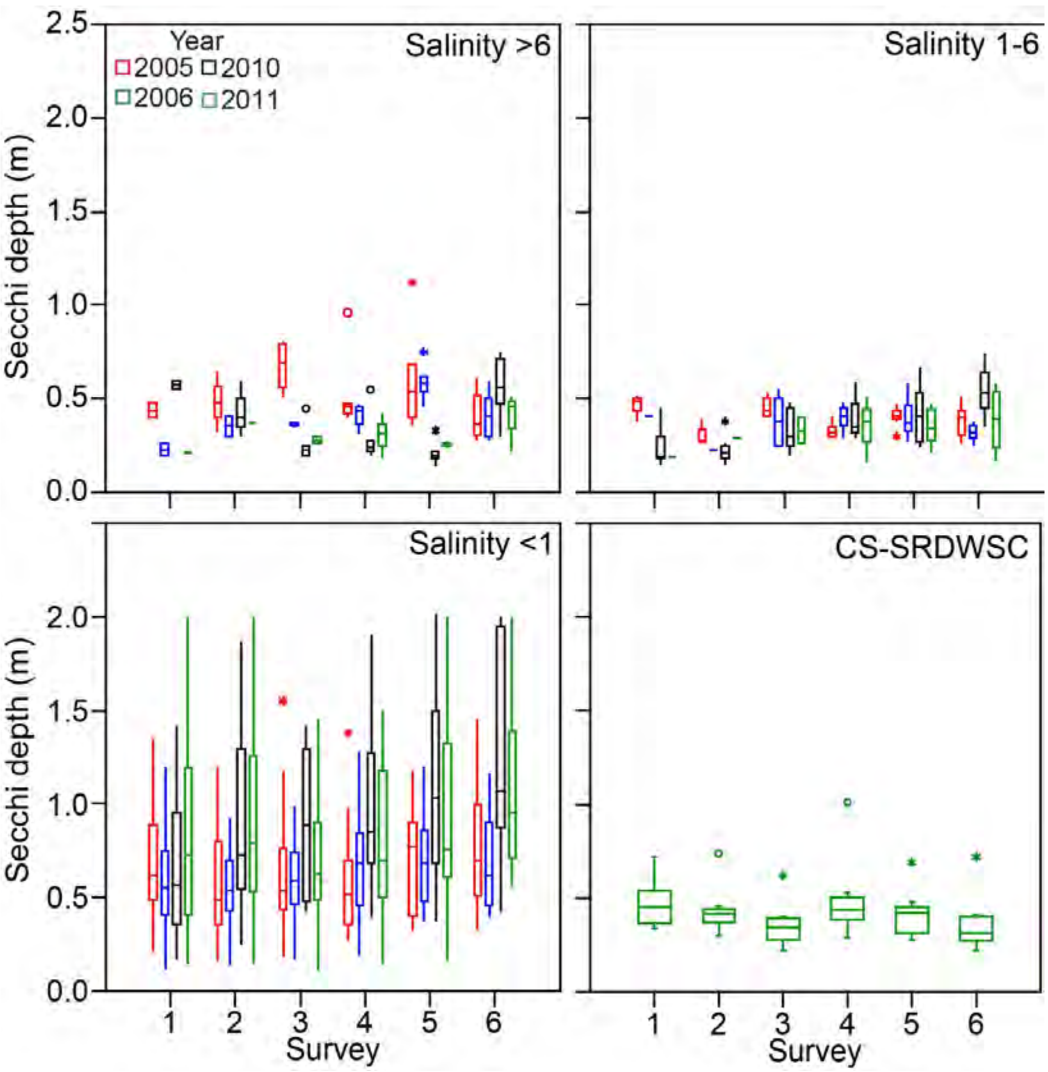
Figure 73. **Turbidity data collected during the Summer Townet Survey. Surveys are conducted biweekly June-August. Note different scales among salinity regions. See Chapter 3: Data Analyses for explanation of boxplots.**



Hypothesis 3. Juvenile Delta Smelt growth and survival is affected by food availability.

As for Hypothesis 1, we are currently unable to evaluate the growth data because water temperature affects development time, and because growth curves are complicated by allometric effects. The general conceptual model is that higher food abundance results in faster growth rates and larger, healthier fish. In addition, larger, healthier Delta Smelt are presumably less vulnerable to predators because of increased size making them difficult for smaller predators to capture and consume. In general, the median abundance of some of the key prey for juvenile Delta Smelt such as calanoid copepods is highest in summer months (Fig. 75), when juvenile Delta Smelt are present; however, the range of observed densities is broad in all months. As noted previously, Kimmerer (2008) found that Delta Smelt survival from summer to fall was positively associated with calanoid copepod biomass in the low salinity zone.

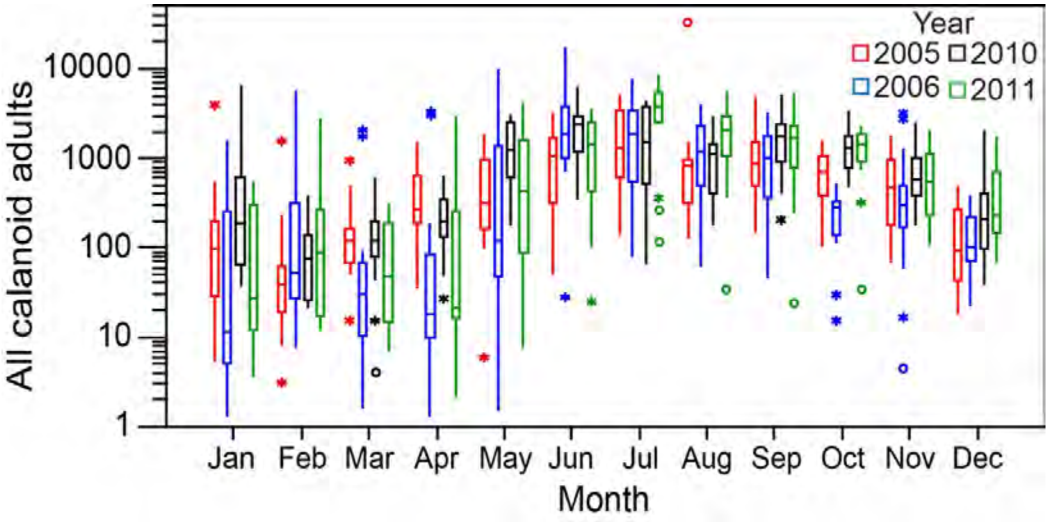
Figure 74. Secchi depth data collected during the Summer Townet Survey. Surveys are conducted biweekly June-August. See Chapter 3: Data Analyses for explanation of boxplots.



Interpretation of the field data is complicated because there are no long-term IEP EMP study stations located in some of the core habitats for Delta Smelt, for example, Cache Slough and the Sacramento River Deep Water Ship Channel. Moreover, densities of calanoid copepods vary among regions based on differing habitat (temperature and salinity) requirements of each species (Fig. 76).

Summer-time phytoplankton data (chlorophyll-*a*) suggest that the base of the food web was most enhanced in July and August 2011 and relatively depleted in 2005 (Fig. 66). There is some evidence that these changes may have affected zooplankton abundance. For example, summer densities of calanoid copepods in the LSZ and <1 ppt regions also tended to be highest in 2011 as compared to the other years (Fig. 76). This pattern generally held when individual taxa are considered including two of the most important food sources for Delta Smelt, *Eurytemora affinis* (Fig. 33) and *Pseudodiaptomus forbesi* (Fig. 34).

Figure 75. Trends in calanoid copepods (number/m^3 for all taxa combined) collected by the IEP Environmental Monitoring Program (EMP) during each the four study years (2005, 2006, 2010, and 2011).

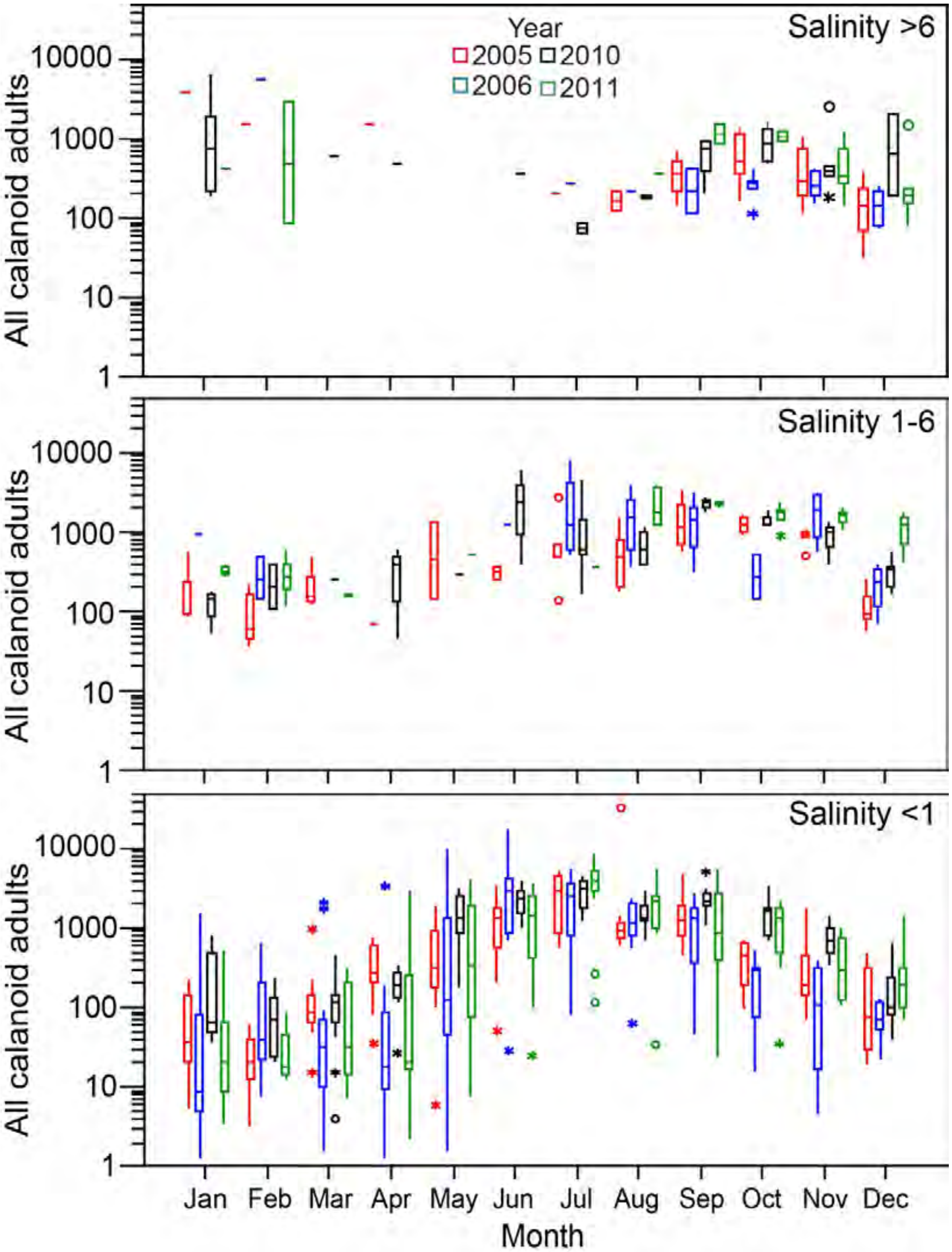


As mentioned above (Hypothesis 1), juvenile to subadult survival was highest in 2011 followed by 2006 and 2005 and lowest in 2010 (Fig. 51). If food availability was the primary habitat attribute driving juvenile survival, our expectation was that summer prey abundance would have been higher in 2011 than 2010. Figure 69 suggests that while differences were not very pronounced, prey levels were indeed somewhat higher in July and August of 2011 than 2010. Calanoid copepod levels varied across the different salinity ranges, but generally followed the same pattern (Fig. 76). In addition, calanoid copepod densities in June and August were higher in 2006 than in 2005 (Fig. 75), which may have contributed to higher juvenile to subadult survival in 2006 compared to 2005 (Fig. 51).

Fish bioenergetics are affected by both food and temperature. As mentioned above, both summer 2010 and 2011 had relatively cool temperatures as compared to 2005 and 2006, which may have affected bioenergetics. In addition, recent studies (S. Slater, CDFW, unpublished data) indicate that Delta Smelt consumption was not just limited to calanoid copepods, so our assessment does not reflect the full dietary range.

In conclusion, our analyses provide some support for the hypothesis that juvenile Delta Smelt growth and survival is affected by food availability; greater food availability may have contributed to greater juvenile survival in 2011 and 2006 compared to 2010 and 2005. However, differences in prey availability among years were not very pronounced and our analyses were limited to calanoid copepods; other species may also be important prey items for Delta Smelt.

Figure 76. Trends in calanoid copepods (number/m^3 for all types combined) collected by the IEP Environmental Monitoring Program (EMP) in three salinity ranges (> 6 ppt; 1-6 ppt; < 1 ppt) during each the four study years (2005, 2006, 2010, and 2011). See Chapter 3: Data Analyses for explanation of boxplots.



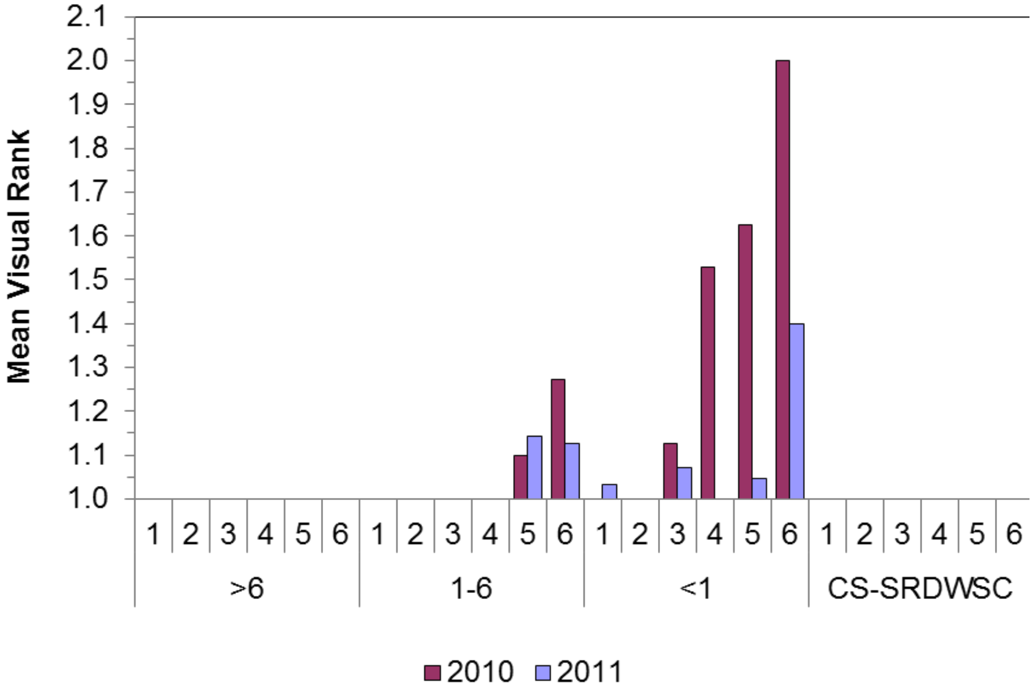
Hypothesis 4. Juvenile Delta Smelt survival and growth is reduced by harmful algal blooms (HAB) because of direct (habitat quality and toxic effects) and indirect (food quality and quantity) effects.

The appearance of late-summer HAB, especially *Microcystis*, is thought to be another component of the decline in habitat quality for Delta Smelt (Baxter et al. 2010, Lehman et al. 2010). Direct effects may include toxicity to Delta Smelt and a reduced area of suitable habitat. There also may be indirect effects on food quantity and quality, particularly with respect to their zooplankton prey (Ger et al. 2009, 2010a,b, Lehman et al. 2010).

The growth responses of Delta Smelt during the four target years are still unclear (see below), but there is evidence that Delta Smelt juvenile to subadult survival was highest in 2011 and lowest in 2010 (Fig. 51). If HABs have a negative effect on survival, we would expect that lower *Microcystis* (or other HAB) abundance would be associated with higher survival in 2011. This seems to have been the case for 2010 and 2011. Densities of *Microcystis* near the water surface were qualitatively assessed (visually ranked) at all TNS stations in these years. In agreement with our expectation, observed levels were low during the TNS in 2011 as compared to 2010 across a range of salinities (Fig. 77).

Unfortunately, we do not have data about other HAB species and more quantitative estimates, nor is similar data available for 2005 and 2006. In general, our expectation is that 2006

Figure 77. **Summer Townet Survey mean visual rank of *Microcystis* spp. (ranks 1-5 possible; 1 = absent) observed at all stations during biweekly surveys (1-6) in various salinity regions (> 6, 1-6, and < 1 ppt) and in the CS-SRDWSC during June through August 2010 and 2011. Observations were not made in Cache Slough-Sacramento River Deepwater Ship Channel (CS-SRDWSC) during 2010.**



Microcystis levels would have been relatively low as a result of higher flow levels that discourage blooms (Lehman et al. 2005). Based on the available qualitative data for 2010 and 2011, this analysis supports the hypothesis that juvenile Delta Smelt survival and growth is better when *Microcystis* does not bloom as intensely, but more data is needed to more conclusively assess this relationship.

Subadult Hypotheses

Hypothesis 1. Subadult Delta Smelt abundance, growth, and survival is affected by food availability.

Similar to juveniles, the general conceptual model is that higher food abundance results in faster growth rates and subsequently, lower predation loss and greater survival (e.g., Houde 1987, Sogard 1997, Takasuka et al. 2003); however the opposite situation in which the fastest growing fishes are most vulnerable to predators has also been observed in at least one east coast estuary (Gleason and Bengston 1996). Fall abundance of Delta Smelt was highest in 2011 followed by 2006, 2010, and 2005 (Fig. 3) while survival of subadults to adults was highest in 2010 followed by 2006 and equal in 2011 and 2005 (Fig. 45). In spite of the lower subadult survival in 2011, the relatively large number of subadults in 2011 gave rise to the highest adult abundance on record in 2012.

In general, fall calanoid copepod abundance and cladocera abundance were higher in 2011 in freshwater and the low-salinity zone compared to the other years, particularly 2005 and 2006 (Fig. 71). However, these data are highly variable, so this conclusion does not apply to each region in every month. With that caveat, the data generally support the hypothesis that food availability affects Delta Smelt abundance and survival; on average, prey density was higher for subadult Delta Smelt in 2011. This may have contributed to the high FMWT abundance index in 2011, although it did not contribute to an equally high survival to adults relative to the other three years. Nevertheless, it seems likely that the relatively good food availability in 2011 also contributed to the high number of adults in 2012. As noted above, we are currently unable to evaluate whether Delta Smelt grew faster in 2011 because water temperature affects spawning and hatch dates, which complicates the interpretation of growth rates.

Hypothesis 2. Distribution and abundance of Striped Bass, temperature, and turbidity influence predation risk/rate on subadult Delta Smelt

As already described for other life stages, predation risk is exceptionally complicated, making it difficult to generate simple hypotheses that describe associated losses of Delta Smelt. The data are not currently available to test this hypothesis (Nobriga et al. 2013). Thus, no firm conclusion can be made.

Hypothesis 3. Subadult Delta Smelt abundance, survival and growth are reduced by harmful algal blooms (HAB) because of direct (habitat quality and toxic effects) and indirect (food quality and quantity) effects.

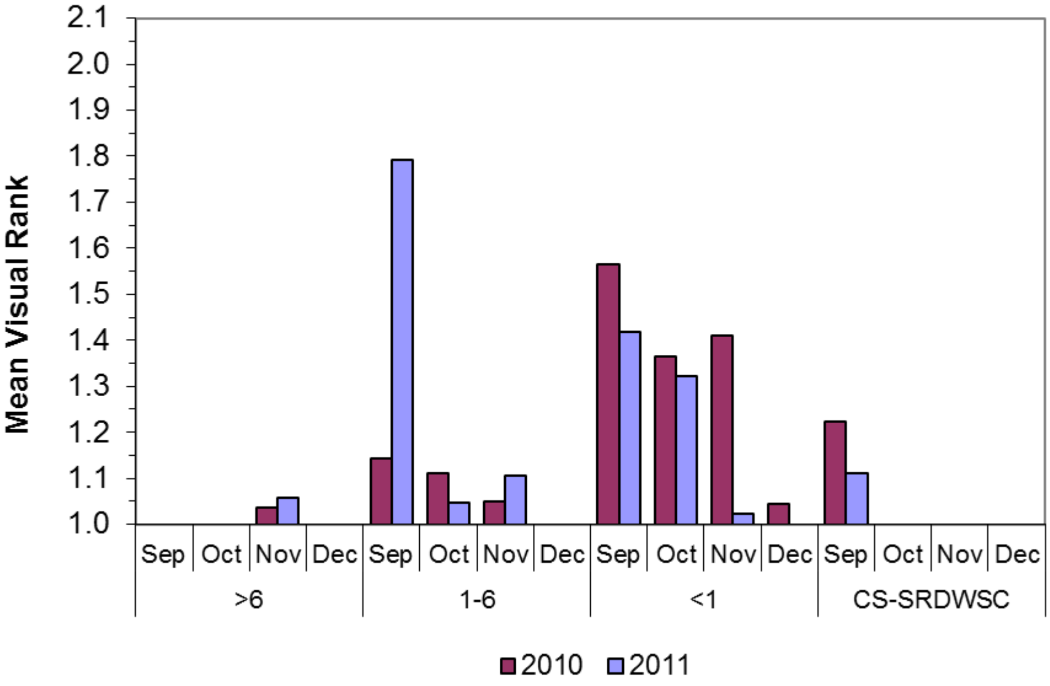
The appearance of late-summer harmful algal blooms (HAB), especially *Microcystis*, is thought to be another detriment to habitat quality for Delta Smelt (Baxter et al. 2010, Lehman et al. 2010). Direct effects may include toxicity to Delta Smelt and a reduced distribution if the fish try to limit their overlap with the bloom. There also may be indirect effects on food quantity and quality, particularly with respect to their zooplankton prey (Ger et al. 2009; 2010a,b, Lehman et al. 2010).

The growth responses of Delta Smelt during the four target years are still unclear (see above), but there is evidence that summer juvenile to subadult survival was highest in 2011, while juvenile survival to adults was highest in 2010 (Fig. 45). Our expectation is therefore that HAB were less prevalent in the summer of 2011 compared to 2010, but more prevalent in fall 2011. As already described for juveniles, the hypothesis that summer *Microcystis* bloom would be less intense in 2011 compared to 2010 was generally supported (Fig. 77). In fall, *Microcystis* levels were also overall lower in 2011 than in 2010, except in September 2011 when a high level of *Microcystis* was observed in the LSZ (Fig. 78). This may be an indication that the higher outflow in September-October 2011 displaced *Microcystis* produced in the Delta seaward into the LSZ. The comparatively high 2011 Delta Smelt FMWT index that coincided with this shift in *Microcystis* distribution is not consistent with the hypothesis; however, the occurrence of fairly high levels of *Microcystis* in the LSZ in 2011 may help explain the lower subadult to adult survival in 2011 compared to 2010. It is also important to remember that the visual survey results presented here are only qualitative and do not necessarily reflect the potential for differences in actual toxicity among years. Overall, these results are inconclusive, although they may provide limited support for the hypothesis that high *Microcystis* levels may have a negative effect on subadult to adult survival; this may help explain the lower subadult survival in 2011 compared to 2010.

Hypothesis 4. Subadult Delta Smelt abundance, survival and growth are affected by the size and position of the low salinity zone during fall.

We do not address this hypothesis in detail because it is the subject of an adaptive management experiment (FLaSH) described earlier (Reclamation 2011, 2012; see also Brown et al. 2014, http://deltacouncil.ca.gov/science-program/fall-low-salinity-habitat-flash-studies-and-adaptive-management-plan-review-0). According to the FLaSH conceptual model, conditions are supposed to be favorable for Delta Smelt when fall X2 is approximately 74 km or less, unfavorable when X2 is approximately 85 km or greater, and intermediate in between (Reclamation 2011, 2012). Surface area for the LSZ at X2s of 74 km and 85 km were predicted to be 4000 and 9000 hectares, respectively (Reclamation 2011, 2012). The data generally supported the idea that lower X2 and greater area of the LSZ would support more subadult Delta Smelt (Table 6). The greatest LSZ area and lowest X2 occurred in September and October 2011 and were associated with a high FMWT index which was followed by the highest SKT index on record, although survival from subadults to adults was actually lower in 2011 than in 2010 and 2006. There was little separation between the other years on the basis of X2, LSZ area, or FMWT index (Table 6). The position and area of the LSZ is a key factor determining the quantity and quality of low salinity rearing habitat available to Delta Smelt and other estuarine species (see Chapter 4 for more detail

Figure 78. **Fall Midwater Trawl mean visual rank of *Microcystis* spp. (ranks 1-5 possible; 1 = absent) observed at all stations during monthly surveys in various salinity regions (> 6, 1-6, and < 1 ppt) and in the CS-SRDWSC during September through December 2010 and 2011.**



and Chapter 8 for additional analysis results). In addition, the complex hydrodynamics produced during higher outflows may alter the lateral mixing environment of the Estuary (especially in shallower areas like Suisun Bay) in ways that improve the quality of Delta Smelt habitat in general (Monismith, personal communication). The limited amount of available data provides some evidence in support of this hypothesis, but additional years of data and investigations are needed.

Chapter 8: Conclusions

As with all reports focusing on conceptual models, this report is intended as a working document, not as the final word on Delta Smelt ecology, because our knowledge will continue to increase. We intend the conceptual model to be used as a framework and tool to further improve our understanding of Delta Smelt ecology and to explore and test management options for improving conditions for the Delta Smelt population. In essence, the updated conceptual model represents a synthesis of our current thinking on the factors affecting vital rates of the Delta Smelt population. We fully expect a wide range of opinion about the relevance of the conceptual models presented here and about the degree of certainty regarding many of its component dynamics and linkages. We have clearly acknowledged that we lack information on many important factors and processes that likely affect Delta Smelt, such as predation and toxicity and their functional relationships

Table 6. Mean and standard deviation (SD) for X2, surface area of low salinity zone (M. McWilliams, Delta Modeling Associates, unpublished data), and values of the Fall Midwater Trawl index (FMWT) for abundance of subadult Delta Smelt.

	X2 (km)		Surface area LSZ (hectares)		FMWT index
YEAR	MEAN	SD	MEAN	SD	
2005	83	2	4889	252	26
2006	82	3	4978	320	41
2010	85	2	4635	226	29
2011	75	1	8366	133	343

with survival and growth. The conceptual model incorporates many hypotheses that should be tested via new research, modeling, and ongoing analysis and synthesis of new and previously collected data. This is how science advances.

Conceptual models are increasingly used as tools to develop questions or hypotheses about specific mechanisms through which stressors or other environmental factors drive ecological outcomes. Conceptual models can be used as a basis for communication among managers and scientists to plan research activities and assess outcomes of management actions (Ogden et al. 2005). Because of their broad utility, conceptual models are viewed as a critical element of adaptive management programs (Thom 2000). In the SFE, conceptual models have become common and even required as the community moves toward adaptive management and collaborative science. A primary outcome of conceptual models is the identification of key areas of uncertainty due to lack of information, or areas of disagreement due to different interpretations of the available data and information. Careful examination of these areas often identifies critical data and information gaps, which if filled, would allow a more robust evaluation of the major hypotheses derived from conceptual models. In this way, conceptual models can guide the research community to the topics critical for understanding Delta Smelt biology and formulating effective management actions.

The development of our conceptual model, based on assessment of recent information, identified some key points about conceptual models that are worth highlighting, including the following:

1. Nested and linked conceptual models of increasing specificity provide a useful framework for capturing the dynamics of ecosystem drivers and habitat attributes over a large range of temporal and spatial scales and for providing a comprehensive picture about their effects.

2. Our knowledge about Delta Smelt and the SFE is constantly growing and conceptual models about them have to be regularly updated and revised to properly reflect this knowledge.

3. Construction of our conceptual model and the formulation and evaluation of hypotheses greatly benefitted from the large amount of high-quality ecological data and information available about Delta Smelt and the SFE. The most critical data about Delta Smelt dynamics came from four long-term IEP fish monitoring surveys. Other monitoring

and studies provided key data and information about habitat attributes and ecosystem drivers.

4. Our conceptual model is also useful for identifying important data and information gaps. More data and information is especially needed about predation risk and toxicity, two potentially important attributes of Delta Smelt habitat.

Conceptual models are meant to be useful tools for scientists, managers, and others. But just how useful are the new conceptual models in this report? To find out, we used them to generate and test hypotheses and highlight data gaps while addressing a specific topic of high management interest—the increased Delta Smelt abundance index in 2011.

We found that our conceptual model allowed us to formulate a variety of testable hypotheses about individual components and the linkages among them. Our hypotheses and the analyses we conducted to test them had some clear limitations (discussed below), but highlighted some key points about Delta Smelt and their habitat. In many respects, the points about Delta Smelt seem self-evident from basic biology and earlier conceptual models, but they warrant reinforcement because they are crucial to understanding Delta Smelt and to developing and assessing habitat management actions. Key points about Delta Smelt include the following:

1. Environmental conditions occurring in all four seasons contribute to year-class strength of Delta Smelt - “it takes a year to make a mature Delta Smelt.”

2. Survival and recruitment are affected by many factors that interact in complex ways and the importance of these factors and interactions varies from season to season and year to year.

3. Recovery of Delta Smelt depends on better than average larval production (recruitment) and survival in all seasons. The number of eggs and larvae sets an upper limit for the production of mature adults. Low survival between any two life stages can substantially reduce the actual production of mature adults. Success of Delta Smelt in 2011 was related to a high level of larval production (recruitment) followed by moderate to high stage-to-stage survival over the entire year. In contrast, the high level of larval production (recruitment) in 2006 was followed by very low survival from larvae to juveniles which led to low abundance of mature adults.

4. Throughout 2011, Delta Smelt may have benefitted from a combination of favorable habitat conditions: 1) adults and larvae benefitted from high winter 2010 and spring 2011 outflows which reduced entrainment risk and possibly improved other habitat conditions, prolonged cool spring water temperatures, and possibly good food availability in late spring; 2) juveniles benefitted from cool water temperatures in late spring and early summer as well as from relatively good food availability and low levels of harmful *Microcystis*; 3) subadults also benefitted from good food availability and from favorable habitat conditions in the large, westward low salinity zone.

Our hypothesis tests were carried out with the simple comparative approach used in the FLaSH investigations (Brown et al. 2014). Specifically, we compared differences in Delta Smelt responses and in individual habitat attributes during the two most recent wet years and the two years immediately preceding the two wet years. Using this approach allowed us to put the FLaSH results into a year-round context as recommended by the FLaSH Panel (FLaSH Panel 2012).

It also provided an opportunity to further assess the utility of this approach for evaluating the outcome of adaptive management actions such as the fall outflow action.

As with the FLaSH investigations (Brown et al. 2014), we restricted our analyses to simple comparisons among four recent years after the 2002 POD decline for several reasons including the following:

1. Using a comparative approach similar to that in the FLaSH investigation allowed us to place the results of the FLaSH investigation in a year-round, life cycle context as recommended by the FLaSH Panel (FLaSH Panel 2012).
2. This report is intended for a broad audience. Simple comparisons are easily replicated and understood by all.
3. More pertinent data is available for recent years than for earlier years. For example, adult Delta Smelt monitoring began in 2002 with abundance index values available starting in 2003.
4. The POD regime shift (Baxter et al. 2010) changed ecological relationships and the strong pre-POD signals would have likely overwhelmed more subtle, yet meaningful, signals in the period after the POD. For example, it appears that high larval recruitment may now be positively associated with wet hydrology, but that this may not have been the case before the onset of the POD.
5. Clear differences in habitat conditions among years might point to new or refined management strategies aimed at improving specific habitat conditions.
6. More complex modeling approaches take much more time and effort than was available to produce this report. A complex life cycle modeling effort is currently underway (see Chapter 9).

As noted above, our analytical approach yielded some interesting results, but it also raised more questions than it could answer. In many cases this was due to critical data and information gaps; these will be described in more detail in Chapter 9. It also illustrates, however, several limitations of our simple comparative approach as well as difficulties associated with posing and testing hypotheses about ecological phenomena in general. Examples of specific limitations and difficulties include the following:

1. Our hypotheses focused on individual habitat attributes and were tested with a series of separate univariate analyses even though we know that Delta Smelt are affected by multiple interacting habitat atributes. We did not conduct multivariate tests or examine the complex interactions that may have occurred when more than one hypothesis was true (or false), nor did we consider or rule out that a hypothesis may be true in some years and false in others.
2. Our simple comparisons of differences in individual habitat attributes among different years cannot conclusively establish whether these differences are indeed mechanistically linked to the observed differences in Delta Smelt dynamics. In addition, an absence of observed differences does not prove that there is really no effect because actual effects can be masked or counteracted by interactions with other causal factors that differ among years. For example predation in the South Delta may mask actual entrainment

effects and toxicity of anthropogenic contaminants may counteract the effects of abundant food in some years, but not in others.

3. Results contrary to our observations may simply indicate different outcomes in other years or that complex interactions among multiple habitat attributes (and corresponding hypotheses) contributed to the observed effects.
4. We restricted our analyses to observational data collected in a small number of moderately and very wet years during the POD period; including data from additional, more historical, and drier years may have provided more conclusive results.
5. Data available for our analyses were not necessarily collected to test hypotheses similar to the ones in this report; targeted data collections are needed in addition to routine status and trends monitoring.

Many of these difficulties and limitations were expected because hypothesis testing in an ecological context is nearly always problematic. For example, Quinn and Dunham (1983) warned that attempts to follow a strictly hypothetico-deductive scheme (Popper 1959, Platt 1964) to draw “strong inference” from a series of univariate tests aiming to falsify hypotheses about the ecological effects of individual causal factors often lead to inconclusive or even erroneous results. One reason for this is that by design, they generally do not consider non-additive interactions among causal factors. While we did not necessarily set out to strictly follow such a scheme, we nevertheless treated habitat attributes as largely independent from each other and formulated a series of distinct hypotheses about their univariate effects on Delta Smelt. But habitat attributes are not necessarily additive and habitat is indeed more than the “sum of its parts.” A more inductive, multivariate modeling approach with hypotheses about interactive effects and evaluations of the relative contributions of multiple interacting habitat attributes to these effects would have likely been more appropriate, but would have required analyses beyond the scope of this report.

We give some examples of multivariate approaches in Chapter 9, but note that even with the most sophisticated modeling techniques, ecological responses to management manipulations and other changes of the SFE have been notoriously difficult to assess and interpret. Reasons for this persistent difficulty include limited opportunities for experimental control, multiple interacting causal factors, multiple ecological response pathways, and changing environmental conditions due to species invasions, species declines, and the many physical and chemical changes and management manipulations described in this report. In other words, the signal to noise ratio of management actions to environmental variation tends to be low in the SFE because of its size and complexity. The fact that Delta Smelt is now a rare species adds another considerable difficulty. Together, these difficulties are part of the reason why adaptive management actions such as those described in the ongoing Fall Outflow Adaptive Management Plan (Reclamation 2011, 2012) and the now concluded Vernalis Adaptive Management Plan (VAMP, San Joaquin River Group Authority 2013) are planned for a minimum of 10 years, allowing accumulation of data, development of appropriate interpretation of these data, and comparison of observations across as broad a range of conditions as is possible given a 10-year time frame. But even after such a relatively long period of manipulation and observation, questions will likely remain about how some factors interact to affect Delta Smelt abundance.

In summary, we conclude that our new conceptual models can be used successfully to derive testable hypotheses about Delta Smelt responses to changing habitat conditions. Our hypotheses and the analyses we conducted to test them highlighted some key points as well as critical data gaps and the challenges associated with formulating and testing hypotheses in complex ecological contexts. The key points about Delta Smelt and their habitat generally agree with basic biological principles and earlier conceptual models, but warrant reinforcement because they are crucial to understanding Delta Smelt and to developing and assessing habitat management actions. Other results are less conclusive because of data limitations and the shortcomings of our largely univariate hypotheses and simple comparative analysis approach. Next steps should include addressing critical data gaps, modeling that more fully considers the effects of interacting factors on Delta Smelt, and applications of the information in this report in support of management actions. Examples of such efforts are provided in Chapter 9.

Chapter 9: Recommendations for Future Work and Management Applications

The conceptual model in this report can be viewed as a collection of hypotheses. These hypotheses are not limited to the hypotheses posed in Chapter 7 of this report; essentially, each component and linkage in the conceptual models can give rise to meaningful questions and hypotheses by itself or together with other components and linkages. This is one of the main functions of conceptual models.

Some of the hypotheses that can be derived from our conceptual model have already been addressed in the published research reviewed in Chapter 4 of this report. These results provide the knowledge base used to construct our conceptual model as well as previous conceptual models. They also provide the knowledge base for current Delta Smelt management efforts. The results and conclusions in this report add to this knowledge, but they also emphasize the need for additional monitoring, focused studies, and/or additional analysis and synthesis of existing data. These are the information gaps that can be used to guide future research activities to enhance our understanding of how factors interact to control Delta Smelt abundance.

Filling these information gaps is critically important for improving management strategies for Delta Smelt and for constantly adapting them to expected and unexpected future changes. It is clear that ecological changes due to continued growth of California’s human population, climate change, new species invasions, and other natural and anthropogenic factors will increase the challenges associated with Delta Smelt management. Moreover, as discussed in the previous Chapter, we will likely never be able to correctly detect or predict all effects of management actions and other changes in an ecosystem as complex and constantly changing as the San Francisco estuary. Science and management have to go hand in hand to constantly identify, implement, evaluate, and refine the best management options for this ever-changing system. In this Chapter, we provide examples of next steps in three major areas where additional work is needed: 1) filling critical data and information gaps; 2) mathematical modeling; and 3) applications to support adaptive management actions. We conclude this report with recommendations for future analysis and synthesis efforts.

Critical Data and Information Gaps

A short list of the most critical data and information gaps identified by the updated conceptual model is given below. It is important to note that this is not an exhaustive list of the potentially productive research questions that could be addressed for Delta Smelt. Instead, these are primary research topics that emerge as major data and information gaps in multiple places within the updated conceptual model. This indicates that additional monitoring and research on these topics may be particularly urgently needed and filling these gaps would provide immediately useful results. The list of critical data and information gaps is organized around the environmental drivers and habitat attributes identified in our conceptual models.

Contaminants and Toxicity

There is a general awareness that exposure to contaminants can impair the health of Delta Smelt and other fishes. A few studies have documented adverse effects, but little is known regarding the thresholds at which most contaminants would be toxic to or otherwise adversely affect Delta Smelt (or their prey). Even less is known about how various contaminants may interact when they co-occur, or how their effects may be enhanced or suppressed by these interactions or by other environmental factors.

1. Focused laboratory studies may provide the most efficient way to assess effects of metals, pesticides, pharmaceutical products, or mixtures of contaminants as long as field-relevant concentrations are used. However, translating results of laboratory tests to the field remains a challenging problem (Scholz et al. 2012).

2. Significant work to understand the effect of nutrient loading from municipal sources on the food web has been done (Weston et al. 2014) (e.g., Sacramento Wastewater Treatment Plant, Parker et al. 2012). A logical next step is to conduct manipulative experiments in which effluent is reduced or shut off. This type of work has recently begun (T. Kraus, USGS, personal communication), but may require multiple iterations during a variety of seasons and environmental conditions in order to understand how such manipulations or future treatment upgrades could be used to provide desired food web responses. Monitoring should continue after any such upgrades to determine if they have the expected outcomes.

Entrainment and Transport

Evaluation of differences in entrainment among years could not be critically evaluated from salvage data; better ways to estimate, monitor, and evaluate entrainment losses due to south Delta exports are needed. Such improved estimates could be derived from experimental research on Delta Smelt and other species along with hydrodynamic modeling. Besides the need to improve the estimates of direct proportional population losses due to entrainment, similarly relevant or more important needs include assessing the influence of entrainment on key population attributes (e.g., genetics, demographics, population dynamics and viability effects).

Predation Risk

The majority of the hypotheses regarding predation risk could not be fully evaluated due to a lack of data regarding co-occurring predator and prey biomass and predation rates of predators on Delta Smelt.

1. The distribution and diet of major predators with respect to the distribution of Delta Smelt needs further investigation. For some predator species, data may already be available that describe distributions over multiple years and one data synthesis effort has already begun (Mississippi Silversides, USFWS Beach Seine Survey; analysis initiated by B. Schreier, DWR). However, data are lacking for several Striped Bass and Largemouth Bass life stages and focused studies are necessary to understand how these species' distributions overlap with the distribution of larval, juvenile, sub-adult, and adult Delta Smelt.

2. The distributional overlaps of Delta Smelt with their predators need to be described over varying conditions of turbidity, salinity, temperature, and hydrology. Linking predation risk to key environmental drivers and habitat attributes will shed light on how Delta Smelt may experience varying degrees of predation across seasons and years.

Food

Food availability is a critical aspect of Delta Smelt habitat throughout the conceptual model. However, many of the hypotheses about effects of food availability in the conceptual model could not be fully evaluated with available observational data due to incomplete information on prey densities and Delta Smelt feeding behavior throughout Delta Smelt habitat.

1. An extension of the IEP EMP into the Cache Slough complex and possibly other areas around the margins of the estuary would allow a fuller regional comparison of prey densities.

2. Another option is to make concurrent zooplankton sampling a routine part of the four major surveys monitoring Delta Smelt (SKT, 20 mm, TNS, FMWT). To varying degrees, this has been ongoing since 2005, but lack of trained staff has resulted in delayed processing of many samples and concurrent zooplankton samples have never been collected during the SKT survey. Adding appropriate zooplankton sampling and sample processing capacity to the fish monitoring surveys would allow for broader and more timely comparisons of pelagic food availability between monitoring stations with and without Delta Smelt present, similar to the analysis conducted in this report for the larvae collected during the 20mm survey (Larval Hypothesis #2).

3. Studies of Delta Smelt growth (from otoliths) and feeding habits (from stomach contents) concurrent with zooplankton sampling would maximize the utility of the concurrent prey sampling by allowing the refinement of functional response models.

4. Studies of Delta Smelt feeding behavior and prey availability with regard to amphipods and other prey that are not well sampled by any of the existing monitoring surveys could help determine the importance of these types of prey to the Delta Smelt population.

Harmful Algal Blooms

While recent research has resulted in improved understanding of the factors influencing the quantity, toxicity and location of HABs, there are still many uncertainties about their direct and indirect effects on Delta Smelt relative to other factors and about what can be done to prevent them. Furthermore and in spite of their importance to ecosystem and human health, there is still no routine quantitative monitoring program in place that specifically targets harmful algae. The TNS and FMWT surveys now include qualitative, visual assessment of *Microcystis*, but more quantitative techniques and techniques that detect additional harmful species and their toxicity would likely provide greater insights. Such techniques are increasingly available (e.g., solid phase adsorption tracking; Wood et al. 2011) and some focused studies that quantify and provide distributions of HABs have been conducted or are underway. These studies should be continued in order to address hypotheses related to the effects of HABs in the conceptual model and evaluate the utility of these techniques for routine monitoring applications.

Delta Smelt Responses

To fully evaluate the interactions of various stressors on Delta Smelt population biology, a quantitative life cycle population model is needed. While such models exist, they can be refined based on research into important aspects of Delta Smelt reproductive biology, including the reproductive output of individual Delta Smelt and the population as a whole, and how it varies with environmental conditions.

In particular, fecundity data on adult female Delta Smelt caught in the SKT have only recently been collected. This is a critical parameter, necessary to assess the reproductive potential of the population in any given year. Continued collection of fecundity data over multiple years and hydrological conditions is crucial to understanding the population response to environmental conditions in the seasons preceding reproduction. In addition, an understanding of variables controlling the number of spawning events in a year for wild Delta Smelt is necessary to understand the full reproductive potential of the population. An exploration of whether spawning events are discernible on otoliths is ongoing (Hobbs group, UC Davis); if so, retrospective analyses relating multiple spawning events to concurrent conditions (e.g., tidal phase, food availability, water temperature) may be possible.

Finally, efforts to better characterize spawning habitat and habitat attributes needed for successful egg hatching should also continue. This is needed to more fully evaluate and understand linkages between environmental drivers such as hydrology and larval recruitment. Of all the life stages of Delta Smelt, we know the least about the egg stage; Delta Smelt eggs have never been found in the wild. Because of this, we were not able to construct a life stage transition conceptual model that specifically focused on eggs. More information about spawning and egg hatching habitat is needed to fill this gap in our conceptual models and to identify management actions that would promote beneficial habitat attributes.

Mathematical Modeling

As demonstrated in this report and by others, conceptual models are useful tools for identifying and understanding key ecosystem components and relationships, but they do not quantify them and cannot be used to quantitatively define functional responses to environmental drivers or make quantitative predictions. Furthermore, as discussed above, the simple univariate and comparative analysis approaches employed throughout this report cannot capture the effects of multiple and often interacting drivers on the Delta Smelt population as a whole and on specific processes such as growth, mortality, and reproduction. The influences of interspecific interactions and abiotic forcing factors on populations and communities in complex ecosystems such as estuaries are also difficult to directly measure in any practical way. Only mathematical models can deal with such complexities and provide quantitative assessments and predictions.

Fortunately, the number of scientific publications about Delta Smelt that include various types of increasingly sophisticated mathematical models is growing rapidly. Recent examples include mathematical models based on statistical approaches (e.g., Bennett 2005, Manly and Chotkowski 2006, Feyrer et al. 2007, Nobriga et al. 2008, Kimmerer 2008, Kimmerer et al. 2009, Feyrer et al. 2010, Thomson et al. 2010, Mac Nally et al. 2010, Miller et al. 2012, Sommer and Mejia 2013, Kimmerer et al. 2013). These efforts generally focused on habitat associations using presence/absence data from the various monitoring surveys or on changes in Delta Smelt abundance based on abundance indices generated by the monitoring surveys and the effects of multiple habitat attributes (covariates) on these changes.

There is also a rapidly developing body of population life cycle models for Delta Smelt and other SFE fish species (e.g., Blumberg et al. 2010, Maunder and Deriso 2011, Massoudieh et al. 2011, Rose et al. 2011, Rose et al. 2013a, b). These models use either a statistically-based “state–space” multistage life cycle modeling approach or a spatially explicit, individual-based simulation modeling approach. Both approaches allow for analysis of the importance of drivers that affect different life stages of Delta Smelt and vary in space and time.

Not surprisingly, results of mathematical modeling efforts to date agree strongly that no single factor can explain the observed Delta Smelt population dynamics and long-term changes in abundance. There is less agreement, however, about which factors are most important (see for example Rose et al. 2013b) and about the exact sequence and nature of their interactions that led to the 2002-3 Delta Smelt POD decline. It is possible, perhaps even likely, that the natural complexity of the estuarine ecosystem coupled with multiple human impacts will prevent definitive answers to these types of questions, especially when they are sought through overly rigid application of formal hypothetico-deductive reasoning and methods (Quinn and Dunham 1983). We agree with Rose et al. (2013b) that the inherent complexity of the system and the challenges it presents for scientists and managers alike “is perhaps the best reason to develop and compare alternative modeling approaches.” Even the most sophisticated modeling oversimplifies complex systems and includes many assumptions. This means that instead of a single modeling approach, multiple alternative conceptual and mathematical modeling approaches, from the simple to the complex, are needed to understand how complex systems work and to predict future changes with sufficient confidence to allow for effective management interventions. The following sections give a brief overview of some of the alternative mathematical modeling efforts currently underway or proposed for the future.

A comprehensive state-space modeling effort that takes advantage of available Delta Smelt abundance data from all monitoring surveys and the even larger monitoring data set about habitat attributes is currently underway (Ken Newman, FWS, personal communication) and future analyses using the individual-based model developed by Rose et al. (2013a) have been proposed (Rose et al. 2013b). As mentioned above, a full description or application of mathematical models is outside of the scope of this report, but to illustrate the utility of additional alternative approaches and further explore some of the linkages and interactions in our conceptual model, we give three additional examples of alternative mathematical modeling approaches that may be used to further test some of the hypotheses in the conceptual models in this report. The first is a qualitative modeling approach, the second a multivariate statistical modeling approach, and the third a numerical simulation modeling approach. Each of these approaches was explored by one of the co-authors of this report. Importantly, these approaches are meant to complement, not replace state-space, individual-based, and other modeling approaches for Delta Smelt. **Furthermore, results are preliminary and included for illustrative purposes only; peer-reviewed publications of these analyses need to be completed before they can be used to draw any conclusions.**

Qualitative Models

Qualitative modeling provides a theoretical foundation for understanding system behavior by minimizing the loss of generality and realism at the expense of model precision (Levins 1974, Levins 1975, Puccia and Levins 1991). Qualitative modeling is based on a mathematically rigorous approach that can be used to gain insight on community level process and to examine the consequences of intended or inadvertent human-induced perturbations in managed systems. Questions often addressed through qualitative modeling include the resilience and stability of the system and the direction of population change (Puccia and Levins 1991), the role of system structure on stability (Dambacher et al. 2003, Fox 2006) and the degree of predictability in the response of populations to perturbations (Montaňo-Moctezuma et al. 2007, Hosack et al. 2009). Such questions have strong implications in terms of stability-complexity relations (May 1972, Pimm 1984, Haydon 1994) and the persistence of populations and communities following regime shifts (Baxter et al. 2010, Brook and Carpenter 2010, Capitán and Cuesta 2010, Cloern and Jassby 2012).

The increased ecological understanding of the upper SFE and the potential drivers and mechanisms underlying the interannual population responses of Delta Smelt reviewed by the FLaSH and MAST syntheses provide a strong rationale to further refine and integrate our knowledge on community level interactions and ecological drivers in this highly altered system. Towards that goal, we envision qualitative modeling as a complementary approach to other types of models to evaluate the response of Delta Smelt and other populations in the upper SFE over several temporal and spatial scales. Qualitative modeling for Delta Smelt can address some relevant system-level knowledge gaps which are usually less amenable to analyses using other modeling approaches, namely, the influence of species interactions and multiple feedback levels on community stability and population changes in response to perturbations on one or more species. For example, understanding the mechanisms leading to Delta Smelt population responses under different hydrological conditions is an area of significant interest.

Signed-digraphs are a useful representation of the structure of a system, as defined by the community matrix, and have been used in qualitative models exploring food webs (Liu et al. 2010), extinction events in communities (Vandermeer 2013), and other ecological topics of theoretical and conservation relevance. Castillo (unpublished data) used this approach to evaluate the predicted response of Delta Smelt to a sustained change in fall outflow as required in the 2008 FWS Biological Opinion. Recognizing that outflows can control X2 and the size and location of the LSZ (see Chapter 4), and affect other segments of the aquatic community supporting Delta Smelt, Castillo (unpublished data) modeled the response of subadult Delta Smelt to low (5,000 cfs; X2 = 85 km), intermediate (8,000 cfs; X2 = 81 km) and high (11,400 cfs; X2 = 74 km) fall outflow scenarios. Community composition for each outflow scenario was determined relative to the geographical distribution of species expected to occupy the LSZ. The high outflow model included six community components: phytoplankton, zooplankton, Delta Smelt, predators of Delta Smelt, the overbite clam *Potamocorbula amurensis*, and outflow. The intermediate outflow scenario included two additional community components: the Asian clam *Corbicula fluminea* and the cyanobacteria *Microcystis aeruginosa*). The low outflow scenario included the same variables as in the intermediate flow scenario, except that the overbite clam was excluded and the Brazilian waterweed, *Egeria densa* was added. For each of these communities, community components could exhibit positive or negative feedbacks and positive or negative interactions with other community components. For each of the assumed flow conditions, the four alternative types of community interactions were assumed and each met the stability criteria, as defined by Puccia and Levins (1991). The predicted response of the Delta Smelt population was: 1) predominantly positive under the high outflow community scenario, 2) ambiguous under the intermediate outflow community scenario and 3) very ambiguous under the low outflow community scenario. According to these preliminary results, both outflow and outflow-induced changes in community composition and structure seem to play a critical role in determining the population response of Delta Smelt. These model predictions supported the hypothesis that a shift in the LSZ towards X2 = 74 km is a necessary condition for the fall outflow action to exert a positive influence on the Delta Smelt population. Qualitative models like these can provide useful assessments when the general direction of community interactions are understood but the data are insufficient to support a quantitative model.

Multivariate Statistical Modeling

In this report we reviewed results from many multivariate statistical modeling efforts such as the multivariate autoregressive modeling (MAR) conducted by MacNally et al (2010) to discern the main factors responsible for the POD declines and the hierarchical log-linear trend modeling by Thomson et al. (2010) that used Bayesian model selection to identify habitat attributes (covariates) with the strongest associations with abundances of the four POD fish species and determine change points in abundance and trends. The state-space life cycle modeling by Maunder and Deriso (2011) is also based on multivariate statistical modeling; an extension of this work is currently underway by Newman and others (Ken Newman, USFWS, unpublished data).

We anticipate that insight from the current conceptual model may be used to facilitate additional multivariate statistical models. As an example, we present preliminary results (Mueller-Solger, USGS, unpublished data) of univariate and multivariate statistical analyses of X2 relationships with annual Delta Smelt abundance indices that follow the approach in Jassby et al. (1995). The purpose is to further explore some of the hypotheses related to hydrology and the size and position of the LSZ included in our conceptual model and to illustrate the importance of considering more than one factor when trying to understand Delta Smelt dynamics. We include this brief exploration in this report because it serves as a useful and relevant example, but as noted above, we advise readers that these are preliminary results from an analysis that has not yet undergone peer review and should be viewed with caution. Moreover, individual and interactive effects of additional factors were not considered in this analysis, but are likely also important (see Chapter 8). As noted in Chapter 7, we recognize that “hydrology” by itself does not affect Delta Smelt, nor does the “X2” index which is used in this analysis as an index of general hydrological (outflow) conditions in the estuary. As shown in our conceptual model (Fig. 38), hydrology affects Delta Smelt through the combined effects of its interactions with other dynamic drivers and stationary landscape attributes (tier 1) on habitat attributes (tier 3). Many of these interactions have been described in this report; others should be explored further in future studies.

This analysis is intended to evaluate the effects of prior abundance, step changes, and concurrent and prior hydrological conditions in the estuary on the relative abundance of larval to early juvenile Delta Smelt (20 mm index, Fig. 3; hereafter referred to as “larval” Delta Smelt). It also considers prior hydrological conditions and the entire available abundance index time series for larval Delta Smelt provided by the 20 mm survey. The 20 mm survey, one of the newest IEP monitoring surveys, was started in 1995. Delta Smelt distribution data from this survey is heavily used to assess and manage entrainment risk. Similar to prior analyses of TNS and FMWT data (Feyrer et al. 2007, Nobriga et al. 2008), Kimmerer et al. (2009, 2013) and Sommer and Mejia (2013) used a generalized additive modeling (GAM) approach to examine the associations between Delta Smelt occurrence or catch per trawl at 20 mm survey stations and habitat attributes (salinity, temperature, turbidity, and calanoid copepod density) measured concurrently at the same stations. There have, however, been few analyses of annual abundance data from this survey. After 19 years, the 20 mm survey now provides barely enough annual abundance data points (indices) to conduct multiple regression analyses with up to two predictor variables. Clearly more years of data collection and more in-depth analyses are needed and the analyses presented here are merely a starting point.

This analysis uses annual abundance indices for larval Delta Smelt (20 mm survey, 1995-2013), adult Delta Smelt (SKT survey, 2003-2013), and subadult Delta Smelt during the previous year (FMWT survey, 1995-2013) (Fig. 3). It also uses larval recruitment indices calculated from the annual abundance indices (20 mm to SKT ratio and 20 mm to $\mathrm{FMWT}_{\mathrm{Year}-1}$ ratio, Fig. 46; see previous chapters for caveats regarding index ratios). Data from the SKT survey was only used for univariate analyses because the SKT index time series only has 11 data points at this time. Spring and fall X2 values were obtained by first calculating mean monthly X2 values calculated from daily X2 values provided by the DWR Dayflow database and then averaging the mean monthly X2 values for the “spring” months February to June and the “fall” months September to December. The 2002-2003 step decline in Delta Smelt abundance (Thomson et al. 2010) was introduced as a before/after factor (“Step”). Details about the data sources are provided in Chapter 3 of this report.

The multivariate analyses presented here were conducted with generalized linear modeling (GLM) following the approach of Jassby et al. (1995) and followed with a classical linear modeling (LM) approach guided by the GLM results. For the GLM, model parameters were estimated with a Poisson error distribution, a log link function describing the relationship between the predictor variables(s) and the mean, and a natural spline to represent non-linearities. The degrees of freedom for the splines were restricted to only 2 (i.e. one interior knot) because of the low number of available data points. Models requiring estimation of more than two independent parameters (aside from the intercept) were not considered for the same reason. Applying the GLM approach avoids the need for log-transforming the abundance data and using natural (quadratic) splines as smoothers allows a more natural representation of non-linearities than using polynomials.

The responses predicted by these models have a fairly high degree of precision as indicated by low values of SE/Mean and residuals were consistent with model assumptions. The results show significant univariate relationships at the $P < 0.05$ level (Table 7) between the 20 mm abundance index and spring X2, prior fall X2, and prior FMWT abundance index. The relationship is strongest with prior fall X2, followed by spring X2 and prior FMWT abundance index (Table

7). The relationship with spring X2 appears unimodal with maximum 20 mm indices associated with spring X2 values between about 55 and 70 km (Fig. 79a). The relationship with prior fall X2 appears negative (Fig. 79b), and the relationship with the prior FMWT abundance index (Fig. 79c) appears positive. Each of these univariate relationships was improved by the inclusion of one of the other predictor variables (Table 7). Relationships with spring and prior fall X2 were also improved by including the 2002-3 step change. As mentioned above, multivariate analyses with more than two predictor variables were not conducted because of the relatively small amount of available data (n = 19, Table 7). Based on AIC comparisons (Table 7), including the 2002 step change (introduced as a before/after factor, “Step”) somewhat improved the relationship of the 20 mm index with spring X2 (Fig. 73a) and with prior Fall X2 (Fig. 79b), but not with the prior FMWT index because that index was the basis for the analyses that detected the step change and thus already includes the step change in the actual data (Fig. 79c, model not included in Table 7). Including the prior FMWT abundance index improved the relationships with spring and fall X2 more substantially, but the model combining the effects of spring and fall X2 fit the 20 mm index data nearly as well as the model combining the effects of spring X2 and prior FMWT (Table 7).

It is interesting to note that while prior fall X2 by itself was a stronger predictor of the 20 mm index than spring X2, spring X2 was the stronger predictor when the step change or previous fall abundance were taken into account. Baxter et al. (2010) hypothesized that the shift toward higher prior fall X2 values (Fig. 17) may have contributed to an ecological “regime shift” associated with the step decline in Delta Smelt and other species. This means that prior fall X2 and the “step” factor and FMWT decline in this analysis may be related, which could explain the very similar outcomes for the two models combining spring X2 with either prior fall X2 or the prior FMWT index.

Partial residual plots show the relationship between a predictor variable and the response variable given that other independent variables are also in the model; in other words, they show the effect of one predictor variable given the effect of one or more additional predictor variables. Partial residual plots for the relationships of the 20 mm index with the combinations of spring X2 and prior fall X2 (Fig. 80 a and b) and spring X2 and prior FMWT abundance index (Fig 80 c and d) show that the general shape and direction of the relationships of the 20 mm index with each of the individual predictor variables (Fig. 79) remains intact in the models with combined predictors, but the partial residuals do not closely follow the fitted lines. This indicates that while each variable has its own, distinct effect on the 20 mm index that is maintained in the presence of the other variables, interactive effects among these variables are quite strong. In summary, low values of prior fall X2, high prior FMWT abundance, and intermediate values of spring X2 have positive associations with the abundance of larval/postlarval Delta Smelt, but the effects of individual variables are mediated by the presence of the other variables.

Because the spline degrees of freedom were strongly restricted in this GLM analysis, the results are quite similar to the results of classical linear models (LM) with log-transformed abundance data and a quadratic term to represent the unimodal non-linearity in the relationship between the 20 mm index and spring X2 (Fig. 81). We include these models here because they are more easily reproducible than the GLM models and offer simple equations for making predictions about larval abundance that can be used in adaptive management applications. As for the GLM analysis (Table 7), the best fits overall were achieved by combining spring X2 with either the step change or the prior FMWT abundance index (Table 8). All predictor combinations improved the models compared to the univariate relationships (Table 8). Based on a comparison of regression

Table 7. Summary of relationships between the 20 mm abundance index for Delta Smelt (response variable) and one or more predictor variables: n, number of observations (years); SE/Mean, model standard error (square root of mean squared residual) as proportion of mean response, P, statistical significance level for the model; R^2, coefficient of determination; adjusted R^2, R^2 adjusted for the number of predictors in the model; AIC, Akaike information criterion; Δ AIC, AIC differences; w (AIC), AIC weights. All relationships modeled with generalized linear models (GLM) with a Poisson error distribution, log link function, and a natural cubic spline with two degrees of freedom as a smoother for all predictor variables except "Step."

Predictor Variable(s)	n	SE/ Mean	P	R^2	Adjusted R^2	AIC	Δ (AIC)	w (AIC)
Spring X2, $\text{FMWT}_{\text{year-1}}$	19	0.119	<0.001	0.791	0.731	39.5	0.00	0.53
Spring X2, Fall $\text{X2}_{\text{year-1}}$	19	0.120	<0.001	0.787	0.726	40.1	0.60	0.39
Fall $\text{X2}_{\text{year-1}}$, $\text{FMWT}_{\text{year-1}}$	19	0.126	<0.001	0.764	0.697	43.2	3.78	0.08
Spring X2, Step (Factor)	19	0.143	<0.001	0.677	0.612	53.6	14.12	0.00
Fall $\text{X2}_{\text{year-1}}$, Step (Factor)	19	0.135	<0.001	0.712	0.655	55.8	16.35	0.00
Fall $\text{X2}_{\text{year-1}}$	19	0.145	<0.001	0.646	0.601	56.0	16.53	0.00
Spring X2	19	0.176	0.006	0.476	0.411	79.9	40.43	0.00
$\text{FMWT}_{\text{year-1}}$	19	0.187	0.015	0.408	0.334	89.4	49.98	0.00

coefficients and P-values, the LM relationships were statistically weaker (Table 8) than in the GLM analysis (Table 7).

Another way of including prior abundance in statistical relationships of abundance with habitat attributes and environmental drivers is to use abundance indices that are proportional to prior abundance indices, in other words, ratios of present to prior abundance indices. In this report, we used the ratios of 20 mm to SKT and 20 mm to $\text{FMWT}_{\text{Year-1}}$ abundance indices (Fig. 46; see also caveats about these indices in Chapter 3) as larval recruitment indices from adults and subadults, respectively. We found that recruitment of larvae from adults was linearly related to spring X2 for the entire available time series (2003-2013, Fig.82a and Table 9). The recruitment index for 2013 was higher than expected based on the other data points. The relationship of the recruitment index from subadults to next year's larvae with winter-spring X2 was also linear for the POD period after the abundance step decline in 2002 (Thomson et al. 2010), but with more scatter at higher X2 values. Interestingly, no relationship was apparent at all before the 2002 step decline when the proportional larval recruitment from then more abundant subadults was generally low (Fig. 82b and Table 9). In the current POD regime, larval recruitment from parental stock appears to be highest when flows through and out of the Delta are high and the interface between fresh and brackish water is located to the west (i.e. low X2), although it can occasionally also be high at lower flows, as was the case in 2013.

In late winter and spring 2013, CVP and SWP exports were reduced to comply with OMR flow requirements in the 2008 USFWS Biological Opinion aimed at reducing the risk of adult and

Figure 79. **Plots of the Delta Smelt 20 mm survey abundance index as a function of a) spring (February-June) X2, b) previous year fall (September-December) X2, and c) Delta Smelt fall midwater-trawl abundance index in the previous year. Details of general linear models (GLM) used to fit the lines are in Table 7.**

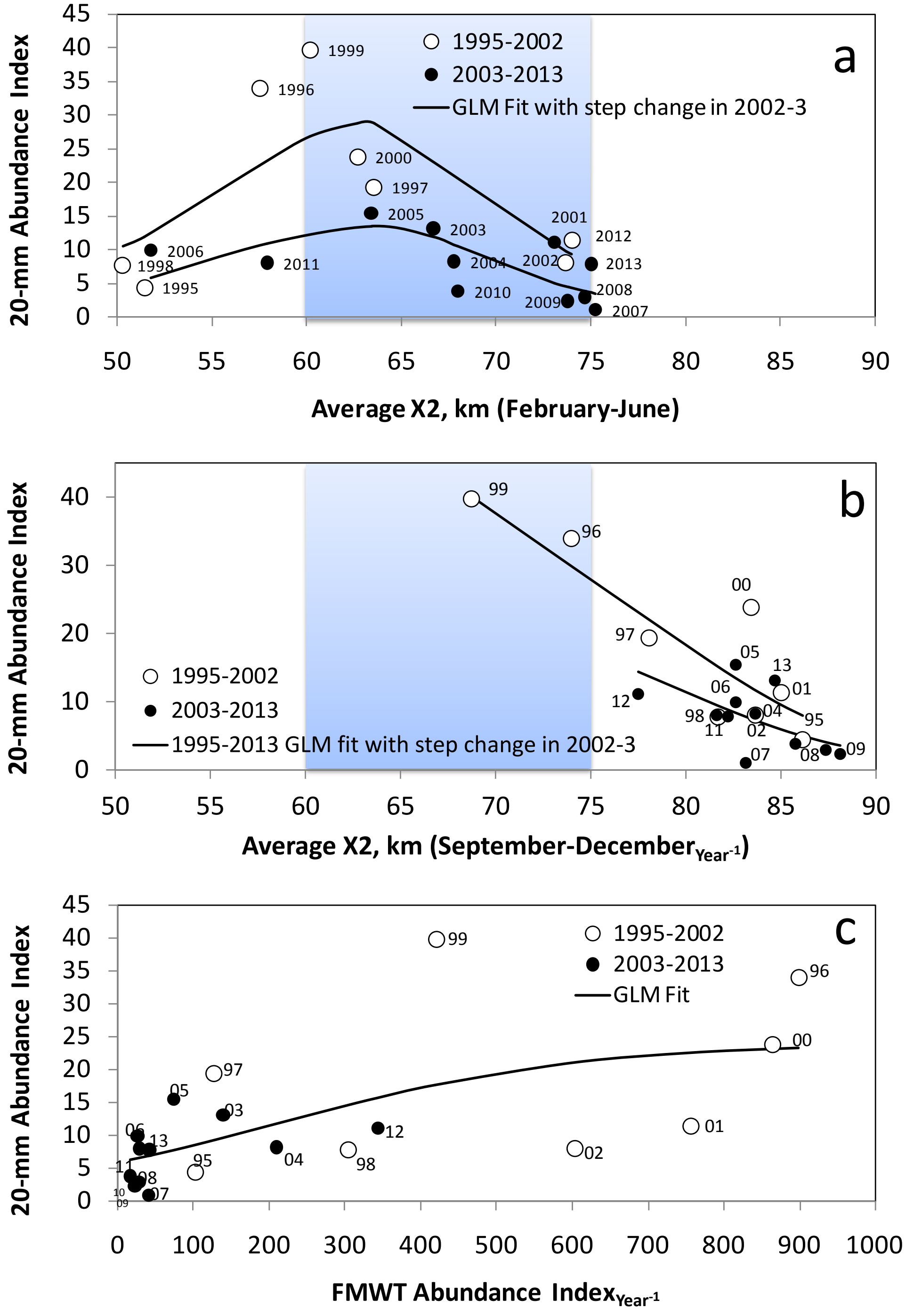


Figure 80. **Plots of partial residuals for the relationships of the 20 mm index with the combinations of spring X2, prior fall X2, and prior FMWT abundance index summarized in Table 1 (panels a, b, d, and e). The plots shown here also include partial fit lines and their 95% confidence intervals. Values for the time period of analysis are shown for: c, X2; and f, the fall midwater trawl abundance index from the previous year**

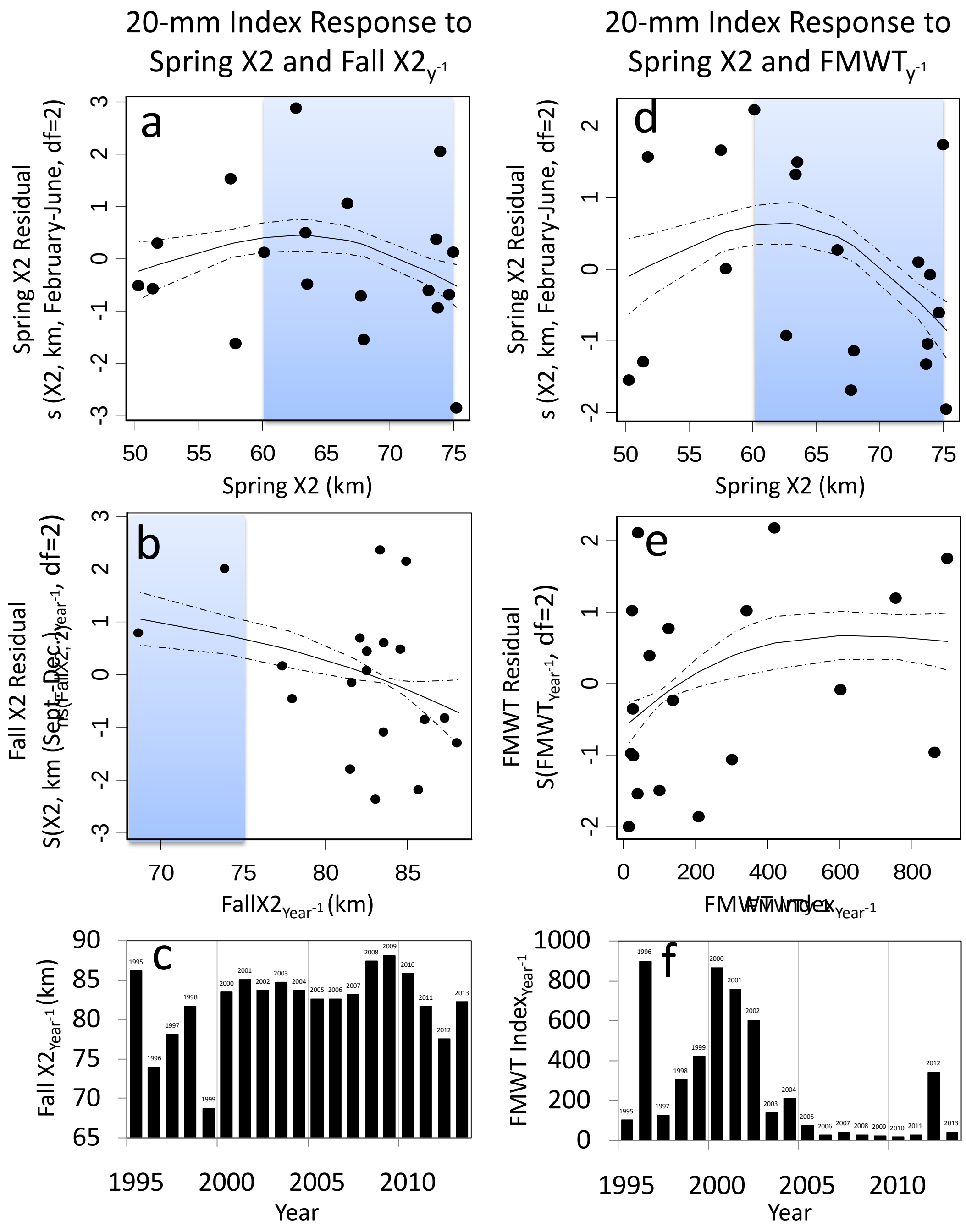
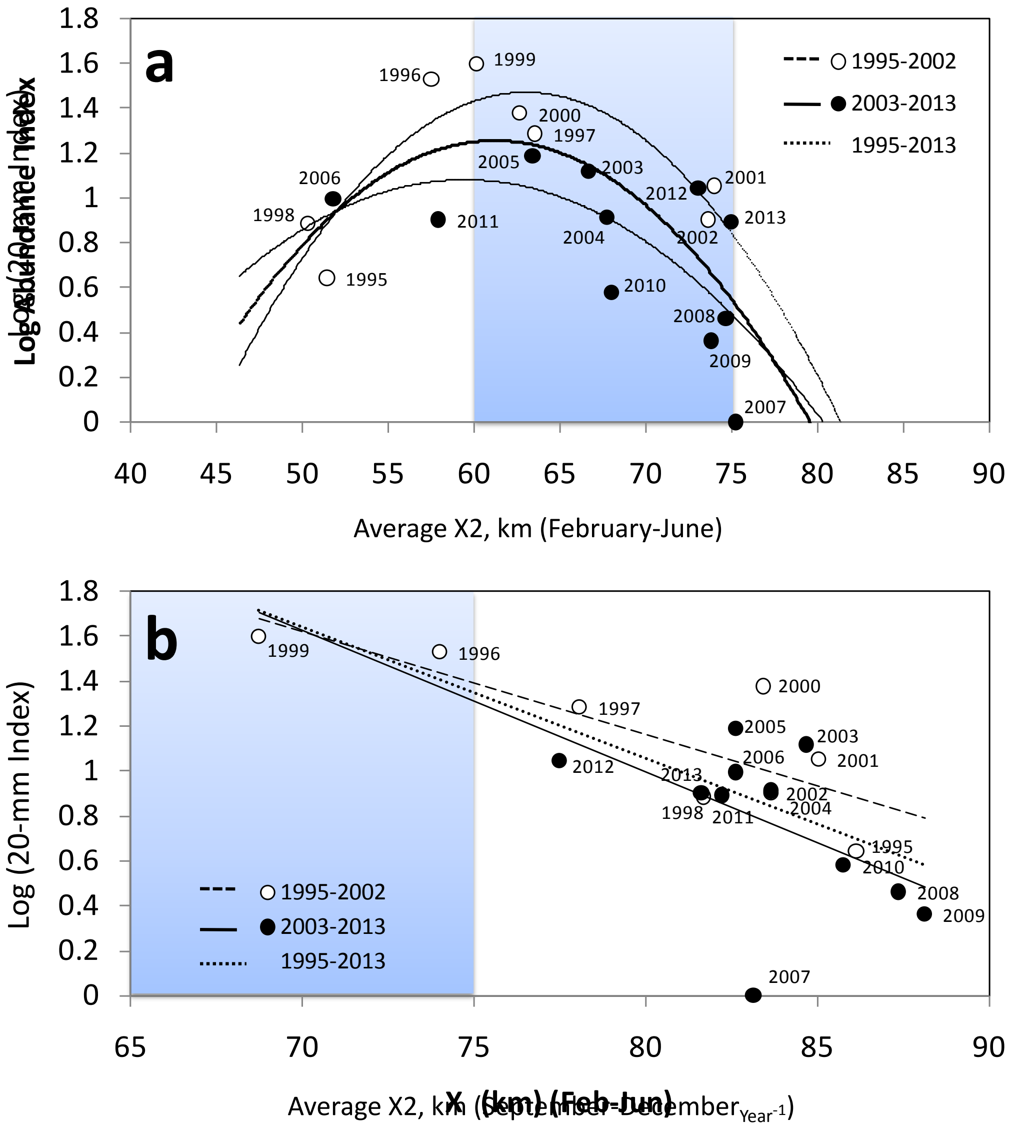


Figure 81. Plots of the Delta Smelt 20 mm survey abundance index as a function of a) spring (February-June) X2, and b) previous year fall (September-December) X2. Lines are either simple linear least squares regression (lines) or quadratic regression (curves). Details of linear models (LM) used to fit the 1995-2013 lines are in Table 8.



larval Delta Smelt entrainment into the water export pumps. This was the first time since the 2008 USFWS Biological Opinion was issued that exports were specifically reduced to lower Delta Smelt entrainment risk. In other years, flows were high enough to allow for higher export levels or export reductions to protect salmon were deemed sufficiently protective for Delta Smelt. It is possible that the intentional reduction in Delta Smelt entrainment risk in 2013 contributed to the high larval recruitment from adults during relatively low flow conditions, but additional years with similar conditions and targeted management actions as well as better estimates of entrainment and more in-depth analyses with other flow variables and flow averaging periods

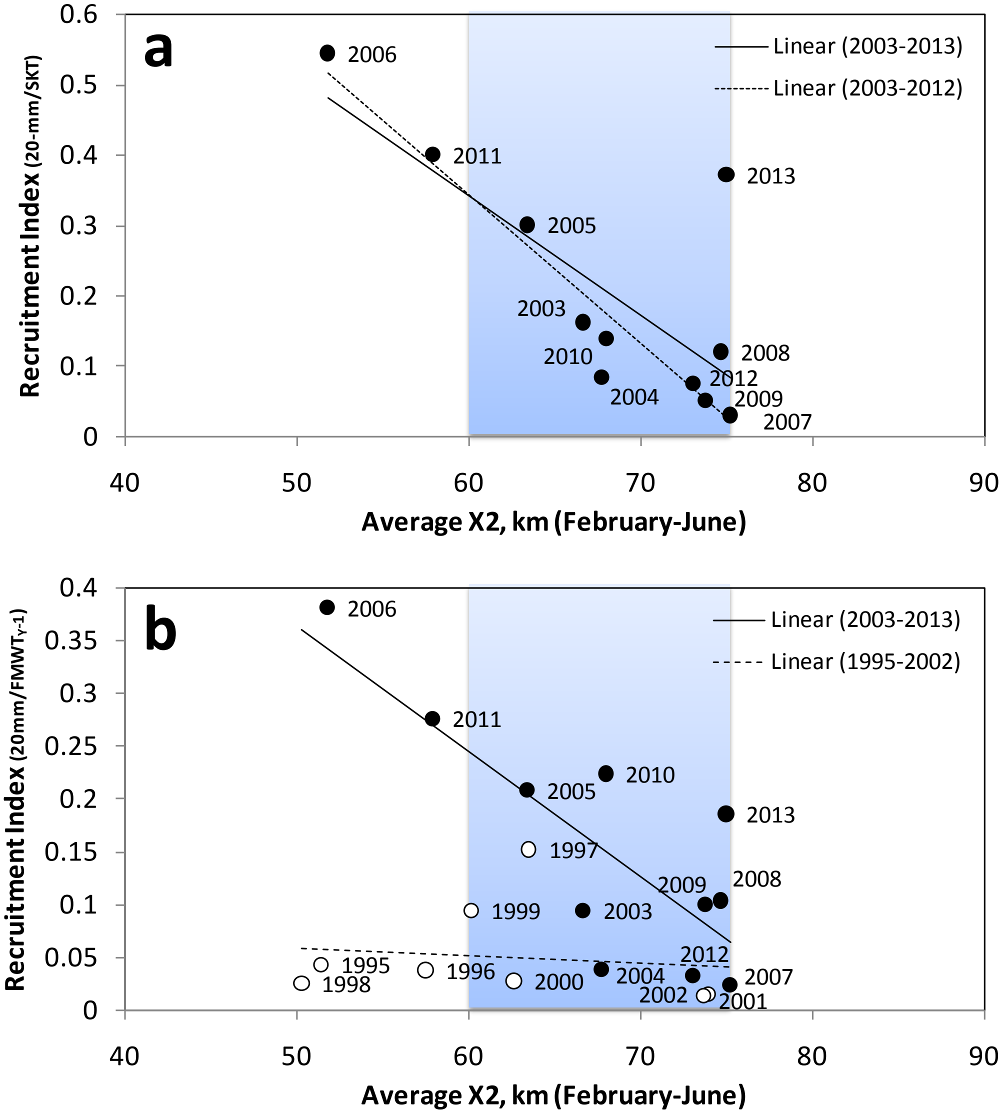
Table 8. **Summary of relationships between the log-transformed 20 mm abundance index for Delta Smelt (response variable) and one or more predictor variables. All relationships modeled with simple least-squares linear models (LM). For explanation of column headings see Table 6.**

Predictor Variable(s)	n	SE/ Mean	P	R^2	Adjusted R^2	AIC	Δ (AIC)	w (AIC)
Spring X2, (Spring X2)^2, log FMWT$_{year-1}$	19	0.237	0.000	0.745	0.694	2.1	0.00	0.85
Spring X2, (Spring X2)^2, Fall X2$_{year-1}$	19	0.274	0.001	0.661	0.593	7.5	5.42	0.06
Fall X2$_{year-1}$, log FMWT$_{year-1}$	19	0.280	0.000	0.621	0.574	7.7	5.54	0.05
Spring X2, (Spring X2)^2, Step (Factor)	19	0.292	0.002	0.616	0.540	9.9	7.78	0.02
Fall X2$_{year-1}$, Step (Factor)	19	0.307	0.002	0.544	0.487	11.2	9.06	
Fall X2$_{year-1}$	19	0.318	0.001	0.479	0.449	11.7	9.58	0.01
Spring X2, (Spring X2)^2	19	0.329	0.006	0.473	0.407	13.9	11.83	0.00
log FMWT$_{year-1}$	19	0.333	0.002	0.430	0.397	13.4	11.29	0.00

are needed to test this hypothesis and obtain a better understanding of flow effects on larval recruitment.

Overall, these preliminary findings suggest that abundance of the larval to early juvenile life stages of Delta Smelt may respond quite strongly to spring and prior fall outflow conditions. The relationships of the 20 mm index with spring X2 shown in this analysis were much stronger than relationships of the TNS and FMWT indices with spring X2 (Table 1, Fig. 17. Similarly, hydrological conditions in the fall seem to have a greater impact on subsequent abundance of larvae than on subsequent juvenile abundance (TNS index; Mount et al. 2013). This is consistent with the findings by Kimmerer et al. (2009) who noted more pronounced relationships of spring X2 with earlier than with later life stages of Delta Smelt and explained that this was “probably because the earlier life stages occupy areas that are fresher and therefore more responsive to changing flow than the more brackish regions.” While the size and location of the LSZ itself may be important for maturing adults in the fall, its interface with fresh water may be important to larvae and spawning adults. A more westward interface means a larger freshwater habitat for spawning and larval rearing that reaches into the shallow eastern region of Suisun Bay and is well connected with Suisun Marsh sloughs and, in wetter years, the Napa River. It also means a larger distance to the export pumps in the southern Delta and thus a reduced risk of entrainment for spawning adults and larvae. Interactions of flow with other drivers and habitat attributes as shown in the conceptual models in this report are likely also important. This suggests that at least

Figure 82. **Adult (panel a, SKT) and subadult (panel b, FMWT the previous year) to larvae (20 mm Survey) recruitment indices (abundance index ratios) as a function of spring X2 (February-June). For 20 mm/SKT a linear regression was calculated with and without 2013, which appears to be an outlier. For 20 mm/FMWT the previous year separate regressions were calculated for the POD period (2003-2013), the period before the POD (1995-2002), and the entire data record (not shown). See Table 9 for regression results.**



at present, increased Delta outflow and a more westward LSZ in fall, winter, and spring may have important beneficial effects on early life stages of Delta Smelt, but other factors (possibly including summer flows which were not included in this analysis) may be more important for their survival to adults.

Finally, similar to previously published analyses, this analysis strongly suggests that previous life stage abundance should always be taken into account in statistical explorations of habitat effects

Table 9. Summary of relationships of larval recruitment indices (abundance index ratios) for Delta Smelt (response variable) and spring X2 (predictor variable; spring: February-June): n, number of observations (years); SE/Mean, model standard error (square root of mean squared residual) as proportion of mean response, P, statistical significance level for the model; R^2, coefficient of determination. All relationships modeled with least-squares linear models (LM).

Index Ratio	Period	n	SE/Mean	P	R^2
20-mm/ SKT	2003-2013	11	0.556	0.006	0.588
20-mm/ SKT	2003-2012	10	0.270	0.000	0.918
20-mm/ $FMWT_{Year-1}$	2003-2013	11	0.469	0.003	0.648
20-mm/ $FMWT_{Year-1}$	1995-2002	8	1.012	0.771	0.015
20-mm/ $FMWT_{Year-1}$	1995-2013	19	0.981	0.321	0.058

on Delta Smelt. Prior abundance can be introduced into these relationships as actual abundance data (e.g. abundance indices or catch per trawl data), periods of relatively constant abundance (here introduced as a “step” factor), or by combining it with present abundance in proportional abundance indices such as the index ratios used here as recruitment indices. Similar to the relationships of juveniles with spring X2 discussed in Chapter 4, the overall depressed abundance of larval Delta Smelt during the POD period that started in 2002 leads to less substantial larval abundance increases with increasing outflows and decreasing X2 values than before the onset of the POD. However, the association of high larval recruitment with high spring outflow suggests that winter and spring hydrology, through its effects on habitat attributes, may be an important driver of larval recruitment during the current POD period, although it may be less important at higher abundance levels.

In summary, this preliminary analysis provides an example of how relatively simple multivariate modeling can yield intereresting insights, in this case about how prior conditions (prior fall X2), prior abundance (prior FMWT), step changes in abundance, and concurrent environmental conditions (spring X2) may all have important effects on Delta Smelt abundance in the spring. While further analyses, more sophisticated life cycle modeling, and publication in a peer-reviewed journal are needed to draw firm conclusions, these preliminary results support the idea discussed throughout this report that neither scientific understanding nor management effectiveness can be improved by only considering a single effect, or a single season or life stage. High larval recruitment is essential for setting the stage for a strong year class, but higher growth and survival through subsequent life stages are also needed to achieve and sustain higher population abundance levels.

Numerical Simulation Modeling

Quantitative simulations of the multiple factors and processes that affect Delta Smelt life stage transitions in our conceptual model are an obvious next step in the exploration and synthesis of the information presented in this report. The purpose of simulation modeling is to represent a phenomenon or process in a way that allows users to learn more about it by interacting with the simulation (Alessi and Trollip 2001). In particular, simulations allow users to easily control experimental variables and test hypotheses. Guidance from simulation model "dry runs" can make actual laboratory and field experimentation much more efficient and effective. Simulations are also valuable in visualizing outcomes, thus further promoting learning and understanding.

The individual-based Delta Smelt model by Rose et al. (2013a, b) is an example of a complex simulation model specifically created for Delta Smelt. Another simulation modeling option is to utilize "off-the-shelf" simulation software such as the "STELLA" (Structural Thinking and Experiential Learning Laboratory) simulation construction kit (http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx). STELLA is designed to let users easily create their own simulations using system dynamics including positive and negative causal loops, and flows, accumulations and conversions of materials.

Culberson (USFWS, unpublished data) created a simple quantitative simulation model in STELLA that includes several life stages of Delta Smelt and is based on seasonal environmental conditions and stage to stage estimates of survival. While this simulation modeling approach appears to be feasible, it remains to be seen how such an approach will approximate actual population dynamics encountered in the field and how results compare to those of other simulation models such as the individual-based life cycle model by Rose et al. (2013a,b). A user-friendly STELLA-based model can be useful in the interim, however, to explore the relative contribution of lifecycle stage and environmental covariates to the overall status of Delta Smelt abundance from year to year and to test hypotheses derived from the conceptual model. In its fullest expression, this MAST-associated lifecycle model will be useful for illustrating how multiple suites of plausible co-variates can allow for different Delta Smelt abundance outcomes. For example, it may be possible to find high abundance under degraded conditions given low entrainment losses across successive winters and springs. Conversely, it is possible to encounter low Delta Smelt abundance given otherwise good environmental and outflow conditions with significantly warmer temperatures during fall pre-adult maturation periods. Moreover, simulated changes in survival can provide a useful frame of reference to evaluate alternative outcomes of cohort size or population size attained at different life stages. For example, given the reported levels of larva, juvenile and sub-adult Delta Smelt in IEP surveys, what levels of daily survival between life stages would be required to attain the relative abundances corresponding to each of the four years being compared? Could the small anticipated differences in assumed daily survival among those four years be attributed to some combination of habitat attributes? Or, could stage-to-stage survival (e.g., percent of individuals surviving from one stage to the next) provide a more useful frame of reference to address that question? Our proposed STELLA simulation model and associated modeling exercises will comfortably allow exploration of these questions and related ideas.

This type of modeling will best be used iteratively with emerging data and within synthesis reports to identify where important gaps exist in the Delta Smelt lifecycle understanding and demonstrate how disparate information sources might be brought together to inform our smelt population estimates through time. Importantly, our model can be used in combination with the narrative description of "a year in the life" of the Delta Smelt population from the conceptual model to more effectively describe environmental and management effects on population status in the SFE. We are especially interested in using such a model to avoid single-factor outcome discussions where smelt populations are seen as the result of "one versus another" environmental or management-related trade off, particularly when single factor analysis is aggregated over decades of data collection efforts in what we know is a constantly-changing estuary.

Figure 83 shows how output from such a model might be useful for keeping track of the variable influence of factors on overall Delta Smelt abundance across seasons within three hypothetical years. Six factors are plotted according to their sensitivity rank (their relative influence on simulated population outcomes). Specific sensitivity levels can then be identified according to the combinations of factors that emerge as important across succeeding seasons and years. Models built to simulate these influences can then be closely examined to discern how different years, year types, or management practices influence simulated abundance, and to detect where potential data gaps or inconsistencies are among the alternative conceptual models or model modes. The basis for using such an approach is a comparative one, and an absolute resolution of the size or behavior of the real Delta Smelt population is not anticipated – but remains the overall objective. Of real interest here is providing a way to interpret our emerging conceptual model within potential regime-shifts, and to capitalize on previous specifications of this model to organize our ever-improving understanding. Of additional benefit is the ability to use these models easily in “learning sessions,” where users interact with the modelers and species experts to deepen understanding of Delta Smelt biology and its relationship to Delta ecology and management.

Applications to Support Delta Smelt Management

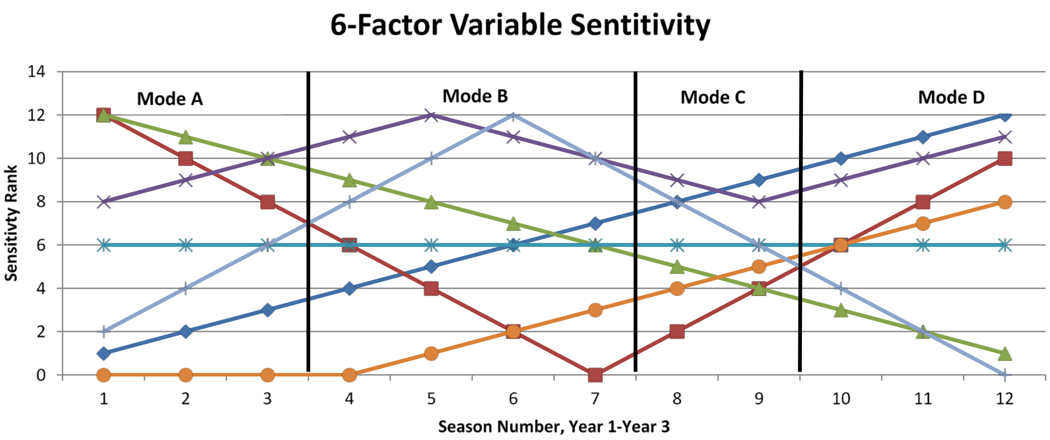
We have shown that the conceptual models in this report provide a reasonable and up to date conceptual framework that can be used to analyze and synthesize existing data and knowledge about Delta Smelt, identify critical data and information gaps, and guide new field and laboratory studies as well as mathematical modeling efforts. We have also discussed many challenges that limit our ability to reach firm conclusions and make highly confident predictions about the effects of management actions and other changes on Delta Smelt. And we have noted that science and management have to go hand in hand to constantly identify, implement, evaluate, and refine the best management options for Delta Smelt in the highly altered and ever-changing estuarine ecosystem that represents the entire range of this species.

Adaptive management is a well-established approach for systematically integrating science and management. As mentioned earlier in this report, it is increasingly required in plans for management of the San Francisco estuary, but to date, the Vernalis Adaptive Management Program (VAMP) and the Fall Ouflow Adaptive Management Plan are among the few clear examples of systematically planned and implemented adaptive management in the estuary.

We end our report with examples of how our conceptual models can be used to adaptively manage and improve Delta Smelt habitat. We conclude with several recommendations for the next analysis, synthesis, and modeling efforts. These efforts are a key ingredient for the more widespread adoption and success of adaptive management strategies; without the conceptual and mathematical models provided by these efforts adaptive management of ecosystems simply cannot proceed.

Table 10 gives examples of adaptive management goals and associated uncertainties to address habitat deficiencies (“habitat problems”) identified and discussed in this report. This table is intended as an illustration of how our conceptual models can be used to inform the first three steps of the nine-step adaptive management framework developed by the DSC Delta Science Program (DSP 2013). These three steps are: 1) definition of the problem; 2) establishment of

Figure 83. **Simulated output from a STELLA model for assessing sensitivity of the model to variation in model variables.**



management goals and actions to address the problem; and 3) modeling of linkages between management goals and actions. The third step specifically requires conceptual or quantitative models for the purpose of evaluating outcomes of alternative management actions and identification of uncertainties and data gaps. Conceptual models are also important in the other six adaptive management steps, for example to design effective adaptive management experiments and appropriate monitoring and to analyze, synthesize and evaluate results.

Table 10 is organized around the habitat attributes identified in the conceptual models. For each habitat attribute, we describe some example categories of management actions that could be considered to improve the status of Delta Smelt. In essence, these actions represent an example “tool box” for the management of Delta Smelt.

Note that the tool box identified in Table 10 is not meant to be exhaustive. Rather, the list is intended as an example set of adaptive management actions suggested by the conceptual models. As such, the list provides no insight into the cost-effectiveness or feasibility of any of the potential actions. Moreover, we acknowledge that there is substantial uncertainty about the potential benefits of actions in the tool box. As mentioned above, identification of uncertainties about the feasibility and benefits of proposed management actions is an important step in adaptive management that can only be accomplished with the help of conceptual or quantitative models. A key point is that these studies are somewhat different than the critical data and information gaps presented earlier in this Chapter. Specifically, Table 10 emphasizes information gaps that are most relevant to specific management questions, while the earlier list focuses on needs to improve the overall scientific understanding that provides the basis for our conceptual models for Delta Smelt. Clearly, efforts to resolve uncertainties and gaps in understanding are needed in both categories. Overlapping uncertainties may highlight especially urgent data and information needs. For Delta Smelt, this includes uncertainties related to contaminants, predation, and entrainment along with interactions of physical habitat attributes with other factors.

Table 10. **Example tool-box for applying the conceptual model to Delta Smelt management.**

Habitat Attribute	Management Actions	Example Study Efforts
Physical Features	Increase habitat area & quality	-Identification of key microhabitats for each life stage and attributes. -Effects of flow/LSZ position on habitat quality, particularly key biotic habitat elements (access to prey, evasion of predators). -Approaches to maintain & expand high turbidity habitat (e.g. supply, habitat design, SAV management). -Approaches to maintain and expand habitat with moderate temperatures (e.g. channel configuration, water depth and velocity). -Evaluation of whether targeted restoration meets habitat needs (e.g. temperature, substrate, turbidity)
Chemical Features	Reduce toxicity	-Identification of chronic effects of contaminants. -Identification of effects of Harmful Algal Blooms. -Approaches to reduce toxicity from contaminants and HABs
Food	Increase pelagic production Increase access to alternative foods (e.g. epibenthic). Reduce sources of loss Manage towards higher quality foods Prevention and control of non-native species	-Role of tidal wetlands as subsidy habitats (not necessarily occupied by smelt) -Ammonia-bivalve interactive effects on diatom, copepod, mysid, amphipod production. -Relative importance (contribution to smelt growth) of epibenthic foods (e.g., mysids, amphipods, aquatic insects). -Effect of bathymetry, vegetation type (and density) on access to epibenthic and pelagic foods. -Role of tidal wetlands and wetland/open-water complexes. -Approaches to reduce losses to benthic grazing (e.g. invasive clams) and/or to the suppression of bivalve populations -Value of different food types to Delta Smelt nutrition. -Effects of habitat conditions (e.g. ammonia, flow) on food quality. -Identification of nutrient sources and sinks. -Improved detection methods for invasive species -Studies to evaluate alternative control methods.
Entrainment	Avoid entrainment region Adjustments to timing and magnitude of exports	-Identification of factors that lead to increased occupancy of South Delta. -Improved measurement of entrainment and its environmental correlates -Effects of exports and entrainment on viability (e.g. abundance, genetics, demographics). -Approaches to reduce entrainment and enhance emigration success.
Predation risk	Reduction of predator population Reduction of predation rate	-Studies on delta smelt responses (behavior, distribution, abundance) to variation in predator abundance. -Identify habitat features that reduce predation rate (e.g. depth, turbidity, food, lower water temperatures).

Recommendations for future analysis and synthesis

Efforts to resolve the management issues listed in Table 10 or carry out the modeling and fill the critical science gaps discussed earlier in this Chapter will not succeed without an organizational commitment to continued systematic and long-term collection, synthesis and evaluation of data and information about Delta Smelt, its habitat, and important drivers of habitat and abundance changes. The importance of Delta Smelt for ecosystem and water supply management in and far beyond the SFE is widely recognized. The impressive rate at which we are learning about Delta Smelt and the estuarine ecosystem and the large amount of existing information about them is less widely recognized by many managers and even by many scientists. Part of the reason for this is that it is difficult to track the large quantity of new (since 2010) information documented in this report and even more difficult to integrate it with the previously existing information in a meaningful way. But without this integration, identification of priorities for additional scientific investigations is ad hoc and piecemeal at best and the value of new information cannot be fully realized in management applications such as those listed in Table 10.

Moreover, comprehensive adaptive management efforts simply cannot succeed without adequate conceptual and mathematical models and important science and management opportunities will be missed. Such efforts currently include the ongoing fall outflow adaptive management for Delta Smelt and new efforts called for by the new “Collaborative Science and Adaptive Management Program” (CSAMP), the California Delta Stewardship Council’s Delta Plan, and the multi-agency Bay Delta Conservation Plan (BDCP). The fact that even the incomplete draft version of our report released for public review in June 2013 already played a central role in CSAMP work planning, court documents, and elsewhere bears clear testimony to the fact that there is a great and urgent policy and management need for analysis, synthesis and conceptual models such as those provided in this report.

In consequence, we strongly recommend that there be a continued management, analysis, and synthesis effort, whether carried out by the IEP, the Delta Science Program, or some other scientist, group or agency. While it is possible for individual scientists to take on such efforts (e.g., Bennett 2005), the amount, diversity, and rapid growth of pertinent data and information suggests that team efforts may usually be a more feasible and possibly also a more effective option. Collaborative, multidisciplinary analysis and synthesis teams are also at the core of the National Center for Ecological Analysis and Synthesis in Santa Barbara, CA (NCEAS, http://www.nceas.ucsb.edu/), the newer National Socio-Environmental Synthesis Center in Annapolis, MD (SESYNC, http://www.sesync.org/) and the Delta Collaborative Analysis and Synthesis (DCAS) approach promoted by the Delta Science Program’s Delta Science Plan (DSP 2013). Important IEP POD and MAST lessons for future synthesis teams are that the role and responsibilities of all team members need to be very clear, that lines of communication need to always be open and available to all, and that there needs to be strong and fully engaged team leadership with a clearly dedicated lead author and/or lead editor for all major team products. In addition, to complete analyses and reports on schedule, it is necessary for team members to prioritize synthesis efforts for sustained periods of time, without being tasked with additional projects that may be urgent for short-term needs.

Another consideration is the type of publication that results from analysis and synthesis efforts. The IEP MAST and POD teams have written comprehensive agency reports, but would have preferred writing peer-reviewed books or monographs (e.g., published by the American Fisheries Society or by U.C. Press) had the time and resources been available to do so. Such books would be considered better scientific products with greater scientific standing and a longer life span and would reach a much larger audience. Another approach would be to write a series of shorter articles that could be published in a special issue of a peer-reviewed scientific journal. This too would take more time and effort and would also somewhat restrict the types of topics that could be covered. Journal articles are, however, the main target for national analysis and synthesis centers such as NCEAS and SESYNC because they have the greatest scientific standing and are the most widely accepted and well established method of written science communication.

Regardless of which analysis, synthesis, and communication approach is chosen, none of these efforts can succeed without commitment of adequate funding, staffing, and other resources. The IEP MAST team that developed and wrote this report was formed in 2012 for IEP science synthesis and work planning, but it has remained a pilot-level effort that was never adequately supported. MAST work remained a part-time effort for all co-authors of this report, and for most it was an “on the side” task compared to their “regular” agency duties. There is no doubt that completion of this report could have proceeded much more rapidly with greater allocation of resources. Public and independent peer reviews of a draft version of this report (see http://www.water.ca.gov/iep/pod/mast.cfm) greatly improved the structure and content, but were not an original part of the MAST planning. Preparing and conducting the reviews as well as responding to the 355 specific and many more general review comments took considerable time (see also Appendix A). Other MAST tasks also added to the delays. In addition to this report, the MAST completed a synthesis report for the Fall Low Salinity Habitat (FLaSH) investigation component of the Fall Outflow Adaptive Management Program (Brown et al. 2014) and prepared a solicitation package for research proposals, which it then also reviewed.

We strongly recommend that adequate, long-term support for these types of efforts be among the highest science and adaptive management priorities for the region and the entire State of California. Given its pivotal role in adaptive management and the increasingly large amounts of new scientific data and information that are produced every year, the authors of this report, individually and as a team, cannot think of any science activity that is more urgently in need of greater support than analysis, synthesis, and communication of scientific results.

For additional analysis and synthesis efforts about Delta Smelt, we recommend that the next individual or team to take this on should:

- Build on this report by evaluating the conceptual model with more rigorous analyses that include more years of data, developing lifecycle and numerical models as discussed above, and/or using the conceptual model to develop a comprehensive list of data and information gaps and approaches to addressing these gaps in order to inform management strategies;
- Early in the process, make clear decisions about the analytical/modeling approaches to be used, the scope of the synthesis to be done, and approaches for review and communication of results;
- Evaluate additional data and information needs concerning Delta Smelt;
- Consider approaches to understand the effects of the wide variety of management actions targeting Delta Smelt, including adaptive management of fall outflow, entrainment, habitat restoration, etc (e.g., Table 10);
- Develop key “indicator” variables that can be used to track and predict the status of Delta Smelt and its habitat and serve as “performance metrics” to evaluate the success of management actions. Such variables, and a “report card” to summarize them, were considered for this report, but the MAST decided that developing them was beyond the scope of

this report and would require a fairly substantial effort that could be the main focus of an additional effort.

An additional recommendation is that an ultimate goal of these efforts should be the integration of conceptual and mathematical models such as those described in the previous section of this Chapter and the routine use of both types of models in adaptive management. Neither the recently published mathematical models nor existing conceptual models for Delta Smelt have been applied to management issues in a consistent manner. This is likely at least partially due to unfamiliarity of managers with the models and the need for specialists (model developers) to apply the mathematical and in some cases even the conceptual models to management issues in the absence of easy to use and understandable model interfaces and specifications. We also recommend a comprehensive biological modeling forum and/or more specific biological modeling teams and "summits" as recommended by the IEP Science Advisory Group (2010, available at http://www.water.ca.gov/iep/docs/IEPModelWorkshopReview.pdf) and, more recently, the Delta Science Plan (DSP 2013). Such groups would not only facilitate communication among modelers, but could also help make the connection from model development to model applications of interest to managers and policy makers. They would complement and could (and likely should) be integrated with the existing, California Water and Environmental Modeling Forum (CWEMF, see http://www.cwemf.org), which tends to focus on modeling physical processes. As with the overall analysis and synthesis teams, these groups could be implemented by the IEP, The Delta Science Program, CWEMF, or others. The chosen organizational umbrella is less important than actual implementation and involvement of appropriate local and outside scientific and management expertise. Some possible topics for these groups include:

1. Reviews and updates to existing conceptual and mathematical models

2. Further development of mathematical models of Delta Smelt population abundance drawn specifically from the conceptual models described in this report; applications and extensions of recently published models to help make management decisions and guide new modeling efforts; additional modeling efforts and future research projects to improve resolution and understanding of the particular factors identified as critical to reproduction, recruitment, survival, and growth.

3. Review and refinement of new models such as the emerging comprehensive state-space population model (Newman, personal communication); development of additional models or modules of models specifically aimed at estimating effects of inadequately monitored or difficult to measure and evaluate habitat attributes such as predation risk and toxicity; development of new "nested" and/or "linked" mathematical modeling approaches that can accommodate multiple drivers and their interactive effects across temporal and spatial scales.

4. Collaboration among physical and biological modelers, experimental and other scientists, managers, and stakeholders to develop and model management scenarios and strategies that move beyond the current focus on relatively crude distinctions among "water year types" toward a more integrative ecosystem and landscape-based management approach.

We end this report with the hope that the conceptual models and information presented will be used for achieving better management outcomes for Delta Smelt and the estuarine ecosystem on which it depends. These precious natural resources are owned by no one, but are held in public trust by the California and U.S. governments for the benefit of all the people. We are grateful for the opportunity to serve our State and nation in the collaborative manner afforded by working under the interagency umbrella of the Interagency Ecological Program for the San Francisco Estuary.

References Cited

Aasen, G.A. 1999. Juvenile delta smelt use of shallow-water and channel habitats in California's Sacramento-San Joaquin Estuary. California Fish and Game 8(4):161–169.

Aasen, G.A. 2013. Predation on salvaged fish during the collection, handling, transport, and release phase of the State Water Project's John E. Skinner Delta Fish Protective Facility. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 86.

Acuña, S., D.F. Deng, P. Lehman, and S. Teh. 2012a. Sublethal dietary effects of *Microcystis* on Sacramento splittail, *Pogonichthys macrolepidotus*. Aquatic Toxicology 110–111:1–8.

Acuña S, D. Baxa, and S. Teh. 2012b. Sublethal dietary effects of microcystin producing *Microcystis* on threadfin shad, *Dorosoma petenense*. Toxicon 60:1191–1202.

Afentoulis V., J. Dubois, and R. Fujimura. 2013. Stress response of delta smelt, *Hypomesus transpacificus*, in the collection, handling, transport and release phase of fish salvage at the John E. Skinner Delta Fish Protective Facility. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 87.

Aksnes, D.L., and J. Giske. 1993. A theoretical model of aquatic visual feeding. Ecological Modeling 67:233–250.

Alessi, S.M., and S.R. Trollip. 2001. Multimedia for learning. Allyn and Bacon, Boston, MA.

Alpine, A.E., and J.E. Cloern. 1992. Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. Limnology and Oceanography 37:946–955.

Anderson, J.T. 1988. A review of size dependent survival during pre-recruit stages of fishes in relation to recruitment. Journal of Northwest Atlantic Fish Society 8:55–66.

Ankley G.T., K.M. Jenson, E.J. Hurhan, E.A. Makynen, B.C. Butterworth, M.D. Kahl, D. L. Villeneuve, A. Linnum, L.E. Gray, M. Cardon, and V.S. Wilson. 2005. Effects of two fungicides with multiple modes of action on reproductive endocrine function in the fat head minnow (*Pimephales promelas*). Toxicological Sciences 86:300-308.

Antao, T., A. Perez-Figueroa, and G. Luikart. 2010. Early detection of population declines: high power of genetic monitoring using effective population size estimators. Evolutionary Applications 4:144–154.

Arnold S.F., D.M. Klotz, B.M. Collins, P.M. Vonier, L.J. Guilette, and J.A. McLachlan. 1996. Synergistic activation of estrogen receptor with combinations of environmental chemicals. Science 5276:1489–1492.

Arthur, J.F., M.D. Ball, and S.Y. Baughman. 1996. Summary of federal and state water project environmental impacts in the San Francisco Bay-Delta estuary, California. Pages 445-495 in Hollibaugh, J.T., editor. San Francisco Bay: the ecosystem: Pacific Division American Association for the Advancement of Science, San Francisco, California.

Ashby J., P.A. Lefevre, J. Odum, C.A. Harris, E.J. Routledge, and J.P. Sumpter. 1997. Synergy between synthetic oestrogens. Nature 385:494.

Baas, J., T. Jager, and B. Kooijman. 2009. A model to analyze effects of complex mixtures on survival. Ecotoxicology and Environmental Safety 72:669–76.

Baas, J., T. Jager, and B. Kooijman. 2010. A review of DEB theory in assessing toxic effects of mixtures. Science of the Total Environment 408:3740-3745.

Baerwald, M.R., B.M. Schreier, G. Schumer, and B. May. 2012. Detection of threatened delta smelt in the gut contents of the invasive Mississippi silverside in the San Francisco Estuary using TaqMan Assays. Transactions of the American Fisheries Society 141:1600–1607.

Baskerville-Bridges, B, J.C. Lindberg, and S.I. Doroshov. 2004a. The effect of light intensity, alga concentration, and prey density on the feeding behavior of delta smelt larvae. American Fisheries Society Symposium 39:219–228.

Baskerville-Bridges, B., J.C. Lindberg, J.V. Eenennaam, and S.I. Doroshov. 2004b. Delta smelt research and culture program 5-year summary, 1998-2003. University of California, Davis, California.

Baskerville-Bridges, B., J.C. Lindberg, and S.I. Doroshov. 2005. Manual for the intensive culture of delta smelt (*Hypomesus transpacificus*). University of California Davis, Department of Animal Science, Davis, CA.

Baxter, R., R. Breuer, L. Brown, M. Chotkowski, F. Feyrer, M. Gingras, B. Herbold, A. Mueller- Solger, M. Nobriga, T. Sommer, and K. Souza. 2008. Pelagic organism decline progress report: 2007 synthesis of results. Interagency Ecological Program for the San Francisco Estuary, Technical Report 227, 86 p. Available at: http://www.water.ca.gov/iep/docs/pod/synthesis_report_031408.pdf.

Baxter, R., R. Breuer, L. Brown, L. Conrad, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, P. Hrodey, A. Mueller-Solger, T. Sommer,and K. Souza. 2010. Interagency Ecological Program 2010 Pelagic Organism Decline work plan and synthesis of results. Interagency Ecological Program for the San Francisco Estuary. 259 p. Available at: http://www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf.

Benli, A.C. K., G. Köksal, A. Özkul. 2008. Sublethal ammonia exposure of Nile tilaplia (*Oreochromis niloticus L.*): Effects on gill, liver and kidney histology. Chemosphere 72:1355–1358.

Bennett, W.A. 1995. Potential effects of exotic inland silversides on delta smelt. IEP Newsletter 8(1):4–6.

Bennett, W.A. 2005. Critical assessment of the delta smelt population in the San Francisco Estuary, California: San Francisco Estuary and Watershed Science 3(2). Available at: http://escholarship.org/uc/item/0725n5vk.

Bennett, W. A. 2011. The “big-mama” hypothesis: evaluating a subtle link between water export operations and the decline of delta smelt. Final Report submitted to: Mark Gowdy, State Water Resources Control Board, Sacramento, California. 11 p.

Bennett, W. A., and J. R. Burau. 2014. Riders on the Storm: selective tidal movements facilitate the spawning migration of threatened Delta Smelt in the San Francisco Estuary. Estuaries and Coasts DOI 10.1007/s12237-014-9877-3: 10 pages.

Bennett, W.A., and P.B. Moyle. 1996. Where have all the fishes gone? Interactive factors producing fish declines in the Sacramento San Joaquin Estuary. Pages 519–542, In: J.T. Hollibaugh, editor. San Francisco Bay: the ecosystem: Pacific Division American Association for the Advancement of Science, San Francisco, California.

Bennett, W.A., J.A. Hobbs, and S.J. Teh. 2008. Interplay of environmental forcing and growth-selective mortality in the poor year-class success of delta smelt in 2005. Final report: “fish otolith and condition study 2005”. Prepared for the POD Management Team of the Interagency Ecological Program for the San Francisco Estuary.

Bennett, W.A., W.J. Kimmerer, and J.R. Burau. 2002. Plasticity in vertical migration by native and exotic estuarine fishes in a dynamic low-salinity zone. Limnology and Oceanography 47:1496-1507.

Berec, L., E. Angulo, and F. Courchamp. 2006. Multiple Allee effects and population management. Trends in Ecology and Evolution 22:185–191.

Berenbaum, M.C. 1989. What is synergy? Pharmacological Reviews 41:93–141.

Beverton, R.J.H., and S.J. Holt. 1957. On the dynamics of exploited fish populations. Her Majesty’s Stationery Office, London.

Blumberg, A., P. Goodwin, E. Houde, S. Monismith, T. M. Powell, and C. Simenstad. 2010. Review of IEP and other Bay-Delta modeling focused on hydrodynamics and fish. Report by the IEP Science Advisory Group. Available at http://www.water.ca.gov/iep/docs/IEPModelWorkshopReview.pdf.

Boening, D.W. 2000. Ecological effects, transport, and fate of mercury: a general review. Chemosphere 40:1335–1351.

Bouley, P. and W.J. Kimmerer. 2006. Ecology of a highly abundant, introduced cyclopoid copepod in a temperate estuary. Marine Ecology Progress Series 324:219–228.

Brander, S.M. 2013. Chapter 5: Thinking outside the box: Assessing endocrine disruption in aquatic life. Pages 103-147 in S. Ahuja, editor. Monitoring Water Quality: Pollution assessment, analysis, and remediation. Elsevier B.V.

Brander, S.M., R.E. Connon, G. He, J.A. Hobbs, K.L. Smalling, S.J. The, J.W. White, I. Werner, M.S. Denison, and G.N. Cherr. 2013. From ‘omics to otoliths: Responses of an estuarine fish to endocrine disrupting compounds across biological scales. Plos One 8(9):1–15.

Brander, S.M., I. Werner, J.W. White, and L.A. Deanovic. 2009. Toxicity of a dissolved pyrethroid mixture to *Hyalella azteca* at environmentally relevant concentrations. Environmental Toxicology and Chemistry 28:1493–1499.

Brar, N.K., C. Waggoner, J.A. Reyes, R. Fairey, and K.M. Kelley. 2010. Evidence for thyroid endocrine disruption in wild fish in San Francisco Bay, California, USA. Relationships to contaminant exposures. Aquatic Toxicology 96:203-215.

Brook, W.A. and S.R. Carpenter. 2010. Interacting regime shifts in ecosystems: implication for early warnings. Ecological Monographs 80:353–367.

Brooks, M.L., E. Fleishman, L.R. Brown, P.W. Lehman, I. Werner, N. Scholz, C. Mitchelmore, J.R. Lovvorn, M.L. Johnson, D. Schlenk, S. van Drunick, J.I. Drever, D.M. Stoms, A.E. Parker, and R. Dugdale. 2012. Life histories, salinity zones, and sublethal contributions of contaminants to pelagic fish declines illustrated with a case study of San Francisco Estuary, California, USA. Estuaries and Coasts 35:603-621.

Brown, L., and J. May. 2006. Variation in spring nearshore resident fish species composition and life histories in the lower Sacramento-San Joaquin watershed and delta. San Francisco Estuary and Watershed Science 4(2). Available at: http://www.escholarship.org/uc/item/09j597dn.

Brown, L.R., and D. Michniuk. 2007. Littoral fish assemblages of the alien-dominated Sacramento–San Joaquin Delta, California, 1980–1983 and 2001–2003. Estuaries and Coasts 30:186–200.

Brown, L.R., and P.B. Moyle. 2005. Native fish communities of the Sacramento-San Joaquin watershed, California: a history of decline. American Fisheries Society Symposium 45:75–98.

Brown, L.R., R. Baxter, G. Castillo, L. Conrad, S. Culberson, G. Erickson, F. Feyrer, S. Fong, K. Gehrts, L. Grimaldo, B. Herbold, J. Kirsch, A. Mueller-Solger, S. Slater, K. Souza, and E. Van Nieuwenhuyse. 2014. Synthesis of studies in the fall low-salinity zone of the San Francisco Estuary, September–December 2011. U.S. Geological Survey Scientific Investigations Report 2014–5041. 136 p.

Brown, L.R., W.A. Bennett, R.W. Wagner, T. Morgan-King, N. Knowles, F. Feyrer, D.H. Schoellhamer, M.T. Stacey, M. Dettinger. 2013. Implications for future survival of delta smelt from four climate change scenarios for the Sacramento-San Joaquin Delta, California. Estuaries and Coasts 36:754–774.

Brown, R., S. Greene, P. Coulston and S. Barrow. 1996. An evaluation of the effectiveness of fish salvage operations at the intake to the California aqueduct, 1979–1993. Pages 497–518 in J.T. Hollibaugh, editor. San Francisco Bay: the ecosystem. Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.

Brown, T. 2009. Phytoplankton community composition: the rise of the flagellates. IEP Newsletter 22(3):20–28.

Bryant, M.E. and J.D. Arnold. 2007. Diets of age-0 striped bass in the San Francisco Estuary, 1973–2002. California Fish and Game 93(1):1–22.

Caissie, D. 2006. The thermal regime of rivers: a review. Freshwater Biology 51:1389-1406.

Capitán, J.A. and J.A. Cuesta. 2010. Catastrophic regime shifts in model ecological communities are true phase transitions. Journal of Statistical Mechanics: Theory and Experiment 2010:1-19.

Carlton, J.T., J.K. Thompson, L.E. Schemel, and F.H. Nichols. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis* I. Introduction and dispersal. Marine Ecology Progress Series 66:81–94.

Carr, E.R., P.M. Wingard, S.C. Yorty, M.C. Thompson, N.K. Jensen, and J. Roberson. 2007. Applying DPSIR to sustainable development. International Journal of Sustainable Development and World Ecology 14:543-555.

Castillo, G., J. Morinaka, J., Lindberg, R. Fujimura, B. Baskerville-Bridges, J. Hobbs, G. Tigan, and L. Ellison. 2012, Pre-screen loss and fish facility efficiency for delta smelt at the south Delta’s State Water Project, California. San Francisco Estuary and Watershed Science 10(4):1-23.

Casulli, V. and P. Zanoli. 2005. High resolution methods for multidimensional advection–diffusion problems in free-surface hydrodynamics. Ocean Modelling 10:137–151.

Casulli, V. and P. Zanolli. 2002. Semi-implicit numerical modeling of nonhydrostatic free-surface flows for environmental problems. Mathematical and Computer Modelling 36:1131–1149.

CDWR (California Department of Water Resources). 2007. California Central Valley unimpaired flow data Fourth Edition. Bay-Delta Office, California Department of Water Resources, Sacramento, CA. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/sjrf_spprtinfo/dwr_2007a.pdf.

Chapman, P.M., W.J. Adams, M.L. Brooks, C.G. Delos, S.N. Luoma, W.A. Maher, H.M. Ohlendorf, T.S. Pressser and D.P. Shaw 20101. Ecological assessment of selenium in the aquatic environment. SETAC Press, Pensacola.

Clark, K.W., M.D. Bowen, R.B. Mayfield, K.P. Zehfuss, J.D. Taplin, and C.H. Hanson. 2009. Quantification of pre-screen loss of juvenile steelhead in Clifton Court Forebay. State of California. The California Natural Resources Agency. Department of Water Resources. Fishery Improvements Section Bay-Delta Office. 119 pp.

Cloern, J.E., B.E. Cole, R.L.J. Wong, and A.A. Alpine. 1985. Temporal dynamics of estuarine phytoplankton: a case study of San Francisco Bay. Hydrobiologia 129:153-176.

Cloern, J.E. 1987. Turbidity as a control on phytoplankton biomass and productivity in estuaries. Continental Shelf Research 7:1367-1381.

Cloern, J.E., and A.D. Jassby. 2012. Drivers of change in estuarine-coastal ecosystems: Discoveries from four decades of study in San Francisco Bay. Reviews of Geophysics, 50, RG4001, doi:10.1029/2012RG000397.

Cloern, J.E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger, T.L. Morgan, D.H. Schoellhamer, M.T. Stacey, M. van der Wegen, R.W. Wagner, A.D. Jassby. 2011. Projected Evolution of California's San Francisco Bay-Delta-River System in a Century of Climate Change. PlosONE 6(9):e24465.

Coats, J.R., D.M. Symonik, S.P. Bradbury, S.D. Dyer, L.K. Timson, and G.J. Atchison. 1989. Toxicology of synthetic pyrethroids in aquatic systems: An overview. Environtal Toxicology and Chemistry 8:671–680.

Cohen, A.N. and J.T. Carlton. 1998. Accelerating invasion rate in a highly invaded estuary. Science 279:555-558.

Connon, R., J. Geist, J. Pfeiff, A.V. Loguinov, L.S. D'Abronzo, H. Wintz, C.D. Vulpe, and I. Werner. 2009. Linking mechanistic and behavioral responses to sublethal esfenvalerate exposure in the endangered delta smelt; *Hypomesus transpacificus* (Fam. Osmeridae). BMC Genomics 10:608.

Connon, R., L.A. Deanovic, E.B. Fritsch, L.S. D'Abronzo, I. Werner. 2011a. Sublethal responses to ammonia exposure in the endangered delta smelt; *Hypomesus transpacificus* (Fam Osmeridae). Aquatic Toxicology 105:369-377.

Connon, R.E., S. Beggel, L.S. D'Abronzo, J.P. Geist, J. Pfeiff, A.V. Loguinov, C.D. Vulpe, and I. Werner. 2011b. Linking molecular biomarkers with higher level condition indiciators to identify effects of copper exposures on the endangered delta smelt (*Hypomesus transpacificus*). Environemtal Toxicology and Chemistry 30:290-300.

Conomos, T.J., R.E. Smith, and J.W. Gartner. 1985. Environmental setting of San Francisco Bay. Hydrobiologia 129:1–12.

Contreras, D., V. Afentoulis, K. Hieb, R. Baxter, and S. Slater. 2011. 2010. Status and trends report for pelagic fishes of the upper San Francisco Estuary. IEP Newsletter 24(2):27-38.

Cornelissen, G., P.C.M. van Noort, and H.A.J. Govers. 1998. Mechanism of slow desorption of organic compounds from sediments: a study using model sorbents. Environmental Science and Technology 32:3124-3131.

Cummins, K.W., and J.C. Wuycheck. 1971. Caloric equivalents for investigations in ecological energetics. Mitteilungen-Internationale Vereinigung für Theoretische und Angewandte Limnologie 18:1-158.

Dambacher, J.M., H-K. Luh, H.W. Li and P.A. Rossignol. 2003. Qualitative stability and ambiguity in model ecosystems. American Naturalist 161:876-888.

Davis, N. D. 1993. Caloric content of oceanic zooplankton and fishes for studies of salmonid food habits and their ecologically related species. (NPAFC Doc.) FRI-UW-9312. Fisheries Research Institute, University of Washington, Seattle. 10 p.

Davis, J.A., L. Sim, and J.M. Chambers. 2010. Multiple stressors and regime shifts in shallow aquatic ecosystems in antipodean landscapes. Freshwater Biology 55:5-18.

Deblois, E.M. and W.C. Leggett. 1993. Impact of amphipod predation on the benthic eggs of marine fish: an analysis of Calliopius laeviusculus bioenergetic demands and predation on the eggs of a beach spawning osmeriid (*Mallotus villosus*). Marine Ecology Progress Series 93:205-216.

Dege, M., and L.R. Brown. 2004. Effect of outflow on spring and summertime distribution and abundance of larval and juvenile fishes in the upper San Francisco Estuary. American Fisheries Society Symposium 39:49–65.

Dettinger, M.D., 2011, Climate change, atmospheric rivers and floods in California—A multimodel analysis of storm frequency and magnitude changes. Journal of American Water Resources Association 47:514–523.

Dettinger, M.D. and B.L. Ingram. 2013. The coming megastorms. Scientific American 308:64–71.

DiGennaro, B., D. Reed, C. Swanson, L. Hastings, Z. Hymanson, M. Healey, et al.,2012. Using conceptual models in ecosystem restoration decision making: An example from the Sacramento-San Joaquin River Delta, California. San Francisco Estuary and Watershed Science, 10(3). Retrieved from: http://www.escholarship.org/uc/item/3j95x7vt.

Doremus, H. 2009. CALFED and the quest for optimal institutional fragmentation. Environmental Science and Policy 12:729–732.

Drexler, J.Z., J.B. Paces, C.N. Alpers, L. Windham-Meyers, L. Neymark, and H.E. Taylor. 2014. 234U/238U and δ87Sr in peat as tracers of paleosalinity in the Sacramento-San Joaquin Delta of California, USA. Applied Geochemistry 40:164–179.

DSC (Delta Stewardship Council). 2013. The Delta Plan. Delta Stewardship Council, Sacramento, CA. Available at: http://deltacouncil.ca.gov/delta-plan-0.

DSP (Delta Science Program). 2013. Delta Science Plan. Delta Science Program, Delta Stewardship Council, Sacramento, CA. Available at: http://deltacouncil.ca.gov/sites/default/files/documents/files/Delta-Science-Plan-12-30-2013.pdf.

Dugdale, R.C., F.P. Wilkerson, and A.E. Parker. 2013. A biogeochemical model of phytoplankton productivity in an urbanestuary: The importance of ammonium and freshwater flow. Ecological Modelling 263:291–307.

Dugdale, R.C., F.P. Wilkerson, V.E. Hogue, and A. Marchi. 2007. The role of ammonium and nitrate in spring bloom development in San Francisco Bay. Estuarine, Coastal, and Shelf Science 73:17–29.

Dugdale, R., F. Wilkerson, A. Parker, A. Marchi, and K. Taberski. 2012. River flow and ammonium discharge determine spring phytoplankton blooms in an urbanized estuary. Estuarine, Coastal and Shelf Science 115:187–199.

Durand, J.R. 2010. Determinants of seasonal abundance of key zooplankton of the San Francisco Estuary. M.S. Ecology and Systematics, San Francisco State University, San Francisco. 55 pp.

Enright, C., and S. Culberson. 2009. Salinity trends, variability, and control in the northern reach of the San Francisco Estuary. San Francisco Estuary and Watershed Science 7(2). Available at: http://escholarship.org/uc/item/0d52737.t

Enright, C., S.D. Culberson, and J.R. Burau. 2013. Broad timescale forcing and geomorphic mediation of tidal marsh flow and temperature dynamics. Estuaries and Coasts 36:1319–1339.

Erkkila, L.F., J.W. Moffett, O.B. Cope, B.R. Smith and R.S. Nielson. 1950. Sacramento-San Joaquin Delta fishery resources: Effects of Tracy pumping plant and Delta cross channel. U.S. Fish and Wildlife Service Special Scientific Report, Fisheries 56:1–109.

Essington, T.E., and S. Hansson. 2004. Predator-dependent functional responses and interaction strengths in a natural food web. Canadian Journal of Fisheries and Aquatic Sciences 61:2215-2226.

Estuarine Ecology Team. 1997. Assessment of the likely mechanisms underlying the “Fish-X2” relationships. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 52.

Ewing, R.D. 1999. Diminishing returns: Salmon decline and pesticides. Funded by the Oregon Pesticide Education Network, Biotech Research and Consulting, Inc., Corvallis, OR. 55 pp.

Falconer, D.S., and T.F.C. Mackay. 1996. Introduction to quantitative genetics. 4th ed. New York, Longman.

Ferrari, M.C.O., L. Ranåker, K.L. Weinersmith, M.J. Young, A. Sih, and J.L. Conrad. 2014. Effects of turbidity and an invasive waterweed on predation by introduced largemouth bass. Environmental Biology of Fishes 97:79-90.

Feyrer, F. and M. Healey. 2003. Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta. Environmental Biology of Fishes 66:123-132.

Feyrer, F., B. Herbold, S.A. Matern, and P.B. Moyle. 2003. Dietary shifts in a stressed fish assemblage: Consequences of a bivalve invasion in the San Francisco Estuary. Environmental Biology of Fishes 67:277–288.

Feyrer, F., K. Newman, M. Nobriga, and T. Sommer. 2010. Modeling the effects of future freshwater flow on the abiotic habitat of an imperiled estuarine fish. Estuaries and Coasts 34:120–128.

Feyrer, F., M.L. Nobriga, and T.R. Sommer. 2007. Multi-decadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA. Canadian Journal of Fisheries and Aquatic Sciences 64:723–734.

Feyrer F., D. Portz, D. Odum, K.B. Newman, T. Sommer, D. Contreras, R. Baxter, S.B. Slater, D. Sereno, and E. Van Nieuwenhuyse. 2013. SmeltCam: Underwater video codend for trawled nets with an application to the distribution of the imperiled Delta Smelt. PLoS ONE 8(7): e67829. doi: 10.1371/journal.pone.0067829

Feyrer, F, T. Sommer, and W. Harrell. 2006. Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California. North American Journal of Fisheries Management 26:408-417.

Fisch, K.M., J.M. Henderson, R.S. Burton, and B. May. 2011. Population genetics and conservation implications for the endangered delta smelt in the San Francisco Bay-Delta. Conservation Genetics 12:1421–1434.

Fischenich, C. 2008. The application of conceptual models to ecosystem restoration. EBA Technical Notes Collection, ERDC/EBA TN-08-1. U.S. Army Engineer Research and Development Center, Vicksburg, MS. www.wes.army.mil/el/emrrp.

Fish, M., D. Contreras, V. Afentoulis, J. Messineo, and K. Hieb. 2009. 2008 Fishes annual status and trends report for the San Francisco Estuary. IEP Newsletter 22(2):17–36.FLaSH Panel (Fall Low Salinity Habitat (FLaSH) Study Review Panel). 2012. Fall low salinity habitat (FLaSH) study synthesis – Year one of the Delta Fall Outflow Adaptive Management Plan, review panel summary report. Delta Science Program, Sacramento, CA. available at: http://deltacouncil.ca.gov/sites/default/files/documents/files/FallOutflowReviewPanelSummaryReport_Final_9_11.pdf.

Forsgren, K. L., N. Riar, D. Schlenk. 2013. The effects of the pyrethroid insecticide, bifenthrin, on steroid hormone levels and gonadal development of steelhead (*Oncorhynchus mykiss*) under hyper saline conditions. General and Comparative Endocrinology 186:101–107.

Fortuin, K.P.J., C.S.A. (Kris) van Koppen and R. Leemans. 2011. The value of conceptual models in coping with complexity and interdisciplinarity in environmental sciences education. BioScience 61:802–814.

Fox, J.W. 2006. Current food web models cannot explain the overall topological structure of observed food webs. Oikos 115:97-109.

Fuiman, L.A. 1983. Growth gradients in fish larvae. Journal of Fish Biology 23:117–123.

Fuller, H. 2012. Benthic monitoring, 2011. IEP Newsletter 25(2):5–10.

Gaines, S., S. Luoma, S. Monismith, S. Simenstad, and S. Sogard. 2006. IEP Delta Smelt review - Science Advisory Group Report. IEP Science Advisory Group, Sacramento, CA. Available at: http://www.water.ca.gov/iep/docs/SAG_Report-IEP_Delta_Smelt_Review.pdf.

Ganju, N.K., D.H. Schoellhamer, M.C. Murrell, J.W. Gartner, and S.A. Wright. 2007. Constancy of the relation between floc size and density in San Francisco Bay. Pages 75-91 in J.P.-Y. Maa, L.P. Sanford, and D.H. Schoellhamer, editors. Estuarine and Coastal Fine Sediments Dynamics. Elsevier Science B.V.

Gascoigne, J.C. and R.N. Lipcius. 2004. Allee effects driven by predation. Journal of Applied Ecology 41:801-810.

Gascoigne, J., L. Berec, S. Gregory, and F. Courchamp. 2009. Dangerously few liaisons: a review of mate-finding Allee effects. Population Ecology 51:355–372.

Gentile, J.H., M.A. Harwell, W. Cropper Jr., C.C. Harwell,D. DeAngelis, S. Davis, J.C. Ogden, and D. Lirman. 2001. Ecological conceptual models: a framework and case study on ecosystem management for South Florida sustainability. The Science of the Total Environment 274:231–253.

Ger, K.A., P. Arneson, C.R. Goldman, and S.J. The. 2010b. Species specific differences in the ingestion of *Microcystis* cells by the calanoid copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi*: Journal of Plankton Research 32:1479–1484.

Ger, K.A., S.J. Teh, D.V. Baxa, S. Lesmeister, and C.R. Goldman. 2010a. The effects of dietary *Microcystis aeruginosa* and microcystin on the copepods of the upper San Francisco Estuary: Freshwater Biology 55:1548–1559.

Ger, K.A., S.J. Teh, and C.R. Goldman. 2009, Microcystin-LR toxicity on dominant copepods *Eurytemora affinis* and *Pseudodiaptomus forbesi* of the upper San Francisco Estuary: Science of the Total Environment 407:4852–4857.

Gifford, S.M., G. Rollwagen-Bollens, S.M. Bollens. 2007. Mesozooplankton omnivory in the upper San Francisco Estuary. Marine Ecological Progress Series 348:33–46.

Gingras, M. 1997. Mark/recapture experiments at Clifton Court Forebay to estimate pre-screening loss to juvenile fishes: 1976–1993. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 55.

Gingras, M., and M. McGee. 1997. A telemetry study of striped bass emigration from Clifton Court Forebay: Implications for predator enumeration and control. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 54.

Gleason, E.C. and J. Adib-Samii. 2007. 20mm Metadata. Available at: ftp://ftp.dfg.ca.gov/.

Gleason, T.R., and D.A. Bengtson. 1996. Growth, survival and size-selective predation mortality of larval and juvenile inland silversides, *Menidia beryllina*. Journal of Experimental Marine Biology and Ecology 199:165-177.

Glibert, P.M. 2012. Ecological stoichiometry and its implications for aquatic ecosystem sustainability: Current Opinion in Environmental Sustainability 4:272–277.

Glibert, P.M., D. Fullerton, J.M. Burkholder, J.C. Cornwell, and T.M. Kana. 2011. Ecological stoichiometry, biogeochemical cycling, invasive species, and aquatic food webs: San Francisco Estuary and comparative systems. Reviews in Fisheries Science 19:358–417.

Gould, A.L. and W.J. Kimmerer. 2010. Development, growth, and reproduction of the cyclopoid copepod *Limnoithona tetraspina* in the upper San Francisco Estuary. Marine Ecology Progress Series 412:163–177.

Greco, W.R., G. Bravo, and J.C. Parsons. 1995. The search for synergy: a critical review from a response surface perspective. Pharmacological Reviews 47:332–385.

Greenberg, J.A., E.L. Hestir, D. Riano, G.J. Scheer, and S.L. Ustin. 2012. Using LiDAR data analysis to estimate changes in insolation under large-scale riparian deforestation. Journal of the American Water Resources Association 48:939–948.

Greenfield, B.K., S.J. The, J.R.M. Ross, J. Hunt, G. Zhang, J. A. Davis, G. Ichikawa, D. Crane, S.S.O. Hung, D. Deng, F. Teh, and P.G. Green. 2008. Contaminant concentrations and histopathological effects in Sacramento Splittail (*Pogonichthys macrolepidotus*). Archives of Environmental Contaminants and Toxicology 55:270-281.

Gregory, R.S., and C.D. Levings. 1998. Turbidity reduces predation on migrating juvenile Pacific salmon. Transactions of the American Fisheries Society 127:275-285.

Gregory, S.D., C.J.A. Bradshaw, B.W.Brook, and F. Courchamp. 2010. Limited evidence for the demographic Allee effect from numerous species across taxa. Ecology 91:2151–2161.

Grimaldo, L.F., R.E. Miller, C.M. Peregrin, and Z.P. Hymanson. 2004. Spatial and temporal distribution of native and alien ichthyoplankton in three habitat types of the Sacramento-San Joaquin Delta. American Fisheries Society Symposium 39:81–96.

Grimaldo, L., R.E. Miller, C.M. Peregrin, and Z. Hymanson. 2012. Fish assemblages in reference and restored tidal freshwater marshes of the San Francisco Estuary. San Francisco Estuary and Watershed Science, 10(1). Available at: http://escholarship.org/uc/item/52t3x0hq.

Grimaldo, L.F., T. Sommer, N. Van Ark, G. Jones, E. Holland, P. Moyle, B. Herbold, and P. Smith. 2009. Factors affecting fish entrainment into massive water diversions in a tidal freshwater estuary: Can fish losses be managed? North American Journal of Fisheries Management 29:1253–1270.

Hallfredsson, E., and T. Pedersen. 2009. Effects of predation from juvenile herring (*Clupea harengus*) on mortality rates of capelin (*Mallotus villosus*) larvae. Canadian Journal of Fisheries and Aquatic Sciences 66:1693–1706.

Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, and B. Thompson. 2011. Managing California's water: From conflict to reconciliation. Public Policy Institute of California. http://www.ppic.org/main/publication.asp?i=944.

Hartman, K.J. and S.B. Brandt. 1995. Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. Canadian Journal of Fisheries and Aquatic Science 52:1647–1666.

Harwood, A.D., J. You, and M.J. Lydy. 2009. Temperature as a toxicity identification evaluation tool for pyrethroid insecticides: Toxicokinetic confirmation. Environmental Toxicology and Chemistry 28:1051–1058.

Hasenbein, M., L.M. Komoroske, R.E. Connon, J. Geist, and N.A. Fangue. 2013. Turbidity and salinity affect feeding performance and physiological stress in the endangered delta smelt. Integrative Comparative Biology 53:620–634.

Hasenbein, M. I. Werner, L.A. Deanovic, J. Geist, E.B. Fritsch, A. Javidmehr, C. Foe, N.A. Fangue, and R.E. Connon. 2013. Transcriptomic profiling permits the identification of pollutant sources and effects in ambient water samples. Science of the Total Environment 468–469:668–698.

Hauser, L., G.J. Adcock, P.J. Smith, J.H. Bernal Ramírez, and G.R. Carvalho. 2002. Loss of microsatellite diversity and low effective population size in an overexploited population of New Zealand snapper (*Pagrus auratus*). Proceedings of the National Academy of Sciences of the United States of America 99:11742–11747.

Haydon, D. 1994. Pivotal assumptions determining the relationship between stability and complexity: an analytical synthesis of the stability-complexity debate. The American Naturalist 144:14–29.

Hazel, C.R. and D.W. Kelley. 1966. Zoobenthos of the Sacramento-San Joaquin Delta. Pages 113–133 in D.W. Kelley, editor, Ecological studies of the Sacramento-San Joaquin Estuary. California Fish and Game, Fish Bulletin 133.

Healey, M.C., M.D. Dettinger, and R.B. Norgaard, editors. 2008. The state of Bay-Delta science, 2008. CALFED Science Program, Sacramento, CA. 174 pp.

Herbold, B., D.M. Baltz, L. Brown, R. Grossinger, W. Kimmerer, P. Lehman, C.S. Simenstad, C. Wilcox, and M. Nobriga. 2014. The role of tidal marsh restoration in fish management in the San Francisco Estuary. San Francisco Estuary and Watershed Science 12(1). Available at: http://escholarship.org/uc/item/1147j4nz.

Herrgesell, P.A. 2013. A historical perspective of the Interagency Ecological Program: Bridging multi-agency studies into ecological understanding of the Sacramento-San Joaquin Delta and Estuary for 40 years. Report to IEP. 184 pp. Available at: http://www.water.ca.gov/iep/docs/Herrgesell_IEP_Report_FINAL.pdf.

Heubach W. [ca. 1973]. Further observation of the densities of king salmon, striped bass, and white catfish collected at the federal and State Fish Facilities. California Department of Fish and Game, Stockton (CA). 11 p.

Hirose, T., and K. Kawaguchi. 1998. Spawning ecology of Japanese surf smelt, *Hypomesus pretiosus japonicus* (Osmeridae), in Otsuchi Bay, northeastern Japan. Environmental Biology of Fishes 52:213–223.

Houde, E.D. 1987. Fish early life dynamics and recruitment variability. American Fisheries Society Symposium 2:17–29.

Houde, E.D. 1989. Comparative growth, mortality, and energetics of marine fish larvae: temperature and implied latitudinal effects. Fishery Bulletin 87:471–495.

Hennessy, A. 2010. Zooplankton monitoring 2009. IEP Newsletter 23(2):15–22.

Hennessy, A. 2011. Zooplankton monitoring 2010. IEP Newsletter 24(2):20–27.

Hennessy, A., and T. Enderlein. 2013. Zooplankton monitoring 2011. IEP Newsletter 26(1):23–30.

Hestir, E.L. 2010. Trends in estuarine water quality and submerged aquatic vegetation invasion. Ph.D. Dissertation. University of California, Davis, CA

Hestir, E.L., D.H. Schoellhamer, T. Morgan-King, S.L. Ustin. 2013. A step decrease in sediment concentration in a highly modified tidal river delta following the 1983 El Niño floods. Marine Geology 345:304–313.

Hieb, K., M. Bryant, M. Dege, T. Greiner, K. Souza and S. Slater. 2005. Fishes in the San Francisco Estuary, 2004 Status and Trends. IEP Newsletter 18(2):19–36.

Hilborn, R., and C. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty, 1st edition. Chapman and Hall, New York.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe viewed in light of biological research. Rapports et Procès-verbaux des Réunions Conseil international pour l'Exploration de la Mer 19:1-228

Hobbs, J.A., W.A. Bennett, and J.E. Burton. 2006. Assessing nursery habitat quality for native smelts (Osmeridae) in the low-salinity zone of the San Francisco estuary. Journal of Fish Biology 69:907–922.

Hobbs, J.A., W.A. Bennett, J. Burton, and M. Gras. 2007. Classification of larval and adult delta smelt to nursery areas by use of trace elemental fingerprinting. Transactions of the American Fisheries Society 136:518–527.

Holling, C.S. 1978. Adaptive environmental assessment and management. Wiley, Chichester, UK.

Honey, K., R. Baxter, Z. Hymanson, T. Sommer, M. Gingras, and P. Cadrett. 2004. IEP long-term fish monitoring program element review. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 78.

Hosack, G.R., H.W. Li and P.A Rossignol. 2009. Sensitivity to model structure. Ecological Modeling 220:1054–1062.

Hunter, J. R. 1980. The feeding behavior and ecology of marine fish larvae. Pages 287-330 in J.E. Bardach, J.J. Magnuson, R.C. May, and J M. Reinhart, editors. Fish behavior and its use in the capture and culture of fishes, volume ICLARM Conference Proceedings 5. International Center for Living Aquatic Resources Management, Manila, Philippines. 512 p.

Hutchings, J.A. 2013. Renaissance of a caveat: Allee effects in marine fish. ICES Journal of Marine Science, doi:10.1093/icesjms/fst179.

Hutchings, J.A., C. Minto, D. Ricard, J.K. Baum, and O.P. Jensen. 2010. Trends in the abundance of marine fishes. Canadian Journal of Fisheries and Aquatic Sciences 67:1205–1210.

IEP (Interagency Ecological Program for the San Francisco Estuary). 2005. Interagency Ecological Program 2005 Work plan to evaluate the decline of pelagic species in the upper San Francisco Estuary. Available at: http://www.science.calwater.ca.gov/pdf/workshops/POD/2005_IEP-POD_Workplan_070105.pdf.

Ingram, B.L. and F. Malamud-Roam. 2012. The West without water. University of California Press. 289 p.

Jackson, L.J., A.S. Trebitz, K.L. Cottingham. 2000. An introduction to the practice of ecological modeling. BioScience 50:694–706.

Jassby, A.D. 2008. Phytoplankton in the upper San Francisco Estuary: recent biomass trends, their causes and their trophic significance. San Francisco Estuary and Watershed Science 6(1). Available at http://www.escholarship.org/uc/item/71h077r1.

Jassby, A.D., and E.E. Van Nieuwenhuyse. 2005. Low dissolved oxygen in an estuarine channel (San Joaquin River, California): Mechanisms and models based on long-term time Series. San Francisco Estuary and Watershed Science 3(2). Available at: http://escholarship.org/uc/item/0tb0f19p.

Jassby, A.D., J.E. Cloern, and B.E. Cole. 2002. Annual primary production: patterns and mechanisms of change in a nutrient-rich tidal ecosystem. Limnology and Oceanography 47:698–712.

Jassby, A.D., W.J. Kimmerer, S.G. Monismith, C. Armor, J.E. Cloern, T.M. Powell, J.R. Schubel, and T.J. Vendlinski. 1995. Isohaline position as a habitat indicator for estuarine populations. Ecological Applications 5:272–289.

Jassby, A.D., A.B. Muller-Solger, and M. Vayssières. 2005. Subregions of the Sacramento-San Joaquin Delta: Identification and use. IEP Newsletter 18(2):46–55.

Johnson, M.L., I. Werner, S. Teh, and F. Loge 2010. Evaluation of chemical, toxicological, and histopathological data to determine their role in the pelagic organism decline. University of California, Davis, Final report to the California State Water Resources Control Board and Central Valley Regional Water Quality Control Board.

Johnson, J.H. and D.S. Dropkin. 1992. Predation on recently released larval American Shad in the Susquehanna River Basin. North American Journal of Fisheries Management 12:504–508.

Jordan, J., A. Zare, L.J. Jackson, H.R. Habibi, and A.M Weljie. 2012. Environmental contaminant mixtures at ambient concentrations invoke a metabolic stress response in goldfish not predicted from exposure to individual compounds alone. Journal of Proteome Research 11:1133–1143.

Jung, S. and E.D. Houde. 2004. Recruitment and spawning-stock biomass distribution of bay anchovy (*Anchoa mitchilli*) in Chesapeake Bay. Fishery Bulletin 102:63–77.

Junges C.M., R.C. Lajmanovich, P.M. Peltzer, A.M. Attademo, and A. Basso. 2010. Predator-prey interactions between *Synbranchus marmoratus* (Teleostei: Synbranchidae) and *Hypsiboas pulchellus* tadpoles (Amphibia: Hylidae): importance of lateral line in nocturnal predation and effects of fenitrothion exposure. Chemosphere 81:1233–1238.

Kano. R.M. 1990. Occurrence and abundance of predator fish in Clifton Court Forebay, California. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 24.

Keith, D.M. and J.A. Hutchings. 2012. Population dynamics of marine fishes at low abundance. Canadian Journal of Fisheries and Aquatic Sciences 69:1150–1163.

Khan, M.Z. and F.C.P. Law. 2005. Adverse effects of pesticides and related chemicals on enzyme and hormone systems of fish, amphibians and reptiles: a review. Proceedings of the Pakistan Academy of Science 42:315–323.

Kimmerer, W. J. 2002a. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. Estuaries 25:1275–1290.

Kimmerer, W.J. 2002b. Effects of freshwater flow on abundance of estuarine organisms: physical effects or trophic linkages. Marine Ecology Progress Series 243:39–55.

Kimmerer, W.J. 2004. Open-water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science 2. Available at: http://escholarship.org/uc/item/9bp499mv.

Kimmerer, W.J. 2006. Response of anchovies dampens effects of the invasive bivalve *Corbula amurensis* on the San Francisco Estuary foodweb. Marine Ecology Progress Series 324:207–218.

Kimmerer, W.J. 2008. Losses of Sacramento River Chinook salmon and delta smelt to entrainment in water diversions in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. 6(2). Available at: http://www.escholarship.org/uc/item/7v92h6fs.

Kimmerer, W.J. 2011. Modeling delta smelt losses at the South Delta Export Facilities. San Francisco Estuary and Watershed Science, 9(1). Available at: http://www.escholarship.org/uc/item/0rd2n5vb.

Kimmerer, W. and M. Nobriga. 2005. Development and evaluation of bootstrapped confidence intervals for the IEP fish abundance indices. IEP Newsletter 18(2):68–75.

Kimmerer, W.J., and M.L. Nobriga. 2008. Investigating particle transport and fate in the Sacramento-San Joaquin Delta using particle tracking model. San Francisco Estuary and Watershed Science 6(1). Available at: http://escholarship.org/uc/item/547917gn.

Kimmerer, W.J., and J.J. Orsi. 1996. Changes in the zooplankton of the San Francisco Bay estuary since the introduction of the clam *Potamocorbula amurensis*. Pages 403–423 in J.T. Hollibaugh, editor. San Francisco Bay: the ecosystem: Pacific Division American Association for the Advancement of Science, San Francisco, California.

Kimmerer, W.J., J.H. Cowan, Jr., L.W. Miller, and K.A. Rose. 2000. Analysis of an estuarine striped bass (*Morone saxatilis*) population: influence of density-dependent mortality between metamorphosis and recruitment. Canadian Journal of Fisheries and Aquatic Sciences 57:478–486.

Kimmerer, W.J., N. Ferm, M.H. Nicolini, and C. Penalva. 2005. Chronic food limitation of egg production in populations of copepods of the genus *Acartia* in the San Francisco Estuary. Estuaries 28:541–550.

Kimmerer, W.J., E. Gartside, and J.J. Orsi. 1994. Predation by an introduced clam as the likely cause of substantial declines in zooplankton of San Francisco Bay. Marine Ecology Progress Series 113:81–93.

Kimmerer, W.J., E.S. Gross, and M.L. MacWilliams. 2009. Is the response of estuarine nekton to freshwater flow in the San Francisco Estuary explained by variation in habitat volume? Estuaries and Coasts 32:375–389.

Kimmerer, W.J. M.L. MacWilliams, and E. Gross. 2013. Variation of fish habitat and extent of the low-salinity zone with freshwater flow in the San Francisco Estuary. San Francisco Estuary and Watershed Science, 11(4). Available at: http://escholarship.org/uc/item/3pz7x1x8.

Kimmerer, W., J. Stillman, and L. Sullivan. 2011. Zooplankton and clam analyses in support of the Interagency Ecological Program's Work Plan on Pelagic Organism Declines (POD). Final report to the POD management team. Romberg Tiburon Center for Environmental Studies, San Francisco State University.

Kitchell, J.F., L.A. Eby, X. He, D.E. Schindler, and R. A. Wright. 1994. Predator-prey dynamics in an ecosystem context. Journal of Fish Biology 45, Issue Supplement sA:209–226.

Kolpin, D.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.B. Barber, and H.T. Buxton. 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. Streams 1999-2000: A national reconnaissance. Environmental Science and Toxicology 36:1201-1211.

Komoroske, L.M., R.E. Connon, J. Lindberg, B.S. Cheng, G. Castillo, M. Hasenbein, N.A. Fangue. 2014. Ontogeny influences sensitivity to climate change stressors in an endangered fish. Conservation Physiology 2: doi:10.1093/conphys/cou008.

Kuivila, K. M., and C.G. Foe. 1995. Concentrations, transport and biological effects of dormant spray pesticides in the San Francisco Estuary, California. Environmental Toxicology and Chemistry 14:1141–1150.

Kuivila, K.M., and M. Hladik. 2008. Understanding the occurrence and transport of current-use pesticides in the San Francisco Estuary Watershed. San Francisco Estuary and Watershed Science 6(3). Available at: http://www.escholarship.org/uc/item/06n8b36k.

Kuivila, K. and G.E. Moon. 2004. Potential exposure of larval and juvenile delta smelt to dissolved pesticides in the Sacramento–San Joaquin Delta, California. American Fisheries Society Symposium 39:229–241.

Kuparinen, A., D.M. Keith and J.A. Hutchings. 2014. Allee effect and the uncertainty of population recovery. Conservation Biology 28:790-798.

Laprise, R., and J.J. Dodson. 1989. Ontogeny and importance of tidal vertical migrations in the retention of larval smelt *Osmerus mordax* in a well-mixed estuary. Marine Ecology Progress Series 55:101-111.

Lavado, R., J.M Rimoldi, and D. Schlenk. 2009. Mechanisms of fenthion activation in rainbow trout (*Oncoryhynchus mykiss*) acclimated to hypersaline environments. Toxicology and Applied Pharmacology 235: 143-152.

Leggett, W. C., and E. Deblois. 1994. Recruitment in marine fishes: is it regulated by starvation and predation in the egg and larval stages? Netherland Journal of Sea Research 32:119-134.

Lehman, P.W., G. Boyer, C. Hall, S. Waller, and K. Gehrts. 2005. Distribution and toxicity of a new colonial *Microcystis aeruginosa* bloom in the San Francisco Bay Estuary, California. Hydrobiologia 541:87–99.

Lehman, P.W., C. Kendall, M. A. Guerin, M. B. Young, S. R. Silva, G. L. Boyer, and S. J. Teh. 2014. Characterization of the *Microcystis* bloom and its nitrogen supply in San Francisco Estuary using stable isotopes. Estuaries and Coasts. DOI: 10.1007/s12237-014-9811-8

Lehman, P.W., K. Marr, G.L. Boyer, S. Acuna, and S J. Teh. 2013. Long-term trends and causal factors associated with *Microcystis* abundance and toxicity in San Francisco Estuary and implications for climate change impacts. Hydrobiologia 718:141-158.

Lehman, P.W., S.J. Teh, G.L. Boyer, M.L. Nobriga, E. Bass, and C. Hogle. 2010. Initial impacts of *Microcystis aeruginosa* blooms on the aquatic food web in the San Francisco Estuary. Hydrobiologia 637:229–248.

Levins, R. 1974. The qualitative analysis of partially specified systems. Annals of the New York Academy of Sciences 231:123-138.

Levins, R. 1975. Evolution in communities near equilibrium. Pages 16-50 in M. L. Cody and J. M. Diamond, editors. Ecology and Evolution of Communities. The Belknap Press of Harvard University Press, Cambridge, Massachusetts.

Liang, T.T., and E.P. Lichtenstein. 1974. Synergism of insecticides by herbicides: effect of environmental factors. Science 4169:1128–1130.

Liermann, M., and R. Hilborn. 1997. Depensation in fish stocks: a hierarchic Bayesian meta-analysis. Canadian Journal Fisheries and Aquatic Sciences 54:1976-1984.

Light, T., T. Grosholz, and P. Moyle. 2005. Delta ecological survey (Phase I): Non-indigenous aquatic species in the Sacramento–San Joaquin Delta, a literature review. Final Report for Agreement # DCN #113322J011 submitted to U.S. Fish and Wildlife Service. Stockton, CA, 35 p.

Lindberg, J.C., G. Tigan, L. Ellison, T. Rettinghouse, M.M. Nagel and K.M. Fisch. 2013. Aquaculture methods for a genetically managed population of endangered delta smelt. North American Journal of Aquaculture 75:186-196.

Liu, W.-C., H.-W. Chen, F. Jordan, W..H. Lin, and C.W. Liu. 2010. Quantifying the interaction structure and the topological importance of species in food webs: A signed digraph approach. Journal of Theoretical Biology 267:355–362.

Loboschefsky, E., G. Benigno, T. Sommer, K. Rose, T. Ginn, and A. Massoudieh. 2012. Individual-level and population-level historical prey demand of San Francisco Estuary striped bass using a bioenergetics model. San Francisco Estuary and Watershed Science 10(1). Available at: http://escholarship.org/uc/item/1c788451.

Lopez, C.B., J.E. Cloern, T.S. Schraga, A.J. Little, L.V. Lucas, J.K. Thompson, and J.R. Burau. 2006. Ecological values of shallow-water habitats: Implications for restoration of disturbed ecosystems. Ecosystems 9:422–440.

Lott, J. 1998. Feeding habits of juvenile and adult delta smelt from the Sacramento-San Joaquin River Estuary. IEP Newsletter 11(1):14–19.

Lotze, H.K., H.S. Lenihan, B.J. Bourque, R.H. Bradbury, R.G. Cooke, M.C. Kay, S.M. Kidwell, M.X. Kirby, C.H. Peterson, and J.B.C. Jackson. 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312:1806–1809.

Lucas, L.V., and J.K. Thompson. 2012. Changing restoration rules: Exotic bivalves interact with residence time and depth to control phytoplankton productivity. Ecosphere 3:117. Available at http://dx.doi.org/10.1890/ES12-00251.1.

Lucas, L.V., J.E. Cloern, J.K. Thompson, and N.E. Monsen. 2002. Functional variability of habitats within the Sacramento-San Joaquin Delta: Restoration implications. Ecological Applications 12:1528–1547.

Lucas, L.V., J.R. Koseff, S.G. Monismith, and J.K. Thompson. 2009a. Shallow water processes govern system–wide phytoplankton bloom dynamics - A modeling study. Journal of Marine Systems 75:70–86.

Lucas, L.V., J.K. Thompson, and L.R. Brown. 2009b. Why are diverse relationships observed between phytoplankton biomass and transport time? Limnology and Oceanography 54:381–390.

Lucas, M.C. and E. Bara 2001 Migration of freshwater fishes. Iowa State Press, Ames.

Mac Nally, R., J.R. Thompson, W.J. Kimmerer, F. Feyrer, K.B. Newman, A. Sih, W.A. Bennett, L. Brown, E. Fleishman, S.D. Culberson, G. Castillo. 2010. An analysis of pelagic species decline in the upper San Francisco Estuary using multivariate autoregressive modeling (MAR). Ecological Applications 20:1417–1430.

MacWilliams, M.L., and E.S. Gross. 2013. Hydrodynamic simulation of circulation and residence time in Clifton Court Forebay. San Francisco Estuary and Watershed Science, 11(2). Available at: http://www.escholarship.org/uc/item/4q82g2bz.

Mager, R.C., S.I. Doroshov, J.P. Van Eenennaam, and R.L. Brown. 2004. Early life stages of delta smelt. American Fisheries Society Symposium 39:169-180.

Manly, B.J.F. and M.A. Chotkowski. 2006. Two new methods for regime change analysis. Archiv für Hydrobiologie 167:593–607.

Marine, K.R., and J.J. Cech, Jr. 2004. Effects of high water temperature on growth, smoltification, and predator avoidance in juvenile Sacramento River Chinook salmon. North American Journal of Fisheries Management 24:198-210.

Martin, K.L.M. and D.L. Swiderski. 2001. Beach spawning in fishes: phylogenetic test of hypotheses. American Zoology 41:526-537.

Massoudieh A., E. Loboschefsky, T. Sommer, T. Ginn, K. Rose, F. J. Loge. 2011. Spatio-temporal modeling of Striped-Bass egg and larvae movement and fate in Sacramento River Delta. Ecological Modeling 222:3513-3523.

Maunder, M.N., and R.B. Deriso. 2011. A state–space multistage life cycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (*Hyposmesus transpacificus*). Canadian Journal of Fisheries and Aquatic Sciences 68:1285–1306.

May, R.M. 1972. Will a large complex system be stable? Nature 238:413-414.

McKenzie, D.J., A. Shingles, G. Claireaux, P. Domenici. 2008. Sublethal concentrations of ammonia impair performance of the teleost fast-start escape response. Physiological and Biochemical Zoology 82:353-362.

McGann M, L. Erikson, E. Wan, C. Powell II, and R.F. Maddocks. 2013. Distribution of biologic, anthropogenic, and volcanic constituents as a proxy for sediment transport in the San Francisco Bay coastal cystem. Marine Geology 345:113–142.

McManus, G.B., J.K. York and W.J. Kimmerer. 2008. Microzooplankton dynamics in the low salinity zone of the San Francisco Estuary. Verhandlungen des Internationalen Verein Limnologie 30:198–202.

Meng, L. and J.J. Orsi. 1991. Selective predation by larval striped bass on native and introduced copepods. Transactions of the Americam Fisheries Society 120:187–192.

Merz, J.E., S. Hamilton, P.S. Bergman, and B. Cavallo. 2011. Spatial perspective for delta smelt: a summary of contemporary survey data. California Fish and Game 97(4):164–189.

Millennium Ecosystem Assessment. 2005. Ecosystems and human well-being: Synthesis. Island Press, Washington. 155pp.

Miller, L.W. 2000. The tow-net survey abundance index for delta smelt revisited. IEP Newsletter 13(1):37-44.

Miller N.A. and J.H. Stillman. 2013. Seasonal and spatial variation in the energetics of the invasive clam *Corbula amurensis* in the upper San Francisco Estuary. Marine Ecology Progress Series 476:129-139.

Miller, W.J. 2011. Revisiting assumptions that underlie estimates of proportional entrainment of delta smelt by State and federal water diversions from the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science, 9(1). Available at: http://escholarship.ucop.edu/uc/item/5941x1h8.

Miller, W.J., B.F.J. Manly, D.D. Murphy, D. Fullerton, and R.R. Ramey. 2012. An investigation of factors affecting the decline of delta smelt (*Hypomesus transpacificus*) in the Sacramento-San Joaquin Estuary. Reviews in Fisheries Science 20:1–19.

Miller N.A. and J.H. Stillman. 2013. Seasonal and spatial variation in the energetics of the invasive clam *Corbula amurensis* in the upper San Francisco Estuary. Marine Ecology Progress Series 476:129-139.

Miner, J.G., and R.A. Stein. 1996. Detection of predators and habitat choice by small bluegills: effects of turbidity and alternative prey. Transactions of the American Fisheries Society 125:97-103.

Miranda, J., R. Padilla, J. Morinaka, J. DuBois and M. Horn. 2010a. Release site predation study. Fishery Improvements Section Bay-Delta Office, California Department of Water Resources. Sacramento, CA.

Miranda, J., R. Padilla, G. Aasen, B. Mefford, D. Sisneros and J. Boutwell. 2010b. Valuation of mortality and injury in a fish release pipe. Fishery Improvements Section Bay-Delta Office, California Department of Water Resources. Sacramento, CA.

Monismith, S.G., J.L. Hench, D.A. Fong, N.J. Nidzieko, W.E. Fleenor, L.P. Doyle, and S.G. Schladow. 2009. Thermal variability in a tidal river. Estuaries and Coasts 32:100–110.

Monismith, S.G., W. Kimmerer, J.R. Burau, M.T. Stacey. 2002. Structure and flow-induced variability of the subtidal salinity field in northern San Francisco Bay. Journal of Physical Oceanography 32:3003–3019.

Monsen, N. E., J.E. Cloern, and J.R. Burau. 2007. Effects of flow diversions on water and habitat quality: examples from California's highly manipulated Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5(3). Available at: http://escholarship.org/uc/item/04822861.

Montaňo-Moctezuma, G., H.W. Li and P.A. Rossignol. 2007. Alternative community structures in kelp –urchin community: A qualitative modeling approach. Ecological Modeling 205:343-354.

Morgan-King, T.L., and D.H. Schoellhamer. 2013. Suspended-sediment flux and retention in a backwater tidal slough complex near the landward boundary of an estuary. Estuaries and Coasts 36:300-318.

Morinaka J. 2014a. Acute mortality and injury of delta smelt associated with collection, handling, transport, and release at State Water Project fish salvage facility. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 89.

Morinaka J. 2013b. A history of the operational and structural changes to the John E. Skinner Delta Fish Protective Facility from 1968 to 2010. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 85.

Morris, T. 2013. *Microcystis aeruginosa* status and trends during the Summer Townet Survey. IEP Newsletter 26(2):28-32.

Moulton, L L. 1974. Abundance, growth, and spawning of the longfin smelt in Lake Washington. Transactions of the American Fisheries Society 103:46–52.

Mount J., W. Fleenor, B. Gray, B. Herbold, W. Kimmerer. 2013. Panel review of the draft Bay Delta Conservation Plan. Report to American Rivers and The Nature Conservancy. Available at: https://watershed.ucdavis.edu/files/biblio/FINAL-BDCP-REVIEW-for-TNC-and-AR-Sept-2013.pdf.

Moyle, P.B. 2002. Inland fishes of California, 2nd edition. University of California Press, Berkeley, CA.

Moyle, P.B., and W.A. Bennett. 2008. The future of the Delta ecosystem and its fish. Technical Appendix D in J. Lund, E. Hanak, W. Fleenor, W. Bennett, R. Howitt, J. Mount, and P. Moyle, editors. Comparing Futures for the Sacramento-San Joaquin Delta. Public Policy Institute of California, San Francisco, California.

Moyle, P.B., W.A. Bennett, W.E. Fleenor, and J.R. Lund. 2010. Habitat variability and complexity in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 8(3). Available at: http://escholarship.org/uc/item/0kf0d32x.

Moyle, P.B., B. Herbold, D.E. Stevens, and L.W. Miller. 1992. Life history and status of delta smelt in the Sacramento-San Joaquin Estuary, California. Transactions of the American Fisheries Society 121:67–77.

Mueller-Solger, A.B., C.J. Hall, A.D. Jassby, and C.R. Goldman. 2006. Food resources for zooplankton in the Sacramento-San Joaquin Delta. Final Report to the Calfed Ecosystem Restoration Program.

Mueller-Solger, A.B., A.D.Jassby, and D.C. Mueller-Navarra. 2002. Nutritional quality of food resources for zooplankton (*Daphnia*) in a tidal freshwater system (Sacramento-San Joaquin River Delta). Limnology and Oceanography 47:1468–1476.

Murawski, S.A., G.R. Clayton, R.J. Reed, and C.F. Cole. 1980. Movements of spawning rainbow smelt, *Osmerus mordax*, in a Massachusetts estuary. Estuaries 3:308-314.

Murphy, D.D., and S.A. Hamilton. 2013. Eastward migration or marshward dispersal: understanding seasonal movements by Delta Smelt. San Francisco Estuary and Watershed Science 11(3). Available at: http://escholarship.org/uc/item/4jf862qz.

Murrell, M.C. and J.T. Hollibaugh. 1998. Microzooplankton grazing in northern San Francisco Bay measured by the dilution method. Aquatic Microbial Ecology 15:53–63.

Murty, A.S. 1986. Toxicity of pesticides to fish. Vols. I and II. C.R.C Press Inc. 483 and 355pp.

Myers, R.A. 1998. When do environment-recruitment correlations work? Reviews in Fish Biology and Fisheries 8:285-305.

Myers, R.A., and N.J. Barrowman. 1996. Is fish recruitment related to spawner abundance? Fishery Bulletin 94:707-724.

Myers R.A., N.J. Barrowman, J.A. Hutchings, and A.A. Rosenberg. 1995. Population dynamics of exploited fish stocks at low population levels. Science 269:1106-1108.

National Weather Service. 2003. WFO Sacramento County Warning Area Meteorology. Available at: http://www.wrh.noaa.gov/sto/CWA.php. Accessed: December 29, 2013.

Newman, K.B. 2008. Sample design-based methodology for estimating delta smelt abundance. San Francisco Estuary and Watershed Science 6. Available at: http://escholarship.org/uc/item/99p428z6.

Nichols, F.H., J.E. Cloern, S.N. Luoma, and D.H. Peterson. 1986. The modification of an estuary, Science 231:567-573.

Nichols, F.H., J.K. Thompson, and L.E. Schemel. 1990. Remarkable invasion of San Francisco Bay (California, USA) by the Asian clam *Potamocorbula amurensis*. II. Displacement of a former community. Marine Ecology Progress Series 66:95–101.

Nicolas, J. 1999. Vitellogenesis in fish and the effects of polycyclic aromatic hydrocarbon contaminants. Aquatic Toxicology 45:77–90.

NMFS (National Marine Fisheries Service). 2009. Biological opinion and conference opinion on the long-term operations of the Central Valley Project and State Water Project. National Marine Fisheries Service, Southwest Region, Long Beach, CA.

Nobriga, M. 2002. Larval delta smelt composition and feeding incidence: environmental and ontogenetic influences. California Fish and Game 88:149–164.

Nobriga, M. and F. Feyrer. 2007. Shallow-water piscivore-prey dynamics in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 5(2). Available at: http://escholarship.org/uc/item/387603c0.

Nobriga, M., F. Feyrer, R. Baxter, and M. Chotkowski. 2005. Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass. Estuaries 28:776–785.

Nobriga, M.L., E. Loboschefsky, F. Feyrer. 2013. Common predator, rare prey: exploring juvenile striped bass predation on delta smelt in California's San Francisco Estuary. Transactions of the American Fisheries Society 142:1563–1575.

Nobriga, M.L., T.R. Sommer, F. Feyrer, K. Fleming. 2008. Long-term trends in summertime habitat suitability for delta smelt, Hypomesus transpacificus. San Francisco Estuary and Watershed Science 6(1). Available at http://escholarship.org/uc/item/5xd3q8tx.

NRC (National Research Council), 2012, Sustainable water and environmental management in the California Bay-Delta: National Research Council, The National Academies Press, Washington, DC.

Null, S.E., J.H. Viers, M.L. Deas, S.K. Tanaka, and J.F. Mount. 2013. Stream temperature sensitivity to climate warming in California's Sierra Nevada: impacts to coldwater habitat. Climatic Change 116:149–170.

Ogden, J.C., S.M. Davis, K.J. Jacobs, T. Barnes, and H.E. Fling. 2005. The use of conceptual ecological models to guide ecosystem restoration in South Florida. Wetlands 25:279–809.

Opperman, J.J. 2012. A conceptual model for floodplains in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science 10(3). Available at: http://escholarship.org/uc/item/2kj52593.

Orlando, J.L., M. McWayne, C. Sanders, and M. Hladik. 2013. Dissolved pesticide concentrations in the Sacramento – San Joaquin Delta anb Grizzly Bay, California, 2011-12. United States Geological Survey Data Series 779. 24 p.

Oros, D.R., J.R.M. Ross, R.B.Spies, T. Mumley. 2006. Policyclic aromatic hydrocarbon (PAH) contamination in San Francisco Bay: A 10-year retrospective of monitoring in an urbanized estuary. Environmental Research 105:101–118.

Orsi, J.J. 1995. Food habits of several abundant zooplankton species in the Sacramento-San Joaquin Estuary. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 41.

Orsi, J.J. and W.L. Mecum. 1996. Food limitation as the probable cause of a long-term decline in the abundance of Neomysis mercedis the opossum shrimp in the Sacramento-San Joaquin estuary. Pages 375–401 in J.T. Hollibaugh, editor. San Francisco Bay: the ecosystem. American Association for the Advancement of Science. San Francisco, CA.

Ostrach, D.J., J.M. Low-Marchelli, K.J. Eder, S.J. Whiteman, and J.G. Zinkl. 2008. Maternal transfer of xenobiotics and effects on larval striped bass in the San Francisco Estuary. Proceedings of the National Academy of Sciences of the United States of America 105:19354–19359.

Pal, A., K.Y.-H. Gin, A.-Y. Lin, and M. Reinhard. 2010. Impacts of emerging organic contmainants on freshwater resources: Review of recent occurrences, sources, fate and effects. Science of the Total Environment 408:6062–6069.

Paradis, A.R., P. Pepin, and J.A. Brown. 1996. Vulnerability of fish eggs and larvae to predation: review of the influence of the relative size of prey and predator. Canadian Journal Fisheries and Aquatic Sciences 53:1226–1235.

Parker, A.E., R.C. Dugdale, and F. P. Wilkerson. 2012. Elevated ammonium concentrations from wastewater discharge depress primary productivity in the Sacramento River and the Northern San Francisco Estuary. Marine Pollution Bulletin 64:574–586.

Pauly, D., V. Christensen, J. Dalsgaard, R. Froese, and F. Torres Jr. 1998. Fishing down marine food webs. Science 279:860–863.

Peterson, M.S. 2003. Conceptual view of the environment-habitat-production linkages in tidal river estuaries: Reviews in Fisheries Science 11:291–313.

Pimm, S.L. 1984. The complexity and stability of ecosystems. Nature 307:321–326.

Platt, J.R. 1964. Strong inference. Science 146:347–353.

Poole, G.C. and C.H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. Environmental Management 27:787–802.

Popper, K. 1959. The logic of scientific discovery, English edition, Hutchinson & Co.

Puccia, C.J. and R. Levins. 1991. Qualitative modeling in ecology: Loop analysis, signed digraphs and time averaging. Pages 119–143 in P.A. Fishwick and P.A. Luker, editors. Qualitative simulation modeling and analysis. Springer-Verlag, New York.

Puget Sound Partnership Science Panel 2012. Priority science for restoring and protecting Puget Sound: A biennial science work plan for 2011-2013. Puget Sound Partnership, Tacoma WA. Available at: http://www.psp.wa.gov/SP_biennium_work_plan_download.php.

Quinn, J.F. and A.E. Dunham. 1983. On hypothesis testing in ecology and evolution. American Naturalist 122:602–617.

Quist, M.C., W.A. Hubert, and F.J. Rahel. 2004. Relations among habitat characteristics, exotic species, and turbid-river cyprinids in the Missouri River drainage of Wyoming. Transactions of the American Fisheries Society 133:727–742.

Radhaiah, V., M. Girija, and K.J. Rao. 1987. Changes in selected biochemical parameters in the kidney and blood of the fish, *Tilapia mossambica* (Peters), exposed to heptachlor. Bulletin of Environmental Contamination and Toxicology 39:1006–1011.

Radke, L.D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations of food of sturgeon. Pages 115–129 in J.L. Turner and D.W. Kelley, editors. Ecological Studies of the Sacramento-San Joaquin Delta Part II: Fishes of The Delta, Fish Bulletin 136.

Reclamation (U.S. Bureau of Reclamation). 2011. Adaptive management of fall outflow for delta smelt protection and water supply reliability. U.S. Bureau of Reclamation, Sacramento, CA. Available at: http://www.usbr.gov/mp/BayDeltaOffice/docs/Adaptive%20Management%20of%20Fall%20Outflow%20for%20Delta%20Smelt%20Protection%20and%20Water%20Supply%20Reliability.pdf.

Reclamation (U.S. Bureau of Reclamation). 2012. Adaptive management of fall outflow for delta smelt protection and water supply reliability. U.S. Bureau of Reclamation, Sacramento, CA. Available at: http://deltacouncil.ca.gov/sites/default/files/documents/files/Revised_Fall_X2_Adaptive_MgmtPlan_EVN_06_29_2012_final.pdf.

Reed, D., J.T. Hollibaugh, J. Korman, E. Peebles, K. Rose, P. Smith, P. Montagna. Workshop on Delta uutflows and related stressors: panel summary report. Report to the Delta Science Program, Sacramento, CA. Available at: http://deltacouncil.ca.gov/sites/default/files/documents/files/Delta-Outflows-Report-Final-2014-05-05.pdf.

Relyea, R.A. and K. Edwards. 2010. What doesn't kill you makes you sluggish: How sublethal pesticides alter predator-prey interactions. Copeia 2010:558–567.

Reyes, R., Z. Sutphin, and B. Bridges. 2012. Effectiveness of fine mesh screening a holding tank in retaining larval and juvenile fish at the Tracy Fish Collection Facility. Tracy Fish Collection Facility Studies. Tracy Technical Bulletin 2012-1. U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center. 20 pp.

Riar, N., J. Crago, W. Jiang, L.A. Maryoung, J. Gan, D. Schlenk. 2013. Effects of salinity acclimation on the endocrine disruption and acute toxicity of bifenthrin in freshwater and euryhaline strains of *Oncorhynchus mykiss*. Environmental Toxicology and Chemistry 32:2779–2785.

Ricker, W.E. 1954. Stock and recruitment. Journal of the Fisheries Board of Canada, 11(5), 559-623.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191:1–382.

Rodriguez, M.A. and W.M. Lewis. 1997. Structure of fish assemblages along environmental gradients in floodplain lakes of the Orinoco River. Ecological Monographs 67:109–128.

Rollwagen-Bollens, G.C. and D.L. Penry. 2003. Feeding dynamics of *Acartia* spp. copepods in a large, temperate estuary (San Francisco Bay, CA). Marine Ecology Progress Series 257:139–158.

Rose, K., J. Anderson, M. McClure, G. Ruggerone. 2011. Salmonid integrated life cycle models workshop report of the Independent Workshop Panel. Delta Science Program. Available at http://deltacouncil.ca.gov/sites/default/files/documents/files/Salmonid_ILCM_workshop_final_report.pdf.

Rose, K.A., J.H. Cowan, K.O. Winemiller, R.A. Myers, and R. Hilborn. 2001. Compensatory density-dependence in fish populations: importance, controversy, understanding, and prognosis. Fish and Fisheries 2:293-327.

Rose, K.A., W.J. Kimmerer, K.P. Edwards, and W.A. Bennett. 2013a. Individual-based modeling of delta smelt population dynamics in the upper San Francisco Estuary: I. Model description and baseline results. Transactions of the American Fisheries Society 142:1238–1259.

Rose, K.A., W.J. Kimmerer, K.P. Edwards, and W. A. Bennett. 2013b. Individual-based modeling of delta smelt population dynamics in the upper San Francisco Estuary: II. Alternative baselines and good versus bad years: Transactions of the American Fisheries Society 142:1260–1272.

Ruhl, C.A., and D.H. Schoellhamer. 2004. Spatial and temporal variability of suspended-sediment concentrations in a shallow estuarine environment. San Francisco Estuary and Watershed Science 2(2). Available at http://escholarship.org/uc/item/1g1756dw.

San Joaquin River Group Authority. 2013. 2011 Annual technical report: On implemention and monitoring of the San Joaquin River Agreement and the Vernalis Adaptive Management Plan (VAMP). Prepared by San Joaquin River Group Authority for the California State Water Resource Control Board in compliance with D-1641. 188 p. Available at: http://www.sjrg.org/technicalreport/default.htm.

Schoellhamer, D.H. 2001. Influence of salinity, bottom topography, and tides on locations of estuarine turbidity maxima in northern San Francisco Bay. Pages 343–357 in W.H. McAnally, and A.J. Mehta, editors. Coastal and Estuarine Fine Sediment Transport Processes. Elsevier Science B.V. Available at: http://ca.water.usgs.gov/abstract/sfbay/elsevier0102.pdf.

Schoellhamer, D.H. 2011. Sudden clearing of estuarine waters upon crossing the threshold from transport to supply regulation of sediment transport as an erodible sediment pool is depleted: San Francisco Bay, 1999. Estuaries and Coasts 34:885–899.

Schoellhamer, D.H., S.A. Wright, and J.Z. Drexler. 2012. Conceptual model of sedimentation in the Sacramento – San Joaquin River Delta. San Francisco Estuary and Watershed Science 10(3). Available at: http://www.escholarship.org/uc/item/2652z8sq.

Schoellhamer, D.H., S.A. Wright, J.Z. Drexler. 2013. Adjustment of the San Francisco estuary and watershed to decreasing sediment supply in the 20th century. Marine Geology 345:63–71. http://dx.doi.org/10.1016/j.margeo.2013.04.007.

Scholz, N.L., E. Fleishman, L. Brown, I. Werner, M.L. Johnson, M.L. Brooks, C.L. Mitchelmore, and D. Schlenk. 2012. A perspective on modern pesticides, pelagic fish declines, and unknown ecological resilience in highly managed ecosystems. Bioscience 62:428–434.

Schwartz. M., G. Luikart, and R. Waples. 2007. Genetic monitoring as a promising tool for conservation and management. Trends in Ecology and Evolution 22:25–33

SFEI. 2007. The pulse of the estuary: Monitoring and management water quality in the San Francisco Estuary. San Francisco Estuary Institute, Oakland, CA.

Shellenbarger, G.G., and D.H. Schoellhamer. 2011. Continuous salinity and temperature data from San Francisco Bay, California, 1982-2002: Trends and the freshwater-inflow relationship. Journal of Coastal Research 27:1191–1201.

Shoji, J., E.W. North, and E.D. Houde. 2005. The feeding ecology of *Morone americana* larvae in the Chesapeake Bay estuarine turbidity maximum: the influence of physical conditions and prey concentrations. Journal of Fish Biology 66:1328–1341.

Silva, E., N. Rajapakse, and A. Kortenkamp. 2002. Something from “nothing”— eight weak estrogenic chemicals combined at concentrations below NOECs produce significant mixture effects. Environmental Science and Technology 36:1751–1756.

Sirois, P., and J.J. Dodson. 2000a. Influence of turbidity, food density and parasites on the ingestion and growth of larval rainbow smelt *Osmerus mordax* in an estuary turbidity maximum. Marine Ecological Progress Series 193:167–179.

Sirois, P., and J.J. Dodson. 2000b. Critical periods and growth-dependent survival of larvae of an estuarine fish, the rainbow smelt *Osmerus mordax*. Marine Ecological Progress Series 203:233–245.

Slater, S. B., and R. D. Baxter. 2014. Diet, prey selection and body condition of age-0 Delta Smelt, *Hypomesus transpacificus*, in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 12(3):23.

Smalling, K.L., K.M. Kuivila, J.L. Orlando, B.M. Phillips, B.S. Anderson, K. Siegler, J.W. Hunt, and M. Hamilton. 2013. Environmental fate of fungicides and other current-use pesticides in a central California estuary. Marine Pollution Bulletin 73:114–153.

Sobczak, W.V., J.E. Cloern, A.D. Jassby, B.E. Cole, T.S. Schraga, and A. Arnsberg. 2005. Detritus fuels ecosystem metabolism but not metazoan food webs in San Francisco estuary's freshwater Delta. Estuaries 28:124–137.

Sobczak, W.V., J.E. Cloern, A.D. Jassby, and A.B. Muller-Solger. 2002. Bioavailability of organic matter in a highly disturbed estuary: The role of detrital and algal resources. Proceedings of the National Academy of Sciences of the United States of America 99:8101–8105.

Sogard, S.M. 1997. Size-selective mortality in the juvenile stage of teleost fishes: A review. Bulletin of Marine Science 60:1129–1157.

Sommer, T., and F. Mejia. 2013. A place to call home: a synthesis of delta smelt habitat in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 11(2). Available at: http://www.escholarship.org/uc/item/32c8t244.

Sommer, T., C. Armor, R. Baxter, R. Breuer, L. Brown, M. Chotkowski, S. Culberson, F. Feyrer, M. Gingras, B. Herbold, W. Kimmerer, A. Mueller-Solger, M. Nobriga, and K. Souza. 2007. The collapse of pelagic fishes in the upper San Francisco Estuary. Fisheries 32(6):270–277.

Sommer, T., F. Mejia, M. Nobriga, F. Feyrer, and L. Grimaldo. 2011. The spawning migration of delta smelt in the upper San Francisco Estuary. San Francisco Estuary and Watershed Science 9(2). Available at: http://www.escholarship.org/uc/item/86m0g5sz.

Souza, K. 2002. Revision of California Department of Fish and Game's Spring midwater trawl and results of the 2002 Spring Kodiak trawl. IEP Newsletter 15(3):44-47.

Stevens, D.E. 1963. Food habits of striped bass, Roccus saxatilis (Walbaum) in the Sacramento-Rio Vista area of the Sacramento River. Master's Thesis. University of California, Berkeley, CA.

Stevens, D.E. 1966. Food habits of striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin Delta. Pages 97–103 in J.T. Turner and D.W. Kelley, editors. Ecological studies of the Sacramento-San Joaquin Delta, part II, fishes of the delta. California Department of Fish and Game Fish Bulletin 136.

Stevens, D.E. 1977. Striped bass (*Morone saxatilis*) monitoring techniques in the Sacramento-San Joaquin Estuary. Pages 91–109 in W. Van Winkle, editor. Assessing the effects of power-plant-induced mortality on fish populations. Pergamon Press, Gatlinburg, Tennessee.

Swanson, C., T. Reid, P.S. Young, and J.J. Cech, Jr. 2000. Comparative environmental tolerances of threatened delta smelt (*Hypomesus transpacificus*) and introduced wakasagi (*H. nipponensis*) in an altered California estuary. Oecologia 123:384–390.

Sweetnam, D.A. 1999. Status of delta smelt in the Sacramento-San Joaquin Estuary. California Fish and Game 85:22–27.

Sweetnam, D.A., and D.E. Stevens. 1993. Report to the Fish and Game Commission: a status review of the delta smelt (*Hypomesus transpacificus*) in California. 68 p. plus appendices.

SWRCB. 2010. Final 2008-2010 Clean Water Act Section 303(d) List of Water Quality Limited Segments (Region 5). State Water Resources Control Board (SWRCB). Sacramento, California. Available at: http://www.waterboards.ca.gov/water_issues/programs/tmdl/integrated2010.shtml.

Takasuka, A., I. Aoki, and I. Mitani. 2003. Evidence of growth-selective predation on larval Japanese anchovy *Engraulis japonicus* in Sagami Bay. Marine Ecology Progress Series 252:223–238.

Thom, R. 2000. Adaptive management of coastal ecosystem restoration projects. Ecological Engineering 15:365–372.

Thomas, J.L. 1967. The diet of juvenile and adult striped bass, *Roccus saxatilis*, in the Sacramento-San Joaquin River system. California Fish and Game 53(1):49–62.

Thompson, J.K. 2005. One estuary, one invasion, two responses: phytoplankton and benthic community dynamics determine the effect of an estuarine invasive suspension feeder. Pages 291–316 in S. Olenin and R. Dame, editors. The comparative roles of suspension feeders in ecosystems. Springer, Amsterdam.

Thomson, B., R. Hoenicke, J.A. Davis, and A. Gunther. 2000. An overview of contamiant – related issues identified by monitoring in San Francisco Bay. Environmental Monitoring and Assessment 64:409–419.

Thomson, J.R., W.J. Kimmerer, L.R. Brown, K.B. Newman, R. Mac Nally, W.A. Bennett, F. Feyrer, and E. Fleishman. 2010. Bayesian change-point analysis of abundance trends for pelagic fishes in the upper San Francisco Estuary. Ecological Applications 20:1431–1448.

Thurston, R.V., R.C. Russo, and G.A. Vinogradov. 1981. Ammonia toxicity to fishes. Effect of pH on the toxicity of the un-ionized ammonia species. Environmental Science and Technology 15:837–840.

Touzeau, S., and G.L. Gouze. 1998. On the stock-recruitment relationships in fish population models. Environmental Modeling and Assessment 3:87–93.

Townend, I.H. 2004. Identifying change in estuaries. Journal of Coastal Conservation 10:5–12.

Turner, J.L. 1966a. Distribution and food habits of centrarchid fishes in the Sacramento-San Joaquin Delta. Pages 144–153 in J.L. Turner and D.W. Kelley, editors. Ecological studies of the Sacramento-San Joaquin Delta Part II: Fishes of the Delta, Fish Bulletin 136.

Turner, J.L. 1966b. Distribution and food habits of ictalurid fishes in the Sacramento-San Joaquin Delta. Pages 130–143 in J.L. Turner and D.W. Kelley, editors. Ecological studies of the Sacramento-San Joaquin Delta Part II: Fishes of The Delta, Fish Bulletin 136.

Turner, J.L. and H.K. Chadwick. 1972. Distribution and abundance of young-of-the-year striped bass, *Morone saxatilis*, in relation to river flow in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 101:442–452.

USFWS (United States Fish and Wildlife Service). 2008. Formal Endangered Species Act consultation on the proposed coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP). U.S. Fish and Wildlife Service, Sacramento, CA.

USGS (U.S. Geological Survey). 2008. Tracking organic matter in Delta drinking water. Science action: News from the CALFED Science Program. CALFED Science Program Sacramento, CA.

Van Nieuwenhuyse, E. 2007. Response of summer chlorophyll concentration to reduced total phosphorus concentration in the Rhine River (Netherlands) and the Sacramento–San Joaquin Delta (California, USA). Canadian Journal of Fisheries and Aquatic Sciences 64:1529–1542.

Vandermeer, J. 2013. Forcing by rare species and intransitive loops creates distinct bouts of extinction events conditioned by spatial pattern in competition communities. Theoretical Ecology 6:395–404.

Vannote, R.L. and B.W. Sweeney. 1980. Geographic analysis of thermal equilibria: a conceptual model for evaluating the effect of natural and modified thermal regimes on aquatic insect communities. The American Naturalist 115:667–695.

Wadsworth, K., and T. Sommer. 1996. Should the delta smelt summer tow-net index be size-standardized? IEP Newsletter 8(2):24–26.

Wagner, R.W. 2012. Temperature and tidal dynamics in a branching estuarine system. Ph.D. dissertation. University of California, Berkeley, CA.

Wagner, R.W., M. Stacey, L.R. Brown, and M. Dettinger. 2011. Statistical models of temperature in the Sacramento–San Joaquin Delta under climate-change scenarios and ecological implications. Estuaries and Coasts 34:544–556.

Walter, H., F. Consolaro, P. Gramatica, and M. Altenburger. 2002. Mixture toxicity of priority pollutants at no observed effect concentrations (NOECs). Ecotoxicology 11:299–310.

Walters, C.J., and R. Hilborn, R. 1978. Ecological optimization and adaptive management. Annual Review of Ecology and Systematics 9:157–188.

Walters, C.J., and F. Juanes. 1993. Recruitment limitation as a consequence of natural selection for use of restricted feeding habitats and predation risk taking by juvenile fishes. Canadian Journal of Fisheries and Aquatic Sciences 50:2058–2070.

Wang, J.C.S. 1986. Fishes of the Sacramento-San Joaquin Estuary and adjacent waters, California: A guide to the early life histories. Interagency Ecological Program of the Sacramento-San Joaquin Estuary, Technical Report 9.

Wang, J.C.S. 1991. Early life stages and early life history of the delta smelt, *Hypomesus transpacificus*, in the Sacramento-San Joaquin estuary with comparison of early life stages of the longfin smelt, *Spirinchus thaleichthy*s. U.S. Army Corps of Engineers, Technical Report FS/BIO-IATR/91-28.

Wang, J.C.S. 2007. Spawning, early life stages and early life histories of the Osmerids found in the Sacramento-San Joaquin Delta of California. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Byron, California. Tracy Fish Facilities Studies, Volume 38, 72 p. plus appendices.

Warner, J.C., D.H. Schoellhamer, C.A. Ruhl, and J.R. Burau. 2004. Floodtide pulses after low tides in shallow subembayments adjacent to deep channels. Estuarine, Coastal and Shelf Science 60:213–228.

Washington State Academy of Sciences. Committee on Puget Sound Indicators. 2012. Sound indicators: A review for the Puget Sound Partnership. Washington State Academy of Sciences, Olympia, WA. Available at: http://www.washacad.org/about/files/WSAS_Sound_Indicators_wv1.pdf.

Walters, C., & Korman, J. (1999). Linking recruitment to trophic factors: revisiting the Beverton--Holt recruitment model from a life history and multispecies perspective. Reviews in Fish Biology and Fisheries, 9(2), 187-202.

Werner, I., L. Deanovic, D. Markiewicz, M. Stillway, N. Offer, R. Connon, and S. Brander. 2008. Pelagic Organism Decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta 2006–2007. Final Report. U.C. Davis–Aquatic Toxicology Laboratory, Davis, California.

Werner, I., L.A. Deanovic, D. Markiewicz, J. Khamphanh, C.K. Reece, M. Stillway, and C. Reece. 2010a. Monitoring acute and chronic water column toxicity in the northern Sacramento-San Joaquin Estuary, California, USA, using the euryhaline amphipod, *Hyalella azteca*: 2006–2007. Environmental Toxicology and Chemistry 29:2190–2199.

Werner, I., D. Markiewicz, L. Deanovic, R. Connon, S. Beggel, S. Teh, M. Stillway, C. Reece. 2010b. Pelagic Organism Decline (POD): Acute and chronic invertebrate and fish toxicity testing in the Sacramento-San Joaquin Delta 2008–2010, Final Report. U.C. Davis–Aquatic Toxicology Laboratory, Davis, California.

Weston, D., A.M. Asbell, S.A. Lesmeister, S.J. Teh, and M.J. Lydy. 2014. Urban and agricultural pesticide inputs to a critical habitat for the threatened Delta Smelt (Hypomesus transpacificus). Environmental Toxicology and Chemistry 33: 920-929.

Weston, D.P. and M.J. Lydy. 2010. Urban and agricultural sources of pyrethroid insecticides to the Sacramento-San Joaquin Delta of California. Environmental Science and Technology 44:1833–1840.

Weston, D.P., A.M. Asbell, S.A. Lesmeister, S.J. Teh, and M.J. Lydy. 2012. Urban and agricultural pesticide inputs to a critical habitat for the threatened delta smelt (*Hypomesus transpacificus*). Final report to the POD Management Team of the Interagency Ecological Program for the San Francisco Estuary.

Weston, D.P., H.C. Poynton, G.A. Wellborn, M.J. Lydy, B.J. Blalock, M.S. Sepulveda, and J.K. Colbourne. 2013. Multiple origins of pyrethroid insecticide resistance across the species complex of a nontarget aquatic crustacean, *Hyalella azteca*. Proceedings of the National Academy of Sciences of the United States of America. 110:16532–16537

Whipple, A.A., R.M. Grossinger, D. Rankin, B. Stanford, and R. Askevold. 2012. Sacramento-San Joaquin Delta historical ecology investigation: Exploring pattern and process. San Francisco Estuary Institute, Richmond, CA.

Whitfield, A.K. 1999. Ichthyofaunal assemblages in estuaries: A South African case study. Reviews in Fish Biology and Fisheries 9:151–186.

Wilkerson F.P., R.C. Dugdale, V.E. Hogue, and A. Marchi. 2006. Phytoplankton blooms and nitrogen productivity in San Francisco Bay. Estuaries and Coasts 29:401–416.

Williams, B.K. 2011. Passive and active adaptive management: Approaches and an example. Journal of Environmental Management 92:1371–1378.

Wilson E.O. 1998. Consilience: The unity of knowledge. Alfred A. Knopf. 322 p.

Winder, M., and A.D. Jassby. 2011. Shifts in zooplankton community structure: Implications for food-web processes in the upper San Francisco Estuary. Estuaries and Coasts 34:675–690

Winder, M., A. Jassby and R. McNally. 2011. Synergies between climate anomalies and hydrological modifications facilitate estuarine biotic invasions. Ecology Letters 14:749–757.

Winemiller, K.O. and K.A. Rose. 1992. Patterns of life-history diversification in North-American fishes implcations for population regulation Canadian Journal of Fisheries and Aquatic Sciences 49:2196–2218.

Wood, S.A., P.T. Holland, L. MacKenzie. 2011. Development of solid phase adsorption toxin tracking (SPATT) for monitoring anatoxin-a and homoanatoxin-a in river water. Chemosphere 82:888–894.

Wright, S.A., and D.H. Schoellhamer. 2004. Trends in the sediment yield of the Sacramento River, California, 1957-2001. San Francisco Estuary and Watershed Science 2(2). Available at: http://escholarship.org/uc/item/891144f4.

Wurtsbaugh, W., and H. Li. 1985. Diel migrations of a zooplanktivorous fish (*Menidia beryllina*) in relation to the distribution of its prey in a large eutrophic lake. Limnology and Oceanography 30:565–576.

Xu, Y., J. Gan, and F. Spurlock. 2008. Effect of aging on desorption kinetics of sediment-associated pyrethroids. Evironmental Toxicology and Chemistry 27:1293–1301.

York, J.K., B.A. Costas and G.B. McManus. 2010. Microzooplankton grazing in green water—results from two contrasting estuaries. Estuaries and Coasts 34:373–385.

Appendix A: How the Delta Smelt MAST Report was Written

The report titled “An updated conceptual model for Delta Smelt: our evolving understanding of an estuarine fish” (hereafter referred to as Delta Smelt MAST report) was written in 2013-2014 by the IEP Management, Analysis, and Synthesis Team (MAST). The Delta Smelt MAST report was developed through a series of report drafts and a public technical review and followed a set of general report guidelines. This report appendix describes the Delta Smelt MAST report guidelines, the report review and revisions, and report milestones.

Delta Smelt MAST Report Guidelines

Report Purpose and Approach

The Delta Smelt MAST report is a technical report intended to synthesize the latest scientific data and information on Delta Smelt, a topic of particularly high relevance to agency managers and decision makers in California. Specifically, it provides an up to date assessment and conceptual model of factors affecting Delta Smelt throughout its primarily annual life cycle and demonstrates how the conceptual model can be used in science and management. The Delta Smelt MAST report updates and redesigns previous conceptual models for Delta Smelt with new data and information since the release of the last synthesis report about the “Pelagic Organism Decline” (POD) by the Interagency Ecological Program (IEP) in 2010. It then uses the conceptual model to generate hypotheses about the factors that may have contributed to the 2011 increase in

Delta Smelt abundance and evaluate them using a simple comparative approach. The Delta Smelt MAST report ends with key conclusions, a discussion of our hypothesis testing approach, and recommendations for future work and adaptive management applications, with examples.

1. **Report Development.** The 2014 MAST report is a synthesis report developed and written by the IEP Management, Analysis, and Synthesis Team (MAST). The MAST is co-chaired by the IEP Lead Scientist and IEP Program Manager and includes senior scientists from IEP member agencies tasked with data analysis, synthesis, and work planning. The MAST report is the collective product of a dynamic and collaborative interagency team process involving focused team discussions at monthly MAST meetings, intensive conceptual model and report development at additional multi-day off-site meetings, presentations and discussions with other scientists, stakeholders, and the public (e.g., at the annual IEP workshop, meetings of the IEP Stakeholder Group and IEP Project Work Teams), and data analysis and synthesis as well as writing, integration, and revisions of report sections by MAST members with written communication via email and the MAST wiki. MAST report authors were expected to follow the MAST report guidelines described here. They were also expected to consider all internal review comments by other MAST members and members of the IEP Management and Coordinators teams as well as external technical review comments received during a 40-day public review period. Details about the public review process are given in II.

2. **Report Authorship.** The “author of record” for the 2013 MAST report is the entire IEP MAST, and the responsibility for authorship lies with the entire MAST as well. Individual authorship of report sections is not credited; the report is a product of the IEP MAST and not of any individual author or an individual IEP member agency. All current MAST members are MAST report authors and are listed alphabetically in the initial pages of the report (see III. below). Former MAST members will not be listed as authors, but will be noted as contributors. Each report section had a lead author who had primary responsibility for writing and revising the section. One designated MAST member (Larry Brown, USGS) functioned as report lead editor who compiled and integrated all sections and sent full draft report versions to the MAST for review by all MAST members. All MAST members sent their edits and comments back to Larry Brown and the section authors for revisions. The report went through multiple draft versions before its finalization.

3. **Report Organization.** The 2014 MAST report is an IEP technical report and follows the same basic organization as other IEP technical reports, including a title page, list of all authors, acknowledgements, table of contents, executive summary, an introductory section with background information and report objectives, and concise sections detailing the analysis and synthesis approach, models and hypotheses, findings, and conclusions as well as illustrative tables, figures, and full references for all citations. In response to reviewer recommendations received during the public technical review (see II.), the report was restructured and expanded from originally six to nine Chapters.

4. **Supporting Evidence.** The 2014 MAST report follows the conventions of IEP and other technical reports regarding supporting evidence, which includes the following. The rationale for any findings, conclusions, and recommendations should be fully explained in the report. Whenever possible, conceptual models and hypotheses should be evaluated through analysis of the available data. Additional supporting information should be obtained from the peer-reviewed literature or from publicly accessible reports. Related or competing hypotheses and models that have been previously published in the peer-

reviewed literature should be acknowledged and discussed in the report and conclusions should be based on even-handed, dispassionate consideration of all available evidence. Sources for all supporting data and information should be clearly identified and cited. Citation of personally communicated unpublished results (e.g. emails, memos) is permissible, but should be used sparingly.

Delta Smelt MAST Report Review and Revisions

1. **What was the purpose of the review?** The purpose of the public technical review of the draft Delta Smelt MAST report was to ensure its scientific credibility, relevance to managers and decision makers, and a transparent and legitimate process that welcomed and considered input and recommendations from other scientists, managers, stakeholders, and the public.

2. **What was expected of draft Delta Smelt MAST report reviewers?** MAST report reviewers were asked to provide written comments on any and all technical aspects of the draft report, but to pay particular attention to review criteria outlined in the MAST report review guidelines.[1]

3. **Who reviewed the draft Delta Smelt MAST report?** The draft Delta Smelt MAST report released for public review on July 23, 2014, was reviewed by invited IEP staff and colleagues as well as by invited external peer reviewers and other scientists who submitted comments during the 40-day public review period, as follows.

   a. IEP Coordinators (1 Reviewer, IEP management review)

   b. Former MAST Members (2 Reviewers, IEP colleague scientific peer review)

   c. Invited Subject Area Expert (1 Reviewer, IEP colleague review of contaminants sections)

   d. Independent Scientific Peer Reviewers (3 Reviewers, external independent scientific peer review facilitated by the Delta Science Program)

   e. Other Scientists, Stakeholders and the Public (7 Reviewers, external public review)

   In addition, the IEP Coordinators were asked to review the revised, near-final version of the Delta Smelt MAST report and the executive summary and to approve the final version. The IEP Directors were briefed and invited to comment on the direction and progress of the Delta Smelt MAST report on a quarterly basis.

4. **How were external draft Delta Smelt MAST report reviewers identified, invited, and informed?** Independent Scientific Peer Reviewers for the draft Delta Smelt MAST report were identified by the Delta Stewardship Council's Delta Science Program (DSP) and Delta Lead Scientist. In accordance with the DSP "Procedures for Independent Scientific Peer Review,"[2] the Delta Lead Scientist determined and invited the independent scientific peer reviewers using the following selection criteria: standing in the scientific community, expertise relevant to the documents being reviewed, and free of conflict of interest.

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[1] http://www.water.ca.gov/iep/docs/mast_report_process_july2013.pdf

[2] http://deltacouncil.ca.gov/docs/2012-11-06/delta-science-program-procedures-conducting-independent-scientific-peer-review

All other review was invited by email and in a notice posted on the IEP website.[3] A draft of the 2013 MAST report, associated figures, and MAST report review guidelines were posted on July 23, 2013, for public technical review. The draft report release for review did not include an executive summary and conclusions. The public review period closed on August 31, 2013.

5. **How many review comments were received and where can they be accessed?** The MAST received 14 sets of review comments on the July 2013 draft MAST report. They included many general comments as well as 355 comments that referred to specific lines in the report, see table A1. All comments by external reviewers (public review comments and the review comments by the three independent scientific peer reviewers) were posted on the IEP website.[4]

6. **How were the review comments addressed?** All review comments received during the 40-day review period were compiled in an Excel spreadsheet and summarized numerically (Table A1). Review comments and procedures for addressing them were discussed by the MAST at its regular monthly meetings and during a one-day offsite meeting in November 2013. The process for addressing review comments included the following:

    a. The lead author for each report section had the primary responsibility for addressing review comments pertaining to that section and for revising the section.

    b. Secondary revision leads were also assigned and assisted the primary revision lead.

    c. For each review comment in the Excel spreadsheet, it was noted whether the comment: (1) Did not suggest a revision and no revision was made; (2) Suggested a revision and a revision was made; or (3) Suggested a revision, but no revision was made, for example because it was outside of the report scope, explained elsewhere, or the lead author did not agree with the recommended revision.

    d. Revised sections and the annotated excel spreadsheet were sent by email to the entire MAST. MAST members were alerted to all major revisions.

    e. Major revisions were discussed with all MAST members during MAST meetings and via email.

    f. Decisions about major revisions were made by the whole MAST; no comment implied consent.

    g. Decisions about more minor revisions were made by the section revision leads and the report lead editor, often in consultation with some or all other MAST members.

    h. The report lead editor (Larry Brown, USGS) compiled, further revised, and integrated all revised report sections and sent full draft report versions to the MAST for review by all MAST members. The final draft versions of the report and executive summary were also sent to the IEP coordinators for their review and approval.

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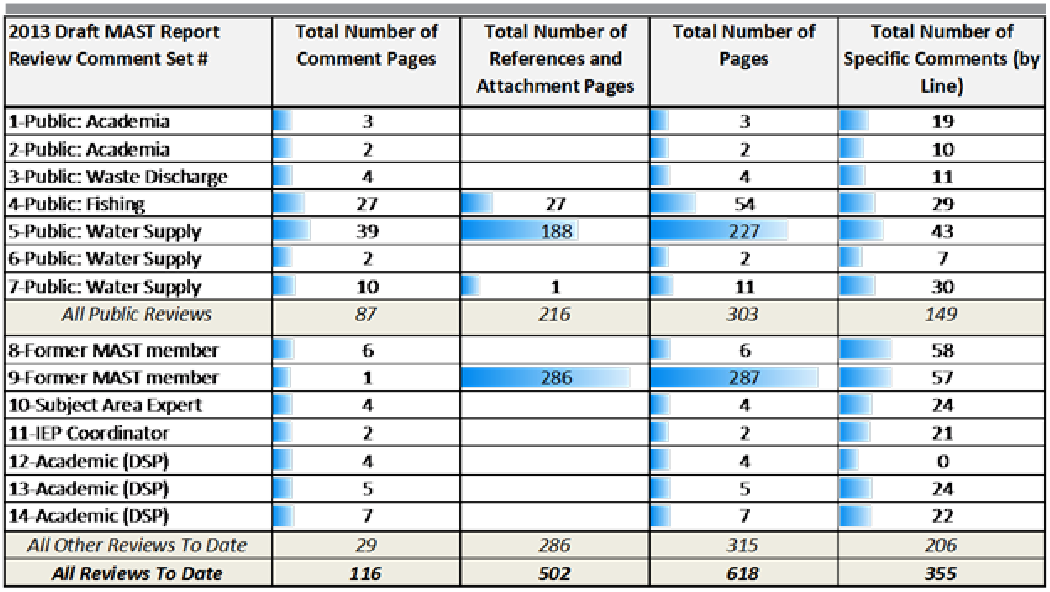
[3] http://www.water.ca.gov/iep/pod/mast.cfm
[4] http://www.water.ca.gov/iep/pod/mast.cfm

Table A1. **Numerical summary of review comments for the July 2013 draft MAST report.**



2013 Draft MAST Report Review Comment Set #	Total Number of Comment Pages	Total Number of References and Attachment Pages	Total Number of Pages	Total Number of Specific Comments (by Line)
1-Public: Academia	3		3	19
2-Public: Academia	2		2	10
3-Public: Waste Discharge	4		4	11
4-Public: Fishing	27	27	54	29
5-Public: Water Supply	39	188	227	43
6-Public: Water Supply	2		2	7
7-Public: Water Supply	10	1	11	30
All Public Reviews	*87*	*216*	*303*	*149*
8-Former MAST member	6		6	58
9-Former MAST member	1	286	287	57
10-Subject Area Expert	4		4	24
11-IEP Coordinator	2		2	21
12-Academic (DSP)	4		4	0
13-Academic (DSP)	5		5	24
14-Academic (DSP)	7		7	22
All Other Reviews To Date	*29*	*286*	*315*	*206*
All Reviews To Date	***116***	***502***	***618***	***355***

7. **What major changes were made to the draft report in response to review comments?** The draft Delta Smelt MAST report underwent several major changes in response to review comments. Changes include the following:

   a. The report purpose and goals were reconsidered, clarified, and somewhat expanded. Specifically, the four-year comparison of factors that may have contributed to the Delta Smelt abundance increase in 2011 was deemphasized in favor of a broader assessment and conceptual model of factors affecting Delta Smelt throughout its primarily annual life cycle and demonstrations of how the conceptual model can be used in science and management.

   b. The report structure was substantially changed to better fit the revised report purpose and goals and to improve the organization of the large amount of information included in the report. Four new Chapters were added to describe the updated conceptual model (Chapter 5), provide a more thorough overview of Delta Smelt life history and population dynamics (Chapter 6), summarize and discuss findings and conclusions (Chapter 8), and provide recommendations and examples of future work and management applications (Chapter 9). An executive summary was also added, along with this appendix.

   c. The content of the report was expanded to accomplish the somewhat expanded report purpose and goals, reflect previously missing information pointed out by reviewers as well as new information from the latest scientific publications, and provide conclusions and recommendations for future work and management applications.

   d. Several reviewers commented that the simple four-year comparative approach that was used to evaluate factors that may have contributed to the Delta Smelt abundance increase in 2011 was too limited and that more years of data and more in-depth analyses and modeling were needed for this evaluation. The MAST agreed, but decided that these types of analyses would require additional time and resources and were outside the scope of this report which emphasized synthesis of existing information over new data analyses. Instead, the MAST decided to discuss some of the benefits and limitations of analysis and synthesis approaches used in the report in Chapter 8 and existing and ongoing analyses and modeling efforts along with additional, analysis, synthesis, modeling, and other science needs and potential management applications in Chapter 9. Three examples of additional mathematical modeling approaches are also included in Chapter 9. These approaches were explored by individual co-authors of this report. Preliminary results of these analyses are given for illustrative purposes only; peer-reviewed publications of these analyses need to be completed before they can be used to draw firm conclusions.

Delta Smelt MAST Report Milestones

Note: The time line for the development, review, revision and completion of the Delta Smelt MAST report had to be adjusted repeatedly because of numerous new work assignments for individual MAST members, the large number and depth of review comments, the federal government shut-down, personnel changes, etc.

2012

March 13-16	Initial MAST off-site meeting (Marconi Center, CA) to discuss MAST products and direction and start MAST work on the 2012 IEP proposal solicitation[5], the “FLaSH” report[6], and the Delta Smelt MAST report (hereafter MAST report)
Sep 13-14	MAST off-site meeting (Yolo Wildlife Area, CA)
Dec 4-5	MAST off-site meeting (Clarksburg, CA)

2013

March 29	First draft MAST report completed
April 24	MAST presentation (talk) at annual IEP Workshop (Larry Brown, USGS)
May 20	Second draft MAST report completed
June 6	Third draft MAST report completed
July 23 – Aug 31	Fourth draft MAST report completed and posted on the IEP website for a 40-day review period
August 14	Draft MAST report discussion with IEP Stakeholder Group
Sep 11	Special IEP Stakeholder Group meeting about the draft MAST report
Oct 30	MAST report poster presentation at 2013 State of the Estuary Conference
Nov 14	MAST off-site meeting (UC Davis, CA)
Dec 8	Fifth draft MAST report completed

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[5] http://www.water.ca.gov/iep/archive/2012/solicitations.cfm

[6] http://deltacouncil.ca.gov/science-program/fall-low-salinity-habitat-flash-studies-and-adaptive-management-plan-review-0

2014

Feb 3	Sixth draft MAST report completed
Feb 11	MAST presentation (talk) at DSP-SWRCB “Delta Outflows” workshop (Larry Brown, USGS)
Feb 20	MAST presentation (talk) at a meeting of the IEP Resident Fishes Project Work Team (Larry Brown, USGS)
Feb 26	MAST presentation (talk) at annual IEP Workshop (Larry Brown, USGS)
April 16	Seventh draft MAST report completed
April 17	First draft MAST report executive summary completed
April 24	Second draft MAST report executive summary completed and sent to IEP Coordinators for review
May 15	Eight draft MAST report completed and sent to IEP Coordinators for a one-week “red flag” review. This draft includes the executive summary and a description of how the MAST report was written and revised with a list of major report revisions in response to review comments (Appendix A)
June 2	Ninth draft MAST report completed and sent to IEP Coordinators for review and IEP Directors briefings
June 11	IEP Coordinators briefed on MAST report including a review of the major changes.
June 17	Agencies and stakeholders of the CAMT Delta Smelt Scoping Team briefed about the MAST report including major findings and changes since 2013.
July 2	IEP Stakeholder Group meeting to discuss MAST report revisions and completion
July 3	Coordinators approve the final draft MAST report for publication as an IEP Technical Report; when ready the draft final report will be posted on the MAST webpage[7] until the IEP Technical Report publication is completed and report is posted on the IEP Technical Reports webpage[8]
July 14	MAST model presented to IEP Wetlands Conceptual Model Team.
July 29	IEP Directors meeting with presentation and discussion of final MAST report
July 30	MAST model presented to IEP Wetlands Project Work Team.
August 6	MAST briefing to Drought Operations Plan Team

Appendix B: Calculation of Annual Abundance Indices

This Appendix describes the data and methods used by 4 long-term fish monitoring surveys for calculating annual abundance indices for Delta Smelt (*Hypomesus transpacificus*). Descriptions are arranged sequentially beginning with the Spring Kodiak Trawl, which calculates an index of abundance for adult Delta Smelt, followed by the 20 mm Survey, which calculates an index

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[7] http://www.water.ca.gov/iep/pod/mast.cfm
[8] http://www.water.ca.gov/iep/products/technicalrpts.cfm

for late-stage larvae and small juveniles; the Summer Townet Survey calculates an index for juveniles and the Fall Midwater Trawl Survey calculates an index for sub-adults. As mentioned in the main document, abundance indices are not population estimates, but they are believed to increase monotonically with increases in true population size.

Spring Kodiak Trawl

The Department of Fish and Wildlife (DFW) initiated the Spring Kodiak Trawl Survey (SKT) in 2002. The SKT replaced the Spring Midwater Trawl and provided a more effective means to monitor the distribution and reproductive status of adult Delta Smelt. Survey results provide near real-time information on the proximity of adult Delta Smelt to south Delta export facilities and can provide an indication of likely spawning areas.

The SKT includes 5 monthly Delta-wide surveys, January through May (Figure 84). Only the first 4 surveys contribute to the annual abundance index. No index exists for 2002, when only 3 surveys were conducted. The index is calculated after all data have been verified for accuracy.

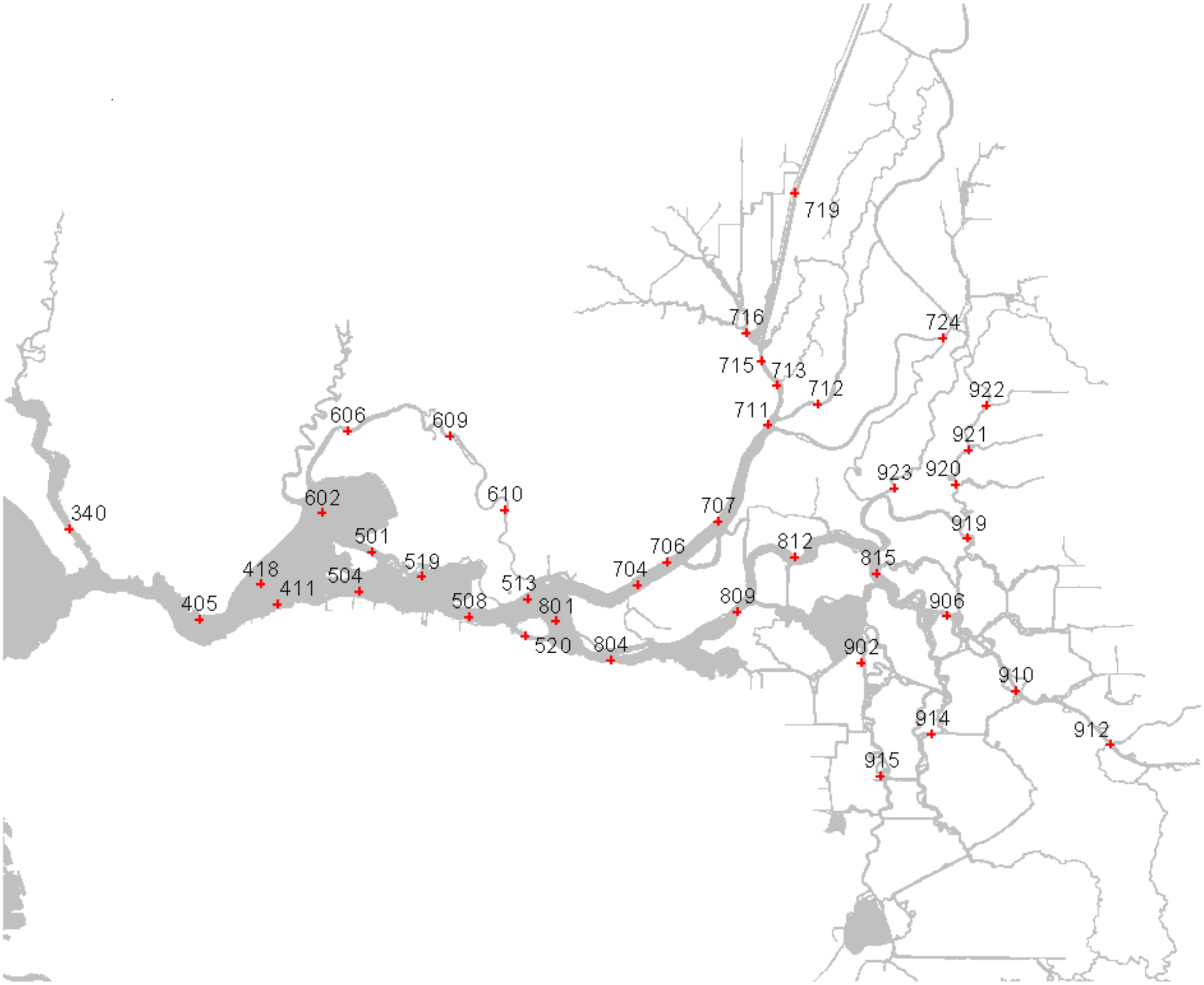
Field crews tow the net at the surface between 2 boats once for 10-min at each station per survey; 5-min surface tows are used at stations with historically high catch to limit excessive Delta Smelt take; a second 5-min surface tow is completed if Delta Smelt catch in the first tow did not exceed 50. A flow meter deployed at the start of the tow and retrieved at the end provides information on distance towed through the water. To calculate fish density, survey personnel assume that the SKT net fishes with the mouth fully opened, an area of 13.95 m^2 (7.62 m wide by 1.83 m deep). Volume filtered is the product of distance towed and mouth area. Volume filtered varies and by convention researchers expand catch per volume filtered (number per m^3) for juvenile and adult fish to catch per 10,000 m^3.

Annual abundance index calculations use adult Delta Smelt data from 39 of the 40 stations (Fig. 84). For each of the first 4 monthly surveys, adult catch per 10,000 m^3 values from each station are grouped into 3 distinct regions based on geographic location: 1) the confluence and Suisun region (sites 340, 405, 411, 418, 501, 504, 508, 513, 519, 520, 602, 606, 609, 610, 801); 2) the Sacramento River and Cache Slough region (sites 704, 706, 707, 711, 712, 713, 715, 716, 719, 724); and 3) the San Joaquin River and Delta region (804, 809, 812, 815, 902, 906, 910, 912, 914, 915, 919, 920, 921, 922, 923). A monthly mean is calculated for each region and the sum of the regional means is the monthly or survey index. The sum of the 4 survey indices is the annual index.

20 mm Survey

DFW initiated the 20 mm Survey in 1995 to monitor the distribution and relative abundance of larval and juvenile Delta Smelt throughout their historical spring range in the upper San Francisco Estuary (Fig. 85), and provide near real-time information on the relative densities and proximities of these young fish to south Delta export pumps. The 20 mm Survey includes sampling on alternate weeks from mid-March through early July, typically resulting in 9 surveys per year. During each survey, field crews complete 3 oblique tows at each of the 47 stations (Fig. 85). The 20 mm Survey added stations over time, but not all contribute to annual abundance index calculation. The survey added 5 Napa River stations in 1996 for a total of 41 core stations, which are included in the annual abundance index calculations (Fig. 85, circles). In 2008, 6 non-

Figure 84. **Map of Spring Kodiak Trawl Survey stations showing all currently sampled stations. Data from all stations except 719 are used in abundance index calculation.**

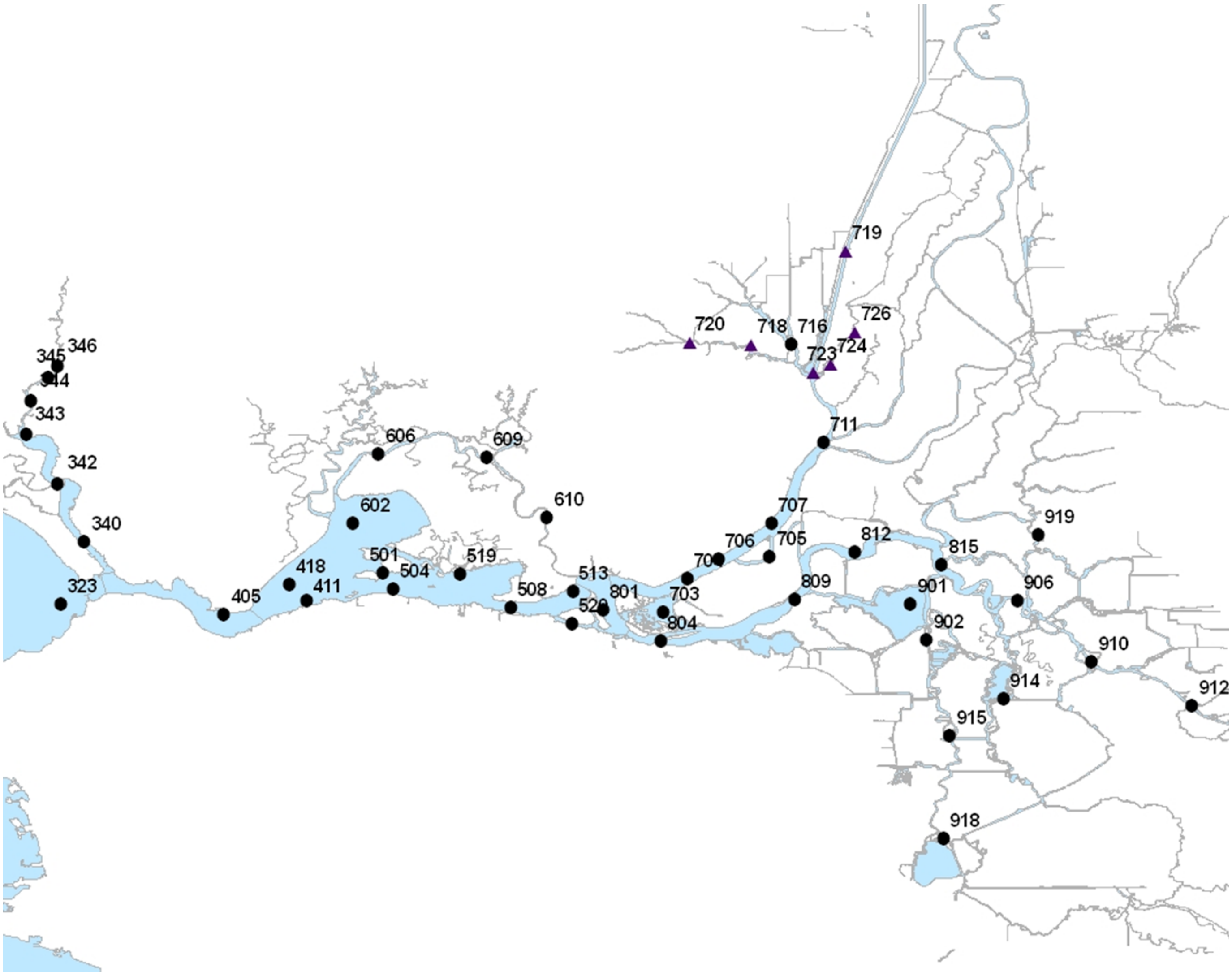


core stations were added, which are not included in the annual abundance index calculations, including Barker Slough (site 720), Lindsey Slough (site 718), Miner Slough (sites 724 and 726), and the Sacramento Deep Water Shipping Channel (n = 2; sites 719 and 723) (Fig. 85, triangles).

The 20 mm net includes a flow meter located within the mouth of the net to measure distance traveled by the net during the tow. This value is then multiplied by the fixed mouth area of the net (1.51 m^2) to provide total volume filtered. The tows are then standardized to catch of Delta Smelt per 10,000 m^3.

As already noted, the annual abundance index calculation uses only catch per 10,000 m^3 values from the 41 index stations. For each survey, the mean fork length of Delta Smelt is calculated from measurements of the fish captured during each survey. The two surveys just before the average fork length reached 20 mm and the 2 surveys just after the average fork length reached 20 mm are included in the annual abundance index calculation. For these 4 surveys the geometric

Figure 85. **Map of 20 mm survey stations showing all currently sampled stations. Data from all core stations are used in abundance index calculation.**



mean of the catch of Delta Smelt per 10,000 m^3 is calculated across the 41 core stations. The geometric mean for each survey is calculated as the arithmetic mean of $\log_{10}(x+1)$-transformed values of Delta Smelt catch per 10,000 m^3 across the 41 core stations. The resulting value is then back-transformed (including subtraction of 1) for the calculation of the annual abundance index. The annual abundance index is calculated as the sum of the geometric means of the 4 selected surveys.

Summer Townet Survey

The Summer Townet Survey (TNS) was started by DFW in 1959 to produce an annual index of summer abundance for age-0 Striped Bass (*Morone saxatilis*). In the mid-1990s, DFW staff developed an abundance index calculation for Delta Smelt. Annual abundance indices for Delta Smelt have been calculated for the period 1959 through the present, except for 1966-1968. The

TNS Survey samples 32 historic stations, 31 of which contribute to index calculation (labeled as “core stations,” Fig. 86). Currently sampled TNS stations range from eastern San Pablo Bay to Rio Vista on the Sacramento River and to Stockton on the San Joaquin River (Fig. 86). In 2011, TNS added 8 supplemental stations in the Cache Slough and the Sacramento River Deepwater Ship Channel region to increase spatial coverage and better describe Delta Smelt range and habitat (Fig. 86). Historically, TNS sampling began when age-0 Striped Bass achieved a mean fork length of 20 mm based on larval sampling, typically in mid-June to early July, and ended when age-0 Striped Bass surpassed a mean size of 38.1 mm fork length. Since 2003, TNS has consistently included 6 surveys annually, running on alternate weeks from early June through mid- to late August.

Field crews perform at least two 10-min oblique tows at most stations. A third tow is conducted when any fish were caught during either of the first 2 tows. At least 1 tow is completed at each of the new Cache Slough and Sacramento River Deepwater Ship Channel stations. To reduce Delta Smelt take, field crews only perform a second tow at these stations if Delta Smelt catch from the first tow is less than 10. Delta Smelt catch per tow data are used for index calculation.

The annual abundance index for Delta Smelt is the arithmetic mean of the abundance indices from the first 2 surveys conducted each year. Delta Smelt abundance indices for each biweekly survey are calculated by summing catch across all tows for each index station, multiplying the summed catch by a station weighting factor representing the water volume of that station (Table B1); then the volume-weighted catches are summed across all 31 index stations and the sum divided by 1000.

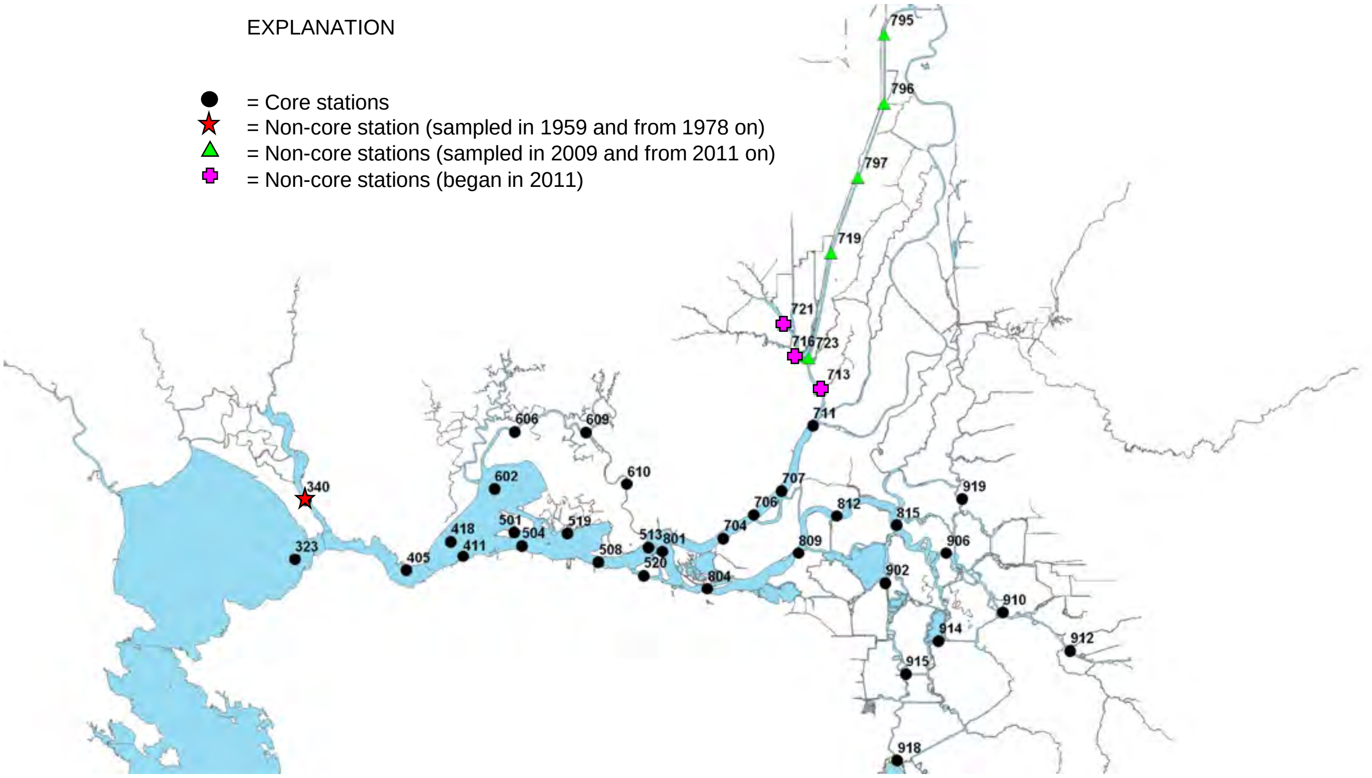
The annual abundance index for age-0 Striped Bass is calculated using similar methods, except the first two surveys are not used. Instead, abundance indices from the 2 surveys that bound the date when the fish reach a mean fork length of 38.1 mm are used; this frequently occurs after several surveys have been completed in a field season.

Fall Midwater Trawl Survey

DFW began the Fall Midwater Trawl Survey (FMWT) in 1967 to provide an annual index of relative abundance and information on the distribution of age-0 Striped Bass for the fall period. Later, DFW staff developed abundance and distribution information for other upper-estuary pelagic fishes, including Delta Smelt. Surveys have been conducted in all years from 1967 to present, except 1974 and 1979. The FMWT survey currently samples 122 stations monthly (Fig. 87), from September through December. Station locations range from San Pablo Bay to Hood on the Sacramento River, and from Sherman Lake to Stockton on the San Joaquin River (Fig. 87). Currently, annual abundance index calculations use catch data from 100 of the 122 stations sampled monthly, but the number of stations used for the index has varied through time. Table 12 contains the complete list of stations used for abundance index calculation for FWMT (n = 117), including historical stations (underlined) that must be included for proper calculation of past indices, but are not included in calculations for recent years. The remaining 22 stations were added in 1990, 1991, 2009, and 2010 to improve our understanding of Delta Smelt habitat use (Fig. 87). At each sampling station, field crews perform a single, 12-min oblique tow monthly.

Delta Smelt catch per tow data are used for calculation of the annual abundance index. Individual survey indices are calculated by first grouping the 100 core stations (Fig. 87) into 14 regions based on their location (Table 12). Survey indices are calculated by averaging Delta Smelt catch

Figure 86. **Map of summer townet survey stations showing all currently sampled stations. Data from all core stations are used in abundance index calculation.**



across index stations within each region, multiplying these regional means by their respective weighting factors (i.e. a scalar based on water volume; Table 12), and summing the weighted values. Annual abundance indices are calculated as the sum of the 4 survey abundance indices (i.e. September through December).

Table B1. Station weighting factors for stations used in calculations of the summer townet survey annual abundance indexes. Regions are geographic areas designated by the California Department of Fish and Wildlife. See fig. 86 for station locations.

Region	Station	Station weighting factor
MONTEZUMA SLOUGH	606	20
	609	15
	610	4
SAN PABLO BAY	323	213
SUISUN BAY	405	13
	411	46
	418	70
	501	49
	504	60
	508	31
	513	43
	519	15
	520	9
	602	44
SACRAMENTO RIVER	704	53
	706	27
	707	35
	711	32
SAN JOAQUIN RIVER	801	26
	804	52
	809	56
	812	22
EAST DELTA	815	40
	906	21
	910	11
	912	8
	919	10
SOUTH DELTA	902	23
	914	15
	915	15
	918	11

Figure 87. Map of fall midwater trawl survey stations showing all currently sampled stations. Data from core stations are used in abundance index calculation.

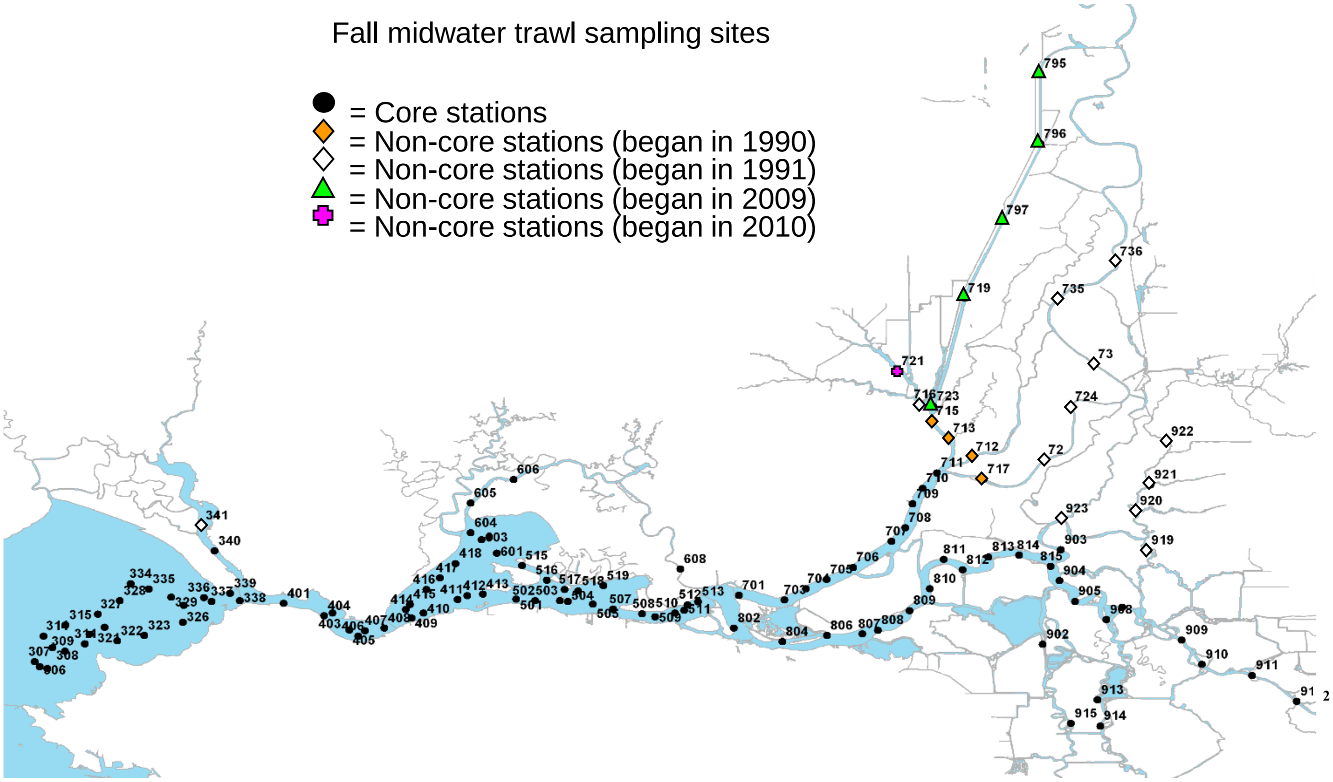


Table B2. Area-regions, weighting factor for each area-region, and stations included within each area-region. Bolded station numbers indicate the current 100 core stations used in calculation of annual abundance indexes. Underlined station numbers indicate stations previously included in calculations but subsequently dropped.

Area-region	Weighting factor	Stations included
1-San Pablo Bay	8.1	**336** **337** **338** **339**
3-San Pablo Bay	11.3	**321** **322** **323** 324 **325** **326**
4-San Pablo Bay	6.5	**327** **328** **329**
5-San Pablo Bay	12.2	330 331 332 333 **334** **335**
7-San Pablo Bay	10.2	312 313 **314** **315** 316
8-San Pablo Bay	18.5	303 304 **305** **306** **307** **308** **309** **310** **311**
10-Napa River	4.8	**340**
11-Carquinez Strait	16.0	**401** **403** 402 **404** **405** **406** **407** **408**
12-Suisun Bay	14.0	**409** **410** **411** **412** **413** **414** **415** **416** **417** **418**

13-Suisun and Honker bays	18.0	**501**
		502
		503
		504
		505
		506
		507
	18.0	**508**
		509
		510
		511
		512
		513
		514
		515
		516
		517
		518
		519
		601
14-Grizzly Bay and Montezuma Slough	5.0	**602**
		603
		604
		605
		606
		607
		608
15-Sacramento River	12.0	**701**
		702
		703
		704
		705
		706
		707
		708
		709
		710
		711
16-San Joaquin River	14.0	**802**
		804
		806
		807
		808
		809
		810
		811
		812
		813
		814
		815
17-South Delta	20.0	901
		902
		903
		904
		905
		906
		907
		908
		909

1.D.2.4 Attachments to Comments of North Coast Rivers Alliance

EXHIBIT
1

Feds scramble to avoid another mass salmon die-off in the Sacramento River

By Phillip Reese and Ryan Sabalow preese@sacbee.com

A year ago, California lost nearly an entire generation of endangered salmon because the water releases from Shasta Dam flowed out warmer than federal models had predicted. Thousands of salmon eggs and newly hatched fry baked to death in a narrow stretch of the Sacramento River near Redding that for decades has served as the primary spawning ground for winter-run Chinook salmon.

Earlier this year, federal scientists believed they had modeled a new strategy to avoid a similar die-off, only to realize their temperature monitoring equipment had failed and Shasta's waters once again were warming faster than anticipated.

In the months since, in what is essentially an emergency workaround, they've revised course, sharply curtailing flows out of Shasta. The hope is that they reserve enough of the reservoir's deep, cold water pool to sustain this year's juvenile winter-run Chinook. But it's meant sacrificing water deliveries to hundreds of Central Valley farmers who planted crops in expectation of bigger releases; and draining Folsom reservoir – the source of drinking water for much of suburban Sacramento – to near-historic lows to keep salt water from intruding on the Delta downstream.

In spite of all this, another generation of wild winter-run Chinook salmon could very well die.

For all the focus on fallowed farm fields and withered lawns in California's protracted drought, native fish have suffered the most dire consequences. The lack of snowmelt, warmer temperatures and persistent demand for limited freshwater supplies have left many of the state's reservoirs – and, by extension, its streams and rivers – hotter than normal. The changing river conditions have threatened the existence of 18 native species of fish, the winter-run Chinook among them.

Chinook are called king salmon by anglers for a reason. They can grow to more than 3 feet in length, and the biggest can top more than 50 pounds. Decades ago, before dams were built blocking their traditional spawning habitat, vast schools of these silver-sided fish with blue-green backs migrated from the ocean to spawn and die in the tributaries that feed the Sacramento River in runs timed with the seasons.

The largest run that remains in the Sacramento River system is the fall run, which survives almost entirely due to hatchery breeding programs below the Shasta, Oroville and Folsom dams. The winter run, in contrast, is still largely reared in the wild, laying its eggs in the gravel beds below Shasta's concrete walls. Their numbers have dwindled in the face of predators and deteriorating river conditions. The federal government declared the run endangered in 1994, and it has flirted with extinction ever since.

Following last year's failed federal efforts, only about 5 percent of the winter-run Chinook survived long enough to begin to migrate out to sea. The species has a three-year spawning cycle, meaning that three consecutive fish kills could lead to the end of the winter run as a wild species. One hatchery below Lake Shasta breeds winter-run Chinook in captivity.

Officials with the U.S. Bureau of Reclamation, which operates both Shasta and Folsom dams, say they believe their emergency efforts at Shasta are working and they anticipate "some" winter-run Chinook will survive this year.

"We believe that we are on track," said bureau spokesman Shane Hunt. "We are sitting in a much better place today than we were a year ago today."

Several biologists interviewed remain dubious. They note that preserving more cold water in Shasta has meant many stretches of the Sacramento River are warmer than they were last year. They worry that salmon eggs and fry will still die – only gradually instead of suddenly.

“We stand a pretty good chance of losing the wild cohort again this year, like we did last year,” said Peter Moyle, a UC Davis researcher and one of the nation’s leading fisheries biologists. “If we get lucky some of those fish will survive. We’re definitely pushing the population to its limits.”

Agricultural leaders, meanwhile, say there’s good reason to suspect the government models will again prove flawed and the fish will die despite the sacrifices farmers have made.

Rep. Jim Costa, a Democrat and third-generation farmer who represents a wide swath of the San Joaquin Valley, is among those who think there’s a good chance farmers have been punished for no benefit to the fish.

“That begs the question: What are we accomplishing?” Costa said. “We are in extreme drought conditions. ... The water districts that I represent in the San Joaquin Valley have had a zero – zero – water allocation. ... Over half a million acres have been fallowed ... It just seems to defy common sense and logic.”

Some members of California’s fisheries industry also have lost confidence in the bureau, arguing the government has badly mismanaged its rivers. Beyond the very existence of a wild population of fish, they say, the government is risking millions of dollars for California’s economy and hundreds of fishing jobs – and a key source of locally caught seafood for markets and restaurants.

Two consecutive fish kills involving an endangered species could lead to more stringent regulation of commercial and recreational fishing. It’s a real possibility, state and federal fisheries regulators said, that salmon fishing could be severely restricted along much of California’s central coast and in the Sacramento River system next year.

Larry Collins, a commercial fisherman operating out of Pier 45 in San Francisco, said that in the fight over water, the fishing industry – and wild fish – lack the political clout compared with municipal and agricultural interests.

“I’ve been around a long time, and I’ve fought the battle for a long time, and I’ve watched the water stolen from the fish,” he said. “The fish are in tough shape because their water is growing almonds down in the valley. To me, it’s just outright theft of the people’s resource for the self-aggrandizement of a few, you know?”

“You got money you can buy anything,” he added. “You can buy extinction.”

Federal models prove faulty

On paper, the requirements for salvaging the winter-run Chinook seem fairly basic. The winter-run Chinook spawn from April to August. Juvenile fish swim downriver from July to March. If the water in the Sacramento River is too hot as the fry emerge from their eggs, they die. Warm water also makes it more difficult for the juveniles to survive their swim downstream to the ocean.

But in practice, there are broad variables to keeping the river cool, involving snowmelt, heat waves, water depths and the temperatures of the tributaries entering the reservoir, as well as conditions in the river downstream.

A year ago, federal and state officials had a plan to keep temperatures in key portions of the Sacramento River below 56 degrees; temperatures above 56 can trigger a die-off. The models built by the Bureau of Reclamation indicated operators could release large amounts of water from Lake Shasta while still maintaining a cool temperature, easing the pressure on farms and cities. According to their calculations, the water would be cold enough at key points in the Sacramento River to ensure survival of 30 percent of the salmon run.

But the models were wrong. The Bureau of Reclamation essentially ran out of cold water reserves in Lake Shasta, limiting its ability to control temperatures in the Sacramento River. Average daily river temperatures rose well above levels needed by salmon to survive. The 5 percent that did transition from eggs to fry were left to navigate to the ocean in tough conditions.

“That 5 percent – I guarantee you they didn’t make it down through the Delta,” said Bill Jennings, executive director of the California Sportfishing Protection Alliance.

Fast forward to this year, and another plan gone awry.

During the spring, government officials again said they would keep winter-run Chinook alive by maintaining water temperatures below 56 degrees. The State Water Resources Control Board signed off on their plan in mid-May.

Only weeks later, Bureau of Reclamation officials told the state that their temperature monitoring equipment wasn’t working. In fact, they said, temperatures in Shasta were warmer than anticipated – and dramatic intervention would be needed to keep winter-run Chinook alive. They asked the board to consider a new plan and immediately restricted flows from Shasta.

The state water board took up the issue at a meeting on June 16. Members of the board bemoaned their lack of good choices and later adopted a plan that left no one happy. Water releases would be curtailed out of Lake Shasta. Folsom Lake would be drawn to historic lows. Deliveries to farmers would be reduced.

And, despite those measures, the average daily temperature in the Sacramento River would rise to 57 degrees on most days and 58 degrees on some days, according to the government models. That’s too high a temperature for all winter-run Chinook to survive, but the Bureau of Reclamation, in documents supporting the change, said its modeling predicted roughly 20 percent of the fish would survive to early adulthood. That would be lower than a typical year – but not a disaster.

But are this year’s models more accurate? Already this summer, average daily temperatures at a key point in the Sacramento River have risen above 58 degrees on seven separate occasions, including several times in late August, state data show.

Federal officials said their models anticipated some temperature spikes, and noted that on each occasion so far, they were able to release cold water into the river and bring temperatures back down.

“It can have an effect” on fish, said Hunt, the bureau spokesman, of river temperatures above 58 degrees. But, he added, “That temperature is not a lethal temperature immediately.”

Jon Rosenfield, a biologist with the Bay Institute, disagreed, saying that many winter-run salmon likely were doomed by the temperature spikes. He offered the analogy of a chicken egg: “If you take an egg and dip it in boiling water, you are jeopardizing its ability to develop into a chick,” he said. “The longer you do that and the hotter the temperatures, the less likely it is to develop.”

Another concern is whether there is still enough cold water in Shasta to keep river temperatures low into the fall. Hunt says yes – that the government projects that Shasta will contain 350,000 acre-feet of cold water, below 56 degrees, at month’s end, far more than in 2014.

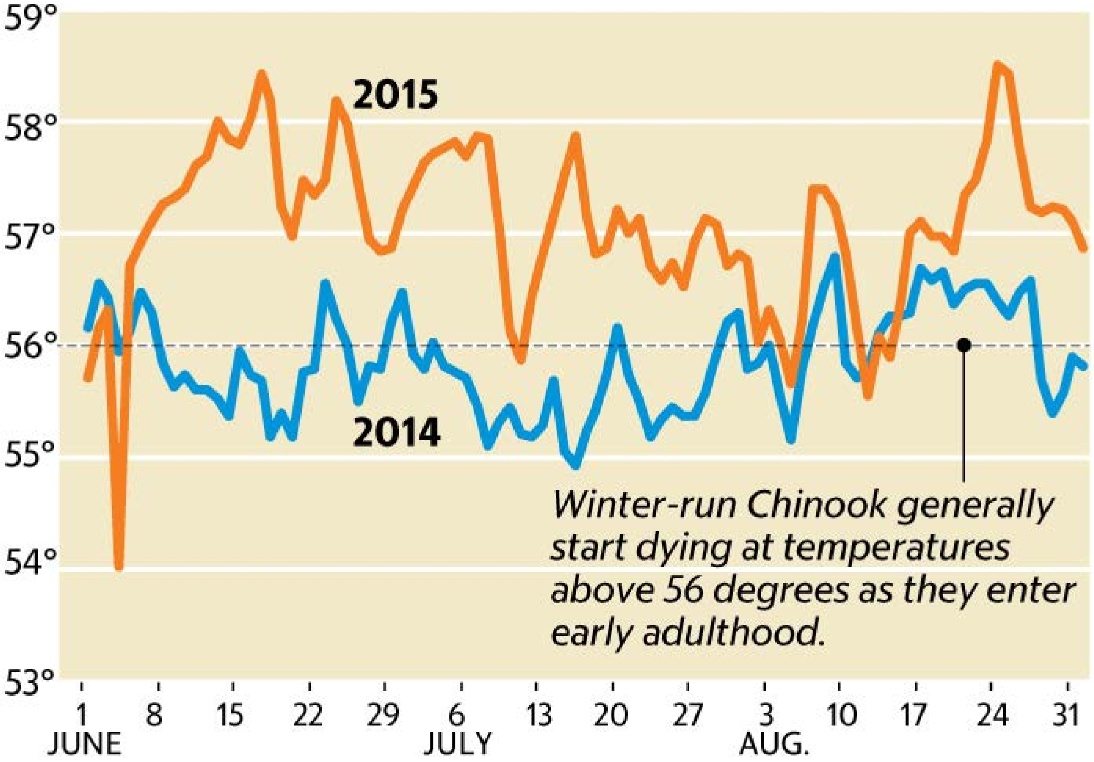
Rosenfield expressed doubts that the bureau is in position to do detailed calculations on its cold water supply. “They are way behind in anything using modern technology in measuring how much cold water they have,” Rosenfield said.

Scientists won’t know whether this year’s plan worked until fish surveys are completed in the winter. In a worst-case scenario, the government could rely even more heavily on its hatchery to sustain winter-run Chinook. Rosenfield called that option a “Band-Aid,” noting it would not preclude the loss of the fish as a wild species. Hatchery fish, he said, tend to come from a limited gene pool and may also have difficulty surviving in warm water.

Higher river temperatures; low lake levels

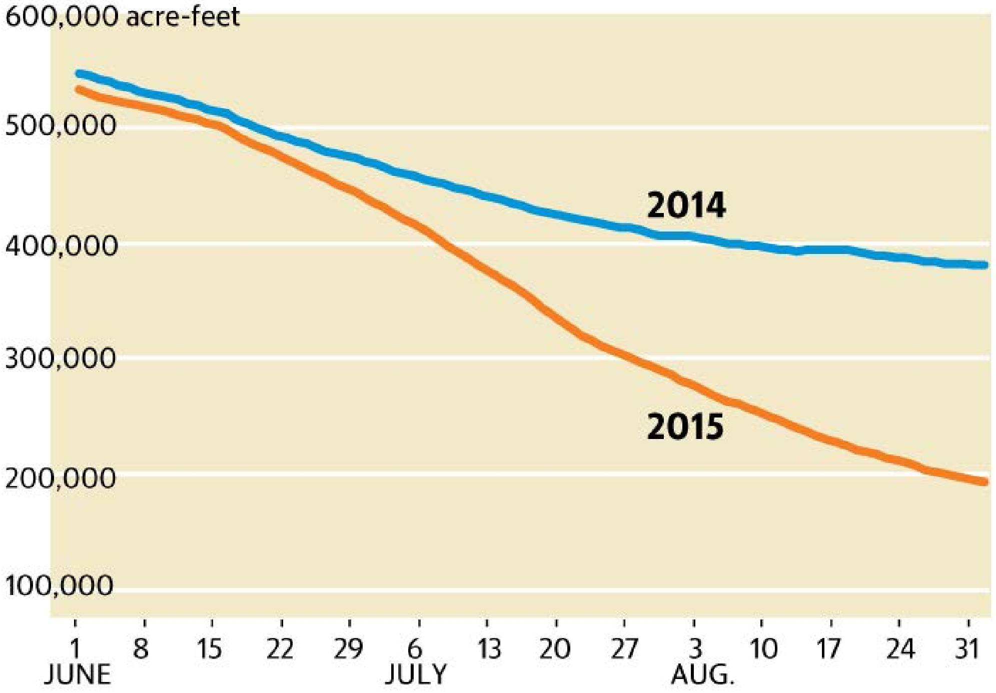
Under a new plan, federal officials have allowed temperatures in the Sacramento River in Shasta County to rise above 56 degrees consistently throughout the summer. They predict the warmer temperatures will not cause a mass salmon die-off; some biologists are dubious.

Average daily water temperatures in the Sacramento River above Clear Creek



One consequence of the temperature plan to keep winter-run Chinook alive has been increased flows out of Folsom Lake.

Daily Folsom Lake storage (in acre-feet)



Source: California Department of Water Resources The Sacramento Bee

Looking to the future

Jeff Gonzales worries about the ripple effects of another bad salmon season. Gonzales, a retired fire captain from Durham who guides clients on river-fishing trips, remembers when fisheries managers shut down the season for the fall-run Chinook in 2008 and 2009.

In those years, officials closed the fall-run fishing season in response to an unprecedented decline in the numbers of Chinook that had returned to the Sacramento, American and Feather rivers to spawn. The run plummeted amid poor ocean conditions and environmental problems in the Sacramento-San Joaquin Delta.

Gonzales thinks a similar scenario could be well underway, and that this year's fall run is also in danger. He's troubled by photos his fellow guides have sent him of fully-grown fall-run salmon floating dead in southern stretches of the Sacramento River. He attributes the deaths to warm water.

On Thursday morning, he was guiding clients on the river near Los Molinos, between Chico and Red Bluff, in search of fall-run salmon. The river is so warm, he said, that it's been tough to find fish in his normal spots. The fish, he said, have either raced upstream seeking colder water, or are holding off the entrance to the Delta in the Pacific, waiting for a cold water flow.

That means slow-going for him and other guides.

On Thursday, his four clients, all firefighters enjoying an off-day, spent a four-hour stretch watching ospreys, wood ducks and herons glide by as their lures wriggled in the swift current. Every so often, a Chinook would breach the water and slap the surface with its tail, almost tauntingly. That morning, just one client saw his rod bend under the weight of a lunging 15-pound, silver-sided king.

Some clients have canceled trips because of the paltry catches, Gonzales said, and business will only get worse if the salmon seasons get shut down due to yet another winter-run die-off.

Maneuvering through the currents, the river rippling out before him, he lamented not just the loss of the fish but of a cultural heritage.

“You’ve gotta think about our future here, you know?” Gonzales said. “Our children and our grandchildren may not be able to see what we’re seeing here.”

Phillip Reese: 916-321-1137, @PhillipHReese.

EXHIBIT
2

STATUS REPORT OF THE 2015 OCEAN SALMON FISHERIES OFF WASHINGTON, OREGON, and CALIFORNIA.

Preliminary Data Through August 31, 2015.[a]

	Season	Effort	CHINOOK			COHO[b]		
Fishery and Area	**Dates**	**Days Fished**	**Catch**	**Quota**	**Percent**	**Catch**	**Quota**	**Percent**
		COMMERCIAL						
Treaty Indian[c]	*5/1-6/30*	683	30,916	30,000	103%		Non-Retention	
	7/1-9/15	364	26,944	29,084	93%	2,961	42,500	7%
Non-Indian North of Cape Falcon[d]	*5/1-6/30*	2,118	38,930	40,200	97%		Non-Retention	
	7/1-9/1[e]	1,090	25,248	26,800	94%	2,924	19,200	15%
	9/4-9/22[f]	NA	NA			NA	NA	NA
Cape Falcon - Humbug Mt.	*4/1-8/27*	6,645	82,752	None	NA		Non-Retention	
	9/3-9/30	NA	NA	None	NA		Non-Retention	
Humbug Mt. - OR/CA Border[g]	*4/1-5/31*	161	1,177	NA	NA		Non-Retention	
	6/1-6/26	100	1,528	1,800	85%		Non-Retention	
	7/1-7/31	88	769	1,184	65%		Non-Retention	
	8/6-8/27	23	50	772	6%		Non-Retention	
OR/CA Border - Humboldt S. Jetty	*9/11-9/30*	NA	NA	3,000			Non-Retention	
Humboldt S. Jetty - Horse Mt.				Closed				
Horse Mt. - Pt. Arena	*5/1-5/31, 6/15-6/30, 7/12-8/26*	3,577	59,515	None	NA		Non-Retention	
	9/1-30	NA	NA	None	NA		Non-Retention	
Pt. Arena - Pigeon Pt.	*5/1-31,6/7-30, 7/8-8/29*	2,281	20,775	None	NA		Non-Retention	
	9/1-30	NA	NA	None	NA		Non-Retention	
Pt. Reyes-Pt. San Pedro	*10/1-2, 5-9 &12-15*	NA	NA	None	NA		Non-Retention	
Pigeon Pt. - Pt. Sur	*5/1-31,6/7-30, 7/8-8/15*	2,289	12,176	None	NA		Non-Retention	
Pt. Sur - U.S./Mexico Border	*5/1-31,6/7-30, 7/8-31*	866	4,412	None	NA		Non-Retention	
		RECREATIONAL						
U.S./Canada Border - Queets River[h]	*5/15-16, 22-23, 5/30-6/12*	751	215	10,000	12%		Non-Retention	
Queets River - Leadbetter Poin[h]	*5/30-6/12*	2,080	745				Non-Retention	
Leadbetter Point - Cape Falcon[h]	*5/30-6/12*	499	242				Non-Retention	
U.S./Canada Border - Cape Alava	*6/13-9/3*	13,255	8,199	8,400	98%	3,665	14,850	25%
	9/4-9/30						4,100	0%
Cape Alava-Queets River	*6/13-9/3*	2,685	2,113	2,600	81%	388	3,610	11%
	9/4-9/30						625	0%
	10/1-10/12			100	0%		100	0%
Queets River - Leadbetter Pt.	*6/13-9/3*	36,583	15,946	27,900	57%	22,793	52,840	43%
	9/4-9/30						13,000	0%
Leadbetter Pt.-Cape Falcon	*6/14-9/3*	32,970	8,881	15,000	59%	38,300	79,400	48%
	9/4-9/30						15,300	0%
Cape Falcon - Humbug Mt.	*3/15-10/31*	29,466	1,227	None	NA	Non-Retention except for periods listed		
Cape Falcon to OR/CA Border	*6/27-8/9*	Included Above or Below		NA	NA	14,925	55,000	27%
Cape Falcon to Humbug Mt.	*9/4-9/30*[i]	Included Above		NA	NA	NA	20,700	NA
Humbug Mt. - OR/CA Border (OR-KMZ)	*5/1-9/7*	2,795	321	None	NA	Included Above		
OR/CA Border - Horse Mt. (CA-KMZ)	*5/1-9/7*	8,711	3,640	None	NA		Non-Retention	
Horse Mt. - Pt. Arena (Ft. Bragg)	*4/4-11/8*	11,181	5,023	None	NA		Non-Retention	
Pt. Arena - Pigeon Pt. (San Francisco)	*4/4-10/31*	28,061	12,972	None	NA		Non-Retention	
Pigeon Pt. - P. Sur (Monterey N.)	*4/4-9/7*	12,648	2,547	None	NA		Non-Retention	
Pt. Sur - U.S./Mexico Border (Monterey S.)	*4/4-7/19*	1,996	359	None	NA		Non-Retention	

	Effort			Chinook Catch			Coho Catch		
TOTALS TO DATE (through Aug. 31)	**2015**	**2014**	**2013**	**2015**	**2014**	**2013**	**2015**	**2014**	**2013**
TROLL									
Treaty Indian	**1,047**	1,342	1,232	**57,860**	62,217	49,518	**2,961**	49,625	43,553
Washington Non-Indian	**2,468**	1,887	2,218	**53,564**	37,993	39,361	**1,874**	10,313	5,764
Oregon	**7,757**	9,491	6,473	**96,890**	195,852	74,407	**1,050**	3,997	309
California	**9,013**	11,807	15,401	**96,878**	151,367	285,592	**0**	0	0
Total Troll	**20,285**	24,527	25,324	**305,192**	447,429	448,878	**5,885**	63,935	49,626
RECREATIONAL									
Washington	**82,288**	101,428	70,938	**34,597**	38,290	26,810	**57,820**	96,034	39,387
Oregon	**38,796**	89,147	65,431	**3,292**	15,194	26,865	**22,251**	70,189	11,680
California	**62,597**	103,319	138,490	**24,541**	64,936	112,022	**38**	476	361
Total Recreational	**183,681**	293,894	274,859	**62,430**	118,420	165,697	**80,109**	166,699	51,428
PFMC Total	**203,966**	318,421	300,183	**367,622**	565,849	614,575	**85,994**	230,634	101,054

[a] Inseason estimates are preliminary.

[b] Non-Indian coho fisheries prior to Sept. are mark-selective and non-mark-selective recreational fisheries occur in Sept., (except SOF rec.) see the regulations for details.

[c] Effort is reported as landings. Chinook summer quota of 30,000 decreased by subtracting spring quota overage on an impact neutral basis by 916 fish.

[d] Numbers shown as Chinook quotas for non-Indian troll and rec. fisheries North of Falcon are guidelines not quotas; only the total Chinook allowable catch is a quota.

[e] September quotas to be adjusted due to iimpact neutral trades and rollovers.

[f] Remaining mark-selective coho quota to be converted to non-mark-selective quota on an impact neutral basis.

[g] July and August quotas adjusted from preseason due to impact neutral rollover of

[h] Mark-selective fishery for Chinook

[i] 12,500 preseason quota plus an impact equivalent roll-over from the Cape Falcon to OR/CA border mark-selective recreational coho fishery.

EXHIBIT
3

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2015GL064924

Key Points:
- Warming since 1901 caused a significant trend toward drought in California
- Recent drought was naturally driven and modestly intensified by warming
- Warming has rapidly amplified the probability of severe drought

Supporting Information:
- Text S1, Table S1, and Figures S1–S7

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Contribution of anthropogenic warming to California drought during 2012–2014

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Abstract A suite of climate data sets and multiple representations of atmospheric moisture demand are used to calculate many estimates of the self-calibrated Palmer Drought Severity Index, a proxy for near-surface soil moisture, across California from 1901 to 2014 at high spatial resolution. Based on the ensemble of calculations, California drought conditions were record breaking in 2014, but probably not record breaking in 2012–2014, contrary to prior findings. Regionally, the 2012–2014 drought was record breaking in the agriculturally important southern Central Valley and highly populated coastal areas. Contributions of individual climate variables to recent drought are also examined, including the temperature component associated with anthropogenic warming. Precipitation is the primary driver of drought variability but anthropogenic warming is estimated to have accounted for 8–27% of the observed drought anomaly in 2012–2014 and 5–18% in 2014. Although natural variability dominates, anthropogenic warming has substantially increased the overall likelihood of extreme California droughts.

1. Introduction

During 2012–2014, drought in California (CA) caused water use restrictions, rapid drawdown of groundwater reserves [*Famiglietti*, 2014; *Harter and Dahlke*, 2014], fallowed agricultural fields [*Howitt et al.*, 2014], and ecological disturbances such as large wildfires and tree mortality [e.g., *Moore and Heath*, 2015; *Worland*, 2015]. The ultimate cause of the recent drought was a persistent ridge of high atmospheric pressure over the Northeast Pacific that blocked cold-season storms from reaching CA and stifled precipitation totals [e.g., *Seager et al.*, 2015]. Tree ring reconstructions from CA indicate that the resultant 3 year precipitation shortfall of 2012–2014 has been matched less than once per century over the past several hundred years [*Griffin and Anchukaitis*, 2014; *Diaz and Wahl*, 2015]. Dynamical studies agree that the Northeast Pacific ridge that caused the precipitation shortfall was part of an atmospheric wave train originating from the western tropical Pacific due to warm sea surface temperatures (SSTs) in that region [*Funk et al.*, 2014; *Seager et al.*, 2014a, 2015; *Wang and Schubert*, 2014; *Wang et al.*, 2014; *Hartmann*, 2015]. The observed ridging anomaly was stronger than the modeled response to tropical SST forcing [e.g., *Wang and Schubert*, 2014; *Seager et al.*, 2015], however, and leaves room for contributions from internal atmospheric variability or anthropogenic climate change. Although it has been suggested that anthropogenic emissions enhance the probability of *extreme* Northeast Pacific ridging events without necessarily affecting the long-term mean state [*Swain et al.*, 2014; *Wang et al.*, 2014, 2015], model projections of increased extremes in cold-season precipitation totals do not emerge as relevant until the second half of this century [*Berg and Hall*, 2015]. Furthermore, observed CA precipitation totals indicate no long-term trend despite cooccurring increases in western tropical Pacific SSTs [*Seager et al.*, 2015], climate models do not produce negative CA precipitation trends when forced by observed SST trends [*Funk et al.*, 2014], and future anthropogenic climate change is projected to result in slight *positive* trends in CA precipitation totals [*Neelin et al.*, 2013; *Seager et al.*, 2014b, 2015; *Simpson et al.*, 2015], all arguing against the likelihood of an anthropogenic role in the recent CA precipitation shortfall.

Importantly, there is widespread consensus that warmth has intensified the effects of the recent precipitation shortfall by enhancing potential evapotranspiration (PET) [*AghaKouchak et al.*, 2014; *Griffin and Anchukaitis*, 2014; *Diffenbaugh et al.*, 2015; *Mann and Gleick*, 2015; *Shukla et al.*, 2015]. Because warming is a well-understood and robustly modeled response to anthropogenic emissions of greenhouse gases, it is expected that warming-induced drying will continue for centuries to come [e.g., *Cook et al.*, 2015; *Diffenbaugh et al.*, 2015]. However, the degree to which anthropogenic warming and resultant increases in PET were responsible for the recent drought severity in CA is unknown.

Griffin and Anchukaitis [2014] used the Palmer Drought Severity Index (PDSI), a proxy for near-surface soil moisture [*Palmer*, 1965], to investigate the role of temperature in the recent drought, but they did not separate the influence of anthropogenic warming from natural temperature variability and their employed version of PDSI (from the National Oceanic and Atmospheric Administration (NOAA)) uses a simplified formulation of PET. *Mao et al*. [2015] attempted to isolate the anthropogenic component of warming using a more physically based PET calculation but focused only on the Sierra Nevada Mountain region and spring snowpack, and simply characterized anthropogenic warming as the observed linear trend in daily minimum temperatures. Other studies investigate the effect of warming on the likelihood of severe drought events in CA [e.g., *AghaKouchak et al*., 2014; *Diffenbaugh et al*., 2015; *Shukla et al*., 2015] but do not directly address the anthropogenic contribution to recent drought severity. Each study noted above considers only a single climate data product without addressing the structural uncertainty across different data products.

Here we quantify the severity of recent CA drought using an ensemble of data products and multiple PDSI formulations, determine the relative roles of individual components of the water balance, and determine the proportion of recent drought severity that can be attributed to increases in PET due to anthropogenic warming.

2. Methods

2.1. Palmer Drought Severity Index

We calculate monthly PDSI to characterize temporal and spatial variations in CA drought from 1901 to 2014: most humidity, wind speed, and insolation data sets do not extend prior to 1901. The PDSI is based on a simple two-layer soil moisture model and is locally normalized to reflect moisture anomalies relative to long-term mean conditions. PDSI is a primary tool used for drought monitoring in the United States [*Heim*, 2002; *Svoboda et al*., 2002] and generally agrees well with modeled and observed soil moisture anomalies [*Dai et al*., 2004; *Cook et al*., 2015; *Smerdon et al*., 2015; *Zhao and Dai*, 2015] and tree ring records [*Cook et al*., 2007]. While some recent studies have taken more complex modeling approaches to investigate the recent CA drought [*Mao et al*., 2015; *Shukla et al*., 2015], we use the PDSI because it allows efficient calculations of centennial-length records at high spatial resolution, which can be computed many hundreds of times with different climate variables, input data sets, and methodological schemes. The PDSI only reflects drought variability from a climatological perspective. Our results therefore do not explicitly reflect human water demand, stream flow and reservoir storage, or accessibility of groundwater. The PDSI also considers all precipitation to occur as rain, neglecting snow storage and subsequently delayed inputs to soil moisture and runoff. To assess implications of this latter simplification, PDSI is compared to modeled soil moisture by *Mao et al*. [2015] for the snow-dominated Sierra Nevada mountains.

Other studies also have used the PDSI to examine recent CA drought [*Griffin and Anchukaitis*, 2014; *Diffenbaugh et al*., 2015; *Robeson*, 2015]. A key difference between these studies, which use data developed by NOAA, and our study is the formulation of PET. The NOAA calculations involve the simplified Thornthwaite formula [*Thornthwaite*, 1948] that considers monthly mean temperature to be the only climatological driver of PET variability. This approach can overemphasize the influence of warmth when temperatures are high, and further inaccuracies are introduced by ignoring the nontemperature components of PET [e.g., *Hobbins et al*., 2008; *Hoerling et al*., 2012; *Sheffield et al*., 2012]. The more physically based Penman-Monteith (PM) formula [*Penman*, 1948; *Monteith*, 1965] considers the suite of variables affecting PET: mean daily maximum temperature (T_{max}), mean daily minimum temperature (T_{min}), humidity, wind speed, and net radiation. We use the PM formula and repeat calculations using Thornthwaite in some cases for comparison. Additionally, we use the newer self-calibrated PDSI ($\mathrm{PDSI}_{\mathrm{sc}}$), developed to make drought severity comparable among locations [*Wells et al*., 2004].

Consistent with several prior studies [e.g., *Cook et al*., 2004, 2007, 2010; *Griffin and Anchukaitis*, 2014], we focus on June–August (JJA). $\mathrm{PDSI}_{\mathrm{sc}}$ is an integration of hydroclimate over multiple months to several years [*Guttman*, 1998] and summer is the ideal season for characterizing drought intensity in CA for two reasons: (1) it is when drought effects tend to be most critical; and (2) it is when $\mathrm{PDSI}_{\mathrm{sc}}$ is most accurate in mountain regions because snowpack has melted or is at a minimum [e.g., *Dai et al*., 2004]. To facilitate interpretation, each grid cell's annual record of JJA $\mathrm{PDSI}_{\mathrm{sc}}$ is normalized so that two $\mathrm{PDSI}_{\mathrm{sc}}$ units equal a 1 standard deviation departure from the 1931–1990 mean, retaining a similar variance in the records of JJA $\mathrm{PDSI}_{\mathrm{sc}}$ as is in the monthly records. Again for interpretability, we renormalize statewide mean JJA $\mathrm{PDSI_{sc}}$ records. We use a 1931–1990 calibration interval in all $\mathrm{PDSI_{sc}}$ calculations to be consistent with NOAA methodology.

2.2. Climate Data

We calculate $\mathrm{PDSI_{sc}}$ records for all 432 combinations of four precipitation, four temperature, three vapor pressure, three wind speed, and three insolation data sets. Data sets are listed with references in Table S1 in the supporting information and described in Text S1. We bilinearly interpolate each monthly climate field for each data set to the spatial resolution of the PRISM data set (0.04167°) [*Daly et al*., 2004]. For each climate variable, data sets were calibrated so that climatological means and variances match during 1961–2010 (see Text S1). Uncertainties are high for humidity, wind speed, and insolation because they are largely based on models or observations of other variables [e.g., *Dai*, 2011]. Although consideration of multiple data products helps to characterize some of this uncertainty, data products are not all produced independently. Errors therefore may be recurrent in multiple data products (see Text S1).

2.3. Decomposition of PET and $\mathrm{PDSI_{sc}}$

We calculate the influence of a given variable, or subset of variables, on PET as the PET anomaly calculated while holding all other variables at their mean annual cycles [e.g., *Cook et al*., 2014; *Scheff and Frierson*, 2014; *Zhao and Dai*, 2015]. Mean annual cycles were always defined over 1961–2010. For $\mathrm{PDSI_{sc}}$, the contribution of precipitation was defined as $\mathrm{PDSI_{sc\_P}}$, calculated by holding PET at its mean annual cycle and only allowing precipitation to vary. The contribution of PET was calculated as the difference between $\mathrm{PDSI_{sc\_P}}$ and a recalculation of $\mathrm{PDSI_{sc}}$ in which both precipitation and PET vary. We isolated the influences of the temperature and nontemperature components of PET by applying versions of PET in which only the component of interest varies. Contributions of subcomponents of PET and $\mathrm{PDSI_{sc}}$ anomalies were nearly perfectly additive, but all relative anomalies were rescaled to sum to exactly 100% of the total anomaly.

2.4. Effect of Anthropogenic Warming

Anthropogenic warming was isolated from that of natural temperature variability by considering four warming scenarios that are described in detail in the next two paragraphs. For each scenario, natural temperature variability is calculated as the observed temperature minus the anthropogenic trend. All records of anthropogenic warming and natural variability were calculated independently for T_{max} and T_{min}, each grid cell, and each month. For each warming scenario, we recalculated PET twice: once considering only the anthropogenic warming record and once considering the residual record of natural temperature variability. Methods were repeated from above to assess $\mathrm{PDSI_{sc}}$ anomalies caused by anthropogenic warming and natural temperature variability.

The four anthropogenic warming scenarios are defined as follows: (1) linear trend, (2) 50 year low-pass filter (using a 10-point butterworth filter), (3) unadjusted mean trend from an ensemble of climate models, and (4) an adjusted version of #3. The first two warming scenarios represent empirical fits to the observed temperature records during 1895–2014. Although a linear trend is commonly used to represent the anthropogenic effect, a linear fit to a centennial temperature record may underestimate the human effect on temperature in recent decades because radiative forcing during this period has increased relatively rapidly [e.g., *Myhre et al*., 2013]. The 50 year low-pass filter partially addresses this issue, but multidecadal natural temperature variability inhibits complete isolation of the anthropogenic effect with either the linear trend or the 50 year filter. Additionally, trends toward the end of the 50 year filter record are affected by boundary constraint assumptions. Although continued warming is likely, we pad the end of the temperature record with a repetition of the last 25 years in reverse order, likely leading to an underestimation of anthropogenic warming in the most recent years.

In the third and fourth warming scenarios, we use modeled records of T_{min} and T_{max} produced for the Coupled Model Intercomparison Project Phase 5 (CMIP5) [*Taylor et al*., 2012] to represent anthropogenic warming trends for each month. Thirty-six models in the CMIP5 archive are used, based on the availability of T_{max} and T_{min} data for the historical (1850–2005) and future (2006–2099, RCP 8.5 [*van Vuuren et al*., 2011]) simulations. For each model, T_{min} and T_{max} are each averaged across all available runs for the historical and future periods, bilinearly interpolated to the geographic resolution of PRISM, and bias corrected for each grid cell so that monthly means during 1961–2010 matched observational means. We calculate 50 year low-pass filtered time series for each month during 1850–2099 and average across the 36 models. The resultant ensemble mean records for 1895–2014 represent the CMIP5 records of anthropogenic warming used in the

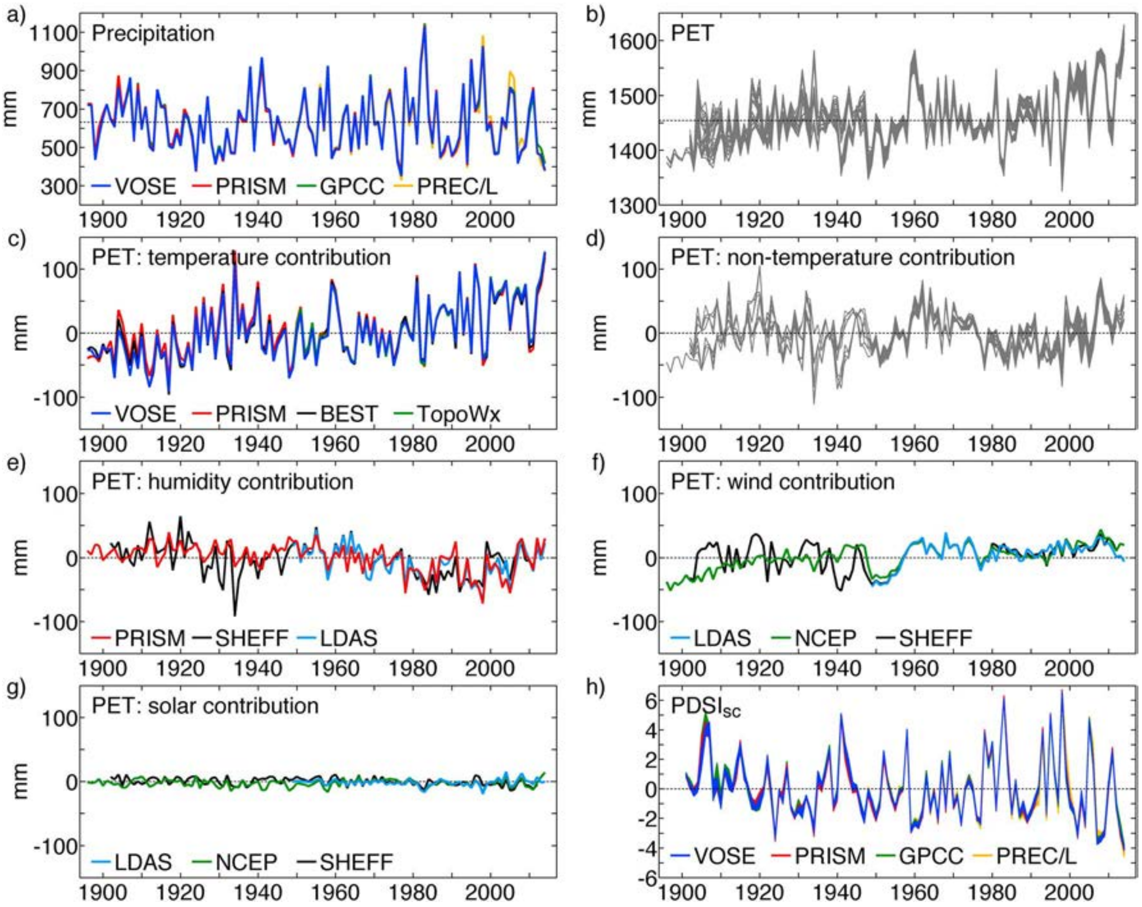

Figure 1. Contributors to interannual (water year) drought variability in CA, calculated from multiple data sets. (a) Precipitation. (b) PET totals, calculated using the PM equation for all combinations of four temperature, three humidity, three wind velocity, and three insolation data sets. (c) Temperature contribution to PET anomalies. Contributions of (d) all nontemperature variables, (e) humidity, (f) wind velocity, and (g) insolation to PET anomalies. (h) JJA PDSI$_{\mathrm{SC}}$ calculated with all 432 combinations of the climate-variable data sets. Horizontal black lines: 1931–1990 means. Colors distinguish data products.

third warming scenario. For the fourth scenario, we linearly adjust these records to best fit the observations from 1895 to 2014. This approach reduces biases in the modeled trends but carries the implicit assumption that observed temperature trends are entirely anthropogenic in origin, which is a questionable assumption. For example, *Johnstone and Mantua* [2014a] indicate that some of the observed warming trend may be due to warming in the Northeast Pacific that is not linked to anthropogenic climate change, but also see *Abatzoglou et al.* [2014] and *Johnstone and Mantua* [2014b].

3. Results and Discussion

3.1. Recent Drought Conditions

Figure 1a shows annual water year (WY: October–September) CA precipitation totals for 1896–2014 and demonstrates general agreement among the four gridded data sets. The WY 2014 precipitation total was the third lowest (fourth lowest for Global Precipitation Climatology Centre (GPCC) [*Schneider et al.*, 2014]) on record (behind WYs 1977 and 1924) and WY 2012–2014 precipitation was the lowest (third lowest for GPCC) 3 year running average on record (Figure S1a). The effects of the recent precipitation deficit have been amplified by positive PET anomalies. Figure 1b shows the 108 records of WY PET, calculated from all combinations of temperature, humidity, wind, and insolation data sets. Among the PET records, 32 include data for 2014. WY 2014 PET was 9–12% above average and the highest on record in every case. PET for WY 2012–2014 was 7–9% above average and either the highest or second highest (behind WY 2007–2009) on record (Figure S1b).

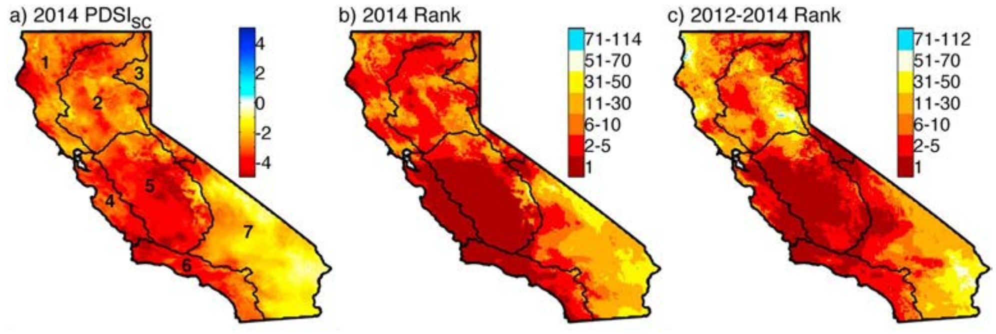

Figure 2. Maps of (a) JJA PDSI$_{sc}$ and ranking for (b) 2014 and (c) 2012–2014. Rankings are based on all years between 1901 and 2014, and a ranking of 1 indicates record-breaking drought. PDSI$_{sc}$ in this figure is based on VOSE precipitation and temperature, PRISM humidity, and LDAS [*Mitchell et al*., 2004; *Rodell et al*., 2004] wind speed and insolation. Polygons bound the seven NOAA climate divisions (division numbers shown in Figure 2a).

All PET data sets indicate positive and significant trends during WY 1949–2014, ranging from 8.2 to 13.7 mm/decade when considering linear trends. These trends are almost entirely due to warming. Since WY 1949, warming positively forced PET by 10–12 mm/decade (65–82 mm total), equivalent to 10–13% of the mean WY precipitation (Figure 1c). The VOSE [*Vose et al*., 2014], BEST [*Rohde et al*., 2013], and TopoWx (which only goes back to 1948 [*Oyler et al*., 2015]) data sets indicate that the temperature contribution to PET was highest on record in 2014 while PRISM indicates that the temperature contribution was higher in 1934. All four data sets agree that the temperature contribution to PET during WY 2012–2014 was substantially higher than that of any other 3 year period on record (Figure S1c).

Nontemperature variables account for approximately one third of WY PET variability (Figure 1d), although much uncertainty exists among the nontemperature data sets. Nearly all interannual variability and inter–data set spread in nontemperature PET (Figure 1d) are due to contributions from vapor pressure and wind speed (Figures 1e–1g). According to the data sets considered, positive wind speed trends contributed positively to PET (4.5 to 4.8 mm/dec), positive humidity trends contributed negatively (−3.5 to −4.0 mm/dec), and insolation had a minimal influence due to very low interannual variability in warm-season insolation relative to the mean. Prior to 1948, trends in the nontemperature components of PET are much less certain due to a nearly complete lack of pre-1948 observational data [e.g., *Dai*, 2011].

Within CA, PET trends were spatially heterogeneous, with much of the Central Valley experiencing reduced PET during the second half of the twentieth century due to suppressed daytime warming and increased humidity, consistent with the effects of increased irrigation [*Lobell and Bonfils*, 2008]. These results are broadly consistent with observed decreases in warm-season pan evaporation at sites in the Central Valley during 1951–2002 [*Hobbins et al*., 2004]. These agricultural trends appear distinct from the well-known global declines in pan evaporation that appear to have been caused by pollution-induced solar dimming during the 1950s–1980s and reductions in wind speed [*Roderick et al*., 2009]. While long-term records of insolation and wind speed are sparse in CA, those that exist indicate insignificant wind trends of inconsistent sign [*Pryor et al*., 2009; *Pryor and Ledolter*, 2010] and twentieth century insolation decreases that were too small to substantially affect statewide mean PET, similar to prior findings in Australia [*Roderick et al*., 2007].

Figure 1h shows all 432 records of JJA PDSI$_{sc}$ for 1901–2014 (128 records extend through 2014). Colors in Figure 1h indicate the precipitation product; spread among colors reflects disagreement among precipitation products and spread within colors reflects disagreement among PET products. All records indicate that 2014 JJA PDSI$_{sc}$ was the lowest on record (−4.64 to −3.67), with 25–37% of CA experiencing record-breaking drought locally. The year 2014 had the highest proportion of record-breaking drought area on record for all data sets, with the most severe anomalies centered in the southern Central Valley and the central and southern CA coasts (Figures 2a and 2b).

Considering 3 year running average PDSI$_{sc}$, 2012–2014 JJA drought intensity was found to be similar to, but generally not as severe as, that of 2007–2009 when averaged across CA, regardless of data sets used (Figure S1h). The similarity of mean PDSI$_{sc}$ during these two periods is interesting given that WY 2012–2014 had the lowest precipitation total on record and PET levels were comparable during each period. The difference

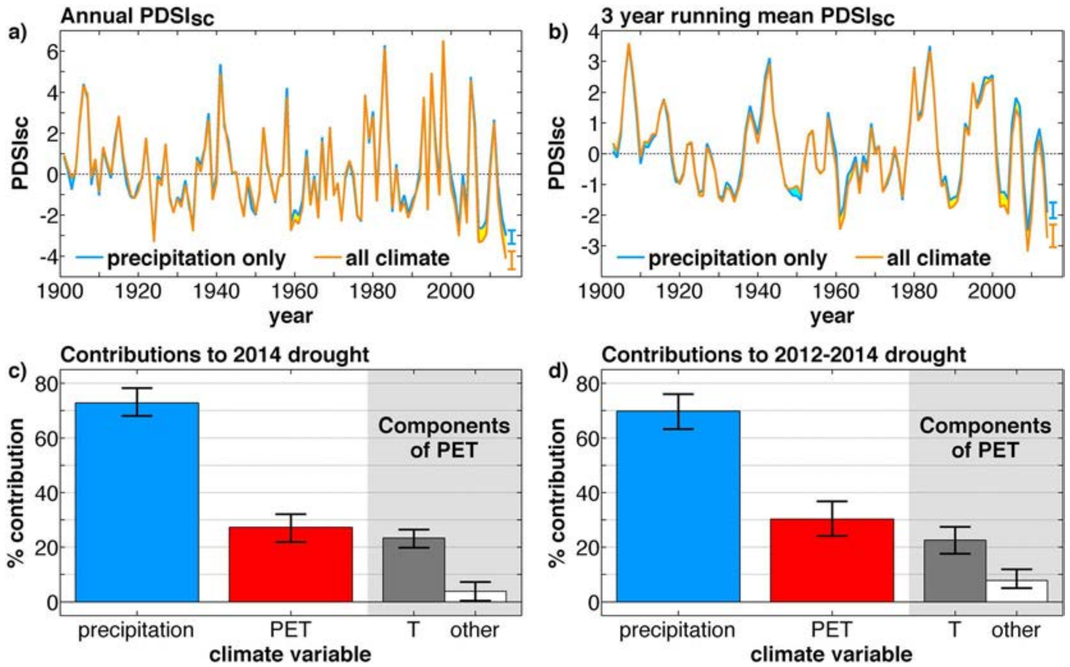

Figure 3. Contributions of precipitation and PET to drought variability. (a) Annual and (b) 3 year running mean JJA $\mathrm{PDSI}_{\mathrm{sc}}$ records calculated when (blue) only precipitation is allowed to vary from the climatological mean and (orange) when both precipitation and PET vary. Thus, departures of the blue line from zero are due to precipitation variability and departures of the orange line from the blue line are due to PET variability. Shading between lines in Figures 3a and 3b indicate periods when (cyan) low PET reduces drought and (yellow) high PET intensifies drought. Percent contributions of precipitation and PET to the (c) 2014 and (d) 2012–2014 $\mathrm{PDSI}_{\mathrm{sc}}$ anomalies. The bars in the shaded area of Figures 3c and 3d break the contribution of PET into contributions from temperature (*T*) and nontemperature (other: humidity, wind, and solar). Time series and bars represent mean conditions across all combinations of climate data products and whiskers bound all values from all combinations of data products.

was in the timing of precipitation. Unlike the 2012–2014 drought, which intensified over time, the 2007–2009 drought was most intense at the onset and the moisture deficit established in 2007 partially propagated into 2008 and 2009. Additionally, spring months for WY 2012-2014 were generally wetter than WY 2007–2009, contributing to soil moisture at a critical time immediately prior to summer (Figure S2).

The finding that the 2012–2014 $\mathrm{PDSI}_{\mathrm{sc}}$ was not as severe as that of 2007–2009 conflicts with prior findings based on NOAA PDSI (which is based on VOSE precipitation and temperature) that 2012–2014 was the most severe 3 year drought on record in CA [*Griffin and Anchukaitis*, 2014; *Robeson*, 2015]. This is attributable to the NOAA calculation of PDSI, which amplifies the effect of extreme heat anomalies in 2014 via the Thornthwaite PET equation (Figures S3 and S4). Importantly, while our calculations indicate that 2012–2014 was probably not a record-breaking drought event when averaged across CA, 2012–2014 drought severity *was* record breaking in much of the agriculturally important Central Valley (Figure 2c). In contrast, drought in 2007–2009 was most severe in the sparsely populated and already dry desert region of southeastern CA.

$\mathrm{PDSI}_{\mathrm{sc}}$ does not account for snowpack effects, which are important for human water supply, and our calculations of statewide $\mathrm{PDSI}_{\mathrm{sc}}$ may therefore not always accurately reflect drought from the perspective of human water supply, which is disproportionately linked to the Sierra Nevada Mountains. For that region, *Mao et al.* [2015] used the Variable Infiltration Capacity (VIC) hydrologic model [*Liang et al.*, 1994] to simulate hydrological dynamics during 1920–2014. Using the *Mao et al.* [2015] meteorological forcing to calculate $\mathrm{PDSI}_{\mathrm{sc}}$ for the Sierra Nevada Mountains, we find strong agreement ($r = 0.93$) with VIC JJA soil moisture (Figure S5). VIC soil moisture nevertheless indicates slightly more severe drought than $\mathrm{PDSI}_{\mathrm{sc}}$ during the most extreme drought years, likely due to early disappearance of snowpack [e.g., *Mote*, 2006; *Mankin and Diffenbaugh*, 2015] and subsequently reduced spring and summer melt-driven soil moisture inputs (Figure S6). Given that the calculation of $\mathrm{PDSI}_{\mathrm{sc}}$ neglects snowpack and therefore cannot capture the effect of early snowmelt on summer soil moisture, the warming effect on summer $\mathrm{PDSI}_{\mathrm{sc}}$ presented in the next section is likely conservative for snow-dominated areas.

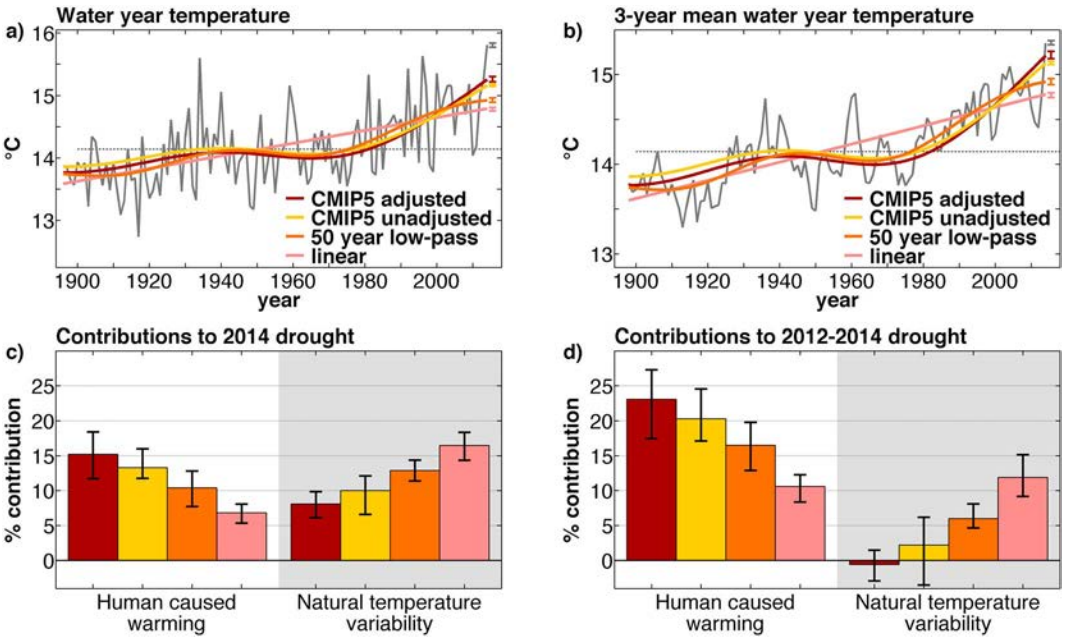

Figure 4. Contributions of anthropogenic warming and natural temperature variability to recent temperature and drought. (a) Annual and (b) 3 year running water year temperature records with four alternate scenarios of anthropogenic warming. Contributions of anthropogenic warming versus natural temperature variability to (c) 2014 and (d) 2012–2014 JJA $\mathrm{PDSI}_{\mathrm{SC}}$ anomalies, where bar colors correspond to the colors of the four anthropogenic warming trends in Figures 4a and 4b. For each of the anthropogenic warming scenarios, natural temperature variability is calculated as the observed temperature minus the warming trend. All time series and bars represent mean conditions across all combinations of climate products. Whiskers bound all values for all combinations of data products.

3.2. Effect of Warming on Recent Drought

Figures 3a and 3b compare $\mathrm{PDSI}_{\mathrm{SC}}$ (orange) to an alternate calculation in which only precipitation varies and PET is held at its mean annual cycle (blue). While there is no long-term trend in precipitation-driven $\mathrm{PDSI}_{\mathrm{SC}}$ since 1948 or 1901, trends in actual $\mathrm{PDSI}_{\mathrm{SC}}$ are significant and negative ($p < 0.05$ according to Spearman's Rho and Kendall's Tau) due to increasing PET. During 2014 and 2012–2014, PET anomalies accounted for 22–32% and 24–37% of the JJA $\mathrm{PDSI}_{\mathrm{SC}}$ anomalies, respectively (Figures 3c and 3d). Recalculating $\mathrm{PDSI}_{\mathrm{SC}}$ considering the temperature and nontemperature components of PET separately, we find that the intensifying effect of high PET on recent drought was nearly entirely caused by warmth (Figures 3c and 3d). High temperatures accounted for 20–26% and 18–27% of the JJA $\mathrm{PDSI}_{\mathrm{SC}}$ anomalies in 2014 and 2012–2014, respectively (Figures 3c and 3d).

The contribution of temperature is further separated into contributions from natural temperature variability and anthropogenic warming in Figure 4. Figures 4a and 4b show the WY temperature record and the four anthropogenic warming scenarios, which indicate an anthropogenic warming contribution in WY 2014 of 0.61–1.27°C relative to the 1931–1990 mean. The empirically derived trends suggest a weaker anthropogenic warming contribution in recent years than the CMIP5 trends because (1) the linear trend does not account for the nonlinear increase in anthropogenic forcing and (2) the 50 year low-pass filter trend indicates slowed warming in the past two decades that is partly due to our conservative smoothing approach and partly due to decadal climate variability. The CMIP5 trends represent the nonlinear increase in radiative forcing without being affected by decadal climate variability or smoothing artifacts. The similarity between the adjusted and unadjusted CMIP5 warming trends suggest that the CMIP5 provides a reasonable representation of the anthropogenic warming influence in CA despite having stronger warming trends than the conservatively designed empirical trends.

Breaking the temperature contributions to $\mathrm{PDSI}_{\mathrm{SC}}$ into anthropogenic and natural components, the four anthropogenic warming trends account for 5–18% of the JJA $\mathrm{PDSI}_{\mathrm{SC}}$ anomaly in 2014 and 8–27% of the anomaly in 2012–2014 (Figures 4c and 4d). Despite differences in these relative contributions of warming to drought during 2014 versus 2012–2014, the *absolute* contributions of anthropogenic warming to drought during these two periods were virtually identical. The absolute anthropogenic contribution does not change much interannually but instead acts as a gradually moving drought baseline upon which the effects of natural climate variability are superimposed (Figure S7a).

As of 2014, the anthropogenic warming forcing accounted for approximately -0.3 to -0.7 standardized PDSI_{sc} units, depending on the anthropogenic warming scenario and combination of climate data sets considered (Figure S7a). To illustrate how this trend in background drought conditions affected the probability of severe drought as of 2014, we compare the probability distribution of 1901–2014 PDSI_{sc} values calculated in the absence of anthropogenic warming to the same distributions shifted negative by 0.46, the 2014 PDSI_{sc} forcing by the 50 year low-pass filter warming trend (Figure S7b, based on VOSE temperature and precipitation data). Comparing the two distributions, we find that severe summer droughts with $\text{PDSI}_{sc} \leq -3$ were approximately twice as likely under 2014 anthropogenic warming levels (Figure S7c). Although uncertainty in probabilities of extreme events is large when based on observed records [e.g., *Swain et al*., 2014], and the anthropogenic trend may not result in a perfectly uniform shift in the PDSI_{sc} distribution, this analysis illustrates the general fact that the anthropogenic drying trend, while still small relative to the range of natural climate variability, has caused previously improbable drought extremes to become substantially more likely, consistent with the conclusions of other recent studies [e.g., *AghaKouchak et al*., 2014; *Cook et al*., 2015; *Diffenbaugh et al*., 2015; *Shukla et al*., 2015; *Williams et al*., 2013, 2014, 2015].

Regarding anthropogenic contributions, there are some important caveats. First, anthropogenic climate change has potentially affected more than just temperature in CA [e.g., *Swain et al*., 2014; *Wang et al*., 2014, 2015]. Lack of long-term observational data on wind speed and humidity in CA, and uncertainties in existing data, make it difficult to quantify anthropogenic influences on these variables. For CA precipitation, current models project a weak overall increase [*Neelin et al*., 2013; *Seager et al*., 2014b, 2015; *Simpson et al*., 2015], but no such precipitation trend has emerged. Hence, we only characterize anthropogenic effects on temperature in this study. Second, observed warming trends are affected by processes not related to greenhouse gas emissions such as land use (e.g., agriculture, urbanization) and natural low-frequency climate variability. While climate models provide a definition of anthropogenic warming that should be unbiased by observations, the accuracy of this approach, as in other attribution studies [e.g., *Bindoff et al*., 2013], is confined by the accuracy of climate models. Finally, our analyses do not account for snowpack, making our results a likely underestimation of the contribution of heat anomalies to recent drought in snow-dominated mountain areas and should be interpreted conservatively regarding the effects of warming on water resources for systems strongly affected by the timing of seasonal runoff from mountains.

4. Conclusions

Anthropogenic warming has intensified the recent drought as part of a chronic drying trend that is becoming increasingly detectable and is projected to continue growing throughout the rest of this century [e.g., *Cook et al*., 2015]. As anthropogenic warming continues, natural climate variability will become increasingly unable to compensate for the drying effect of warming. Instead, the soil moisture conditions associated with the current drought will become increasingly common. Impacts of drought on society may be increasingly intensified due to declining availability of groundwater reserves [e.g., *Famiglietti*, 2014]. The Central Valley may be particularly vulnerable to warming-driven drought if reductions in water supply cause reductions in irrigation, as irrigation has slowed warming in this region [*Lobell and Bonfils*, 2008]. The dramatic effects of the current drought in CA, combined with the knowledge that the background warming-driven drought trend will continue to intensify amidst a high degree of natural climate variability, highlight the critical need for a long-term outlook on drought resilience, even if wet conditions soon end the current drought in CA.

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References

Abatzoglou, J. T., D. E. Rupp, and P. W. Mote (2014), Questionable evidence of natural warming of the northwestern United States, *Proc. Natl. Acad. Sci. U.S.A.*, *111*(52), E5605–E5606, doi:10.1073/pnas.1421311112.

AghaKouchak, A., L. Cheng, O. Mazdiyasni, and A. Farahmand (2014), Global warming and changes in risk of concurrent climate extremes: Insights from the 2014 California drought, *Geophys. Res. Lett.*, *41*, 8847–8852, doi:10.1002/2014GL062308.

Berg, N., and A. Hall (2015), Increased interannual precipitation extremes over California under climate change, *J. Clim.*, *28*(16), 6324–6334, doi:10.1175/JCLI-D-14-00624.1.

Bindoff, N. L., et al. (2013), Detection and attribution of climate change: From global to regional, in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. F. Stocker et al., pp. 867–952, Cambridge Univ. Press, Cambridge, U. K., and New York.

Cook, B. I., J. E. Smerdon, R. Seager, and S. Coats (2014), Global warming and 21st century drying, *Clim. Dyn.*, *43*(9–10), 2607–2627, doi:10.1007/s00382-014-2075-y.

Cook, B. I., T. R. Ault, and J. E. Smerdon (2015), Unprecedented 21st century drought risk in the American Southwest and Central Plains, *Sci. Adv.*, *1*(1), e1400082, doi:10.1126/sciadv.1400082.

Cook, E. R., C. A. Woodhouse, C. M. Eakin, D. M. Meko, and D. W. Stahle (2004), Long-term aridity changes in the western United States, *Science*, *306*(5698), 1015–1018, doi:10.1126/science.1102586.

Cook, E. R., R. Seager, M. A. Cane, and D. W. Stahle (2007), North American drought: Reconstructions, causes, and consequences, *Earth Sci. Rev.*, *81*(1–2), 93–134, doi:10.1016/j.earscirev.2006.12.002.

Cook, E. R., R. Seager, R. R. Heim Jr., R. S. Vose, C. Herweijer, and C. Woodhouse (2010), Megadroughts in North America: Placing IPCC projections of hydroclimatic change in a long-term palaeoclimate context, *J. Quat. Sci.*, *25*(1), 48–61, doi:10.1002/jqs.1303.

Dai, A. (2011), Characteristics and trends in various forms of the Palmer Drought Severity Index during 1900–2008, *J. Geophys. Res.*, *116*, D12115, doi:10.1029/2010JD015541.

Dai, A., K. E. Trenberth, and T. Qian (2004), A global dataset of Palmer Drought Severity Index for 1870–2002: Relationship with soil moisture and effects of surface warming, *J. Hydrometeorol.*, *5*(6), 1117–1130, doi:10.1175/JHM-386.1.

Daly, C., W. P. Gibson, M. Dogget, J. Smith, and G. Taylor (2004), Up-to-date monthly climate maps for the coterminous United States, paper presented at Proceedings of the 14th AMS Conference on Applied Climatology, 84th AMS Annual Meeting, Am. Meteorol. Soc., Seattle, Washington, 13–16 Jan.

Diaz, H. F., and E. R. Wahl (2015), Recent California water year precipitation deficits: A 440-year perspective, *J. Clim.*, *28*(12), 4637–4652, doi:10.1175/JCLI-D-14-00774.1.

Diffenbaugh, N. S., D. L. Swain, and D. Touma (2015), Anthropogenic warming has increased drought risk in California, *Proc. Natl. Acad. Sci. U.S.A.*, *112*(13), 3931–3936, doi:10.1073/pnas.1422385112.

Famiglietti, J. S. (2014), The global groundwater crisis, *Nat. Clim. Change*, *4*(11), 945–948, doi:10.1038/nclimate2425.

Funk, C., A. Hoell, and D. Stone (2014), Examining the contribution of the observed global warming trend to the California droughts of 2012/13 and 2013/14, in *Explaining Extreme Events of 2013 From a Climate Perspective*, *Bull. Am. Meteorol. Soc.*, edited by S. C. Herring, et al., pp. S11–S15, Am. Meteorol. Soc., Boston, Mass, doi:10.1175/1520-0477-95.9.S1.1.

Griffin, D., and K. J. Anchukaitis (2014), How unusual is the 2012–2014 California drought?, *Geophys. Res. Lett.*, *41*, 9017–9023, doi:10.1002/2014GL062433.

Guttman, N. B. (1998), Comparing the Palmer drought index and the standardized precipitation index, *J. Am. Water Resour. Assoc.*, *34*(1), 113–121, doi:10.1111/j.1752-1688.1998.tb05964.x.

Harter, T., and H. Dahlke (2014), OUTLOOK: Out of sight but not out of mind: California refocuses on groundwater, *Calif. Agric.*, *68*(3), 54–55.

Hartmann, D. L. (2015), Pacific sea surface temperature and the winter of 2014, *Geophys. Res. Lett.*, *42*, 1894–1902, doi:10.1002/2015GL063083.

Heim, R. R., Jr. (2002), A review of twentieth-century drought indices used in the United States, *Bull. Am. Meteorol. Soc.*, *83*(8), 1149–1165, doi:10.1175/1520-0477(2002)083<1149:AROTDI>2.3.CO;2.

Hobbins, M. T., J. A. Ramírez, and T. C. Brown (2004), Trends in pan evaporation and actual evapotranspiration across the conterminous US: Paradoxical or complementary?, *Geophys. Res. Lett.*, *31*, L13503, doi:10.1029/2004GL019846.

Hobbins, M. T., A. Dai, M. L. Roderick, and G. D. Farquhar (2008), Revisiting potential evapotranspiration parameterizations as drivers of long-term water balance trends, *Geophys. Res. Lett.*, *35*, L12403, doi:10.1029/2008GL033840.

Hoerling, M. P., J. K. Eischeid, X.-W. Quan, H. F. Diaz, R. S. Webb, R. M. Dole, and D. R. Easterling (2012), Is a transition to semipermanent drought conditions imminent in the US Great Plains?, *J. Clim.*, *25*(24), 8380–8386, doi:10.1175/JCLI-D-12-00449.1.

Howitt, R., J. Medellin-Azuara, D. MacEwan, J. Lund, and D. A. Sumner (2014), Economic analysis of the 2014 drought for California agriculture, UC Davis Cent. for Watershed Sci., Davis, Calif. [Available at https://watershed.ucdavis.edu/files/biblio/DroughtReport_23July2014_0.pdf.]

Johnstone, J. A., and N. J. Mantua (2014a), Atmospheric controls on northeast Pacific temperature variability and change, 1900–2012, *Proc. Natl. Acad. Sci. U.S.A.*, *111*(40), 14,360–14,365, doi:10.1073/pnas.1318371111.

Johnstone, J. A., and N. J. Mantua (2014b), Reply to Abatzoglou et al.: Atmospheric controls on northwest United States air temperatures, 1948–2012, *Proc. Natl. Acad. Sci. U.S.A.*, *111*(52), E5607–E5608, doi:10.1073/pnas.1421618112.

Liang, X., D. P. Lettenmaier, E. F. Wood, and S. J. Burges (1994), A simple hydrologically based model of land surface water and energy fluxes for general circulation models, *J. Geophys. Res.*, *99*(D7), 14,415–14,428, doi:10.1029/94JD00483.

Lobell, D. B., and C. Bonfils (2008), The effect of irrigation on regional temperatures: A spatial and temporal analysis of trends in California, 1934–2002, *J. Clim.*, *21*(10), 2063–2071, doi:10.1175/2007JCLI1755.1.

Mankin, J. S., and N. S. Diffenbaugh (2015), Influence of temperature and precipitation variability on near-term snow trends, *Clim. Dyn.*, *45*(3–4), 1099–1116, doi:10.1007/s00382-014-2357-4.

Mann, M. E., and P. H. Gleick (2015), Climate change and California drought in the 21st century, *Proc. Natl. Acad. Sci. U.S.A.*, *112*(13), 3858–3859, doi:10.1073/pnas.1503667112.

Mao, Y., B. Nijssen, and D. P. Lettenmaier (2015), Is climate change implicated in the 2013–2014 California drought? A hydrologic perspective, *Geophys. Res. Lett.*, *42*, 2805–2813, doi:10.1002/2015GL063456.

Mitchell, K. E., et al. (2004), The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system, *J. Geophys. Res.*, *109*, D07S90, doi:10.1029/2003JD003823.

Monteith, J. L. (1965), Evaporation and environment, *Symp. Soc. Exp. Biol.*, *19*, 205–224.

Moore, J. W., and Z. R. Heath (2015), Forest health protection survey: Aerial detection survey—April 15th–17th, USDA Forest Service, Davis, Calif. [Available at http://www.fs.usda.gov/detail/r5/forest-grasslandhealth/?cid=fsbdev3_046696.]

Mote, P. W. (2006), Climate-driven variability and trends in mountain snowpack in Western North America, *J. Clim.*, *19*(23), 6209–6220, doi:10.1175/JCLI3971.1.

Myhre, G., et al. (2013), Anthropogenic and natural radiative forcing, in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. F. Stocker et al., pp. 659–740, Cambridge Univ. Press, Cambridge, U. K., and New York.

Neelin, J. D., B. Langenbrunner, J. E. Meyerson, A. Hall, and N. Berg (2013), California winter precipitation change under global warming in the Coupled Model Intercomparison Project Phase 5 ensemble, *J. Clim.*, *26*(17), 6238–6256, doi:10.1175/JCLI-D-12-00514.1.

Oyler, J. W., A. Ballantyne, K. Jencso, M. Sweet, and S. W. Running (2015), Creating a topoclimatic daily air temperature dataset for the conterminous United States using homogenized station data and remotely sensed land skin temperature, *Int. J. Climatol.*, *35*(9), 2258–2279, doi:10.1002/joc.4127.

Palmer, W. C. (1965), Meteorological drought, 58 pp., U. S. Weather Bur., Washington, D. C. [Available at http://drought.unl.edu/Portals/0/docs/workshops/03222012_Kingston_Jamaica/references/Palmer_PDSIpaper.pdf.]

Penman, H. L. (1948), Natural evaporation from open water, bare soil, and grass, *Proc. R. Soc., Ser. A*, *193*, 120–145.

Pryor, S., and J. Ledolter (2010), Addendum to "Wind speed trends over the contiguous United States", *J. Geophys. Res.*, *115*, D10103, doi:10.1029/2009JD013281.

Pryor, S. C., R. J. Barthelmie, D. T. Young, E. S. Takle, R. W. Arritt, D. Flory, W. J. Gutowski, A. Nunes, and J. Roads (2009), Wind speed trends over the contiguous United States, *J. Geophys. Res.*, *114*, D14105, doi:10.1029/2008JD011416.

Robeson, S. M. (2015), Revisiting the recent California drought as an extreme value, *Geophys. Res. Lett.*, *42*, doi:10.1002/2015GL064593, in press.

Rodell, M., P. R. Houser, U. Jambor, J. Gottschalck, K. Mitchell, C. J. Meng, K. Arsenault, B. Cosgrove, J. Radakovich, and M. Bosilovich (2004), The global land data assimilation system, *Bull. Am. Meteorol. Soc.*, *85*(3), 381–394, doi:10.1175/BAMS-85-3-381.

Roderick, M. L., L. D. Rotstayn, G. D. Farquhar, and M. T. Hobbins (2007), On the attribution of changing pan evaporation, *Geophys. Res. Lett.*, *34*, L17403, doi:10.1029/2007GL031166.

Roderick, M. L., M. T. Hobbins, and G. D. Farquhar (2009), Pan evaporation trends and the terrestrial water balance. II. Energy balance and interpretation, *Geogr. Compass*, *3*(2), 761–780, doi:10.1111/j.1749-8198.2008.00214.x.

Rohde, R., R. A. Muller, R. Jacobsen, E. Muller, S. Perlmutter, A. Rosenfeld, J. Wutele, D. Groom, and C. Wickham (2013), A new estimate of the average Earth surface land temperature spanning 1753 to 2011, *Geoinf. Geostat.*, *1*(1), 1–7, doi:10.4172/2327-4581.1000101.

Scheff, J., and D. M. W. Frierson (2014), Scaling potential evapotranspiration with greenhouse warming, *J. Clim.*, *27*(4), 1539–1558, doi:10.1175/JCLI-D-13-00233.1.

Schneider, U., A. Becker, P. Finger, A. Meyer-Christoffer, M. Ziese, and B. Rudolf (2014), GPCC's new land surface precipitation climatology based on quality-controlled in situ data and its role in quantifying the global water cycle, *Theor. Appl. Climatol.*, *115*(1–2), 15–40, doi:10.1007/s00704-013-0860-x.

Seager, R., M. Hoerling, S. Schubert, H. Wang, B. Lyon, A. Kumar, J. Nakamura, and N. Henderson (2014a), Causes and predictability of the 2011–14 California drought, Natl. Oceanic and Atmos. Admin., Washington, D. C. [Available at http://cpo.noaa.gov/ClimatePrograms/ModelingAnalysisPredictionsandProjections/MAPPTaskForces/DroughtTaskForce/CaliforniaDrought.aspx.]

Seager, R., D. Neelin, I. Simpson, H. Liu, N. Henderson, T. Shaw, Y. Kushnir, M. Ting, and B. Cook (2014b), Dynamical and thermodynamical causes of large-scale changes in the hydrological cycle over North America in response to global warming, *J. Clim.*, *27*(20), 7921–7948, doi:10.1175/JCLI-D-14-00153.1.

Seager, R., M. Hoerling, S. Schubert, H. Wang, B. Lyon, A. Kumar, J. Nakamura, and N. Henderson (2015), Causes of the 2011 to 2014 California drought, *J. Clim.*, doi:10.1175/JCLI-D-14-00860.1, in press.

Sheffield, J., E. F. Wood, and M. L. Roderick (2012), Little change in global drought over the past 60 years, *Nature*, *491*(7424), 435–438, doi:10.1038/nature11575.

Shukla, S., M. Safeeq, A. AghaKouchak, K. Guan, and C. Funk (2015), Temperature impacts on the water year 2014 drought in California, *Geophys. Res. Lett.*, *42*, 4384–4393, doi:10.1002/2015GL063666.

Simpson, I. R., R. Seager, M. Ting, and T. A. Shaw (2015), Causes of change in Northern Hemisphere winter meridional winds and regional hydroclimate, *Nat. Clim. Change*, doi:10.1038/NCLIMATE2783, in press.

Smerdon, J. E., B. I. Cook, E. R. Cook, and R. Seager (2015), Bridging past and future climate across paleoclimatic reconstructions, observations, and models: A hydroclimate case study, *J. Clim.*, *28*(8), 3212–3231, doi:10.1175/JCLI-D-14-00417.1.

Svoboda, M., D. LeComte, M. Hayes, R. Heim, K. Gleason, J. Angel, B. Rippey, R. Tinker, M. Palecki, and D. Stooksbury (2002), The drought monitor, *Bull. Am. Meteorol. Soc.*, *83*(8), 1181–1190, doi:10.1175/1520-0477%282002%29083%3C1181:TDM%3E2.3.CO;2.

Swain, D., M. Tsiang, M. Haughen, D. Singh, A. Charland, B. Rajarthan, and N. Diffenbaugh (2014), The extraordinary California drought of 2013/2014: Character, context and the role of climate change, in *Explaining Extreme Events of 2013 From a Climate Perspective*, *Bull. Am. Meteorol. Soc.*, edited by S. C. Herring, et al., pp. S3–S6, Am. Meteorol. Soc., Boston, Mass., doi:10.1175/1520-0477-95.9.S1.1.

Taylor, K. E., R. J. Stouffer, and G. A. Meehl (2012), An overview of CMIP5 and the experiment design, *Bull. Am. Meteorol. Soc.*, *93*(4), 485–498, doi:10.1175/BAMS-D-11-00094.1.

Thornthwaite, C. W. (1948), An approach toward a rational classification of climate, *Geogr. Rev.*, *38*(1), 55–94, doi:10.2307/210739.

van Vuuren, D. P., et al. (2011), The representative concentration pathways: An overview, *Clim. Change*, *109*(1–2), 5–31, doi:10.1007/s10584-011-0148-z.

Vose, R. S., S. Applequist, M. Squires, I. Durre, M. J. Menne, C. N. Williams Jr., C. Fenimore, K. Gleason, and D. Arndt (2014), Improved historical temperature and precipitation time series for US climate divisions, *J. Appl. Meteorol. Climatol.*, *53*(5), 1232–1251, doi:10.1175/JAMC-D-13-0248.1.

Wang, H., and S. Schubert (2014), Causes of the extreme dry conditions over California during early 2013, in *Explaining Extreme Events of 2013 From a Climate Perspective*, *Bull. Am. Meteorol. Soc.*, edited by S. C. Herring, et al., pp. S7–S10, Am. Meteorol. Soc., Boston, Mass., doi:10.1175/1520-0477-95.9.S1.1.

Wang, S. Y., L. Hipps, R. R. Gillies, and J. H. Yoon (2014), Probable causes of the abnormal ridge accompanying the 2013–2014 California drought: ENSO precursor and anthropogenic warming footprint, *Geophys. Res. Lett.*, *41*, 3220–3226, doi:10.1002/2014GL059748.

Wang, S. Y. S., W. R. Huang, and J. H. Yoon (2015), The North American winter 'dipole' and extremes activity: A CMIP5 assessment, *Atmos. Sci. Lett.*, *16*(3), 338–345, doi:10.1002/asl2.565.

Wells, N., S. Goddard, and M. J. Hayes (2004), A self-calibrating Palmer drought severity index, *J. Clim.*, *17*(12), 2335–2351, doi:10.1175/1520-0442(2004)017<2335:ASPDSI>2.0.CO;2.

Williams, A. P., et al. (2013), Temperature as a potent driver of regional forest drought stress and tree mortality, *Nat. Clim. Change*, *3*(3), 292–297, doi:10.1038/nclimate1693.

Williams, A. P., et al. (2014), Causes and implications of extreme atmospheric moisture demand during the record-breaking 2011 wildfire season in the southwestern United States, *J. Appl. Meteorol. Climatol.*, *53*(12), 2671–2684, doi:10.1175/JAMC-D-14-0053.1.

Williams, A. P., et al. (2015), Correlations between components of the water balance and burned area reveal new insights for predicting fire activity in the southwest US, *Int. J. Wildland Fire*, *24*(1), 14–26, doi:10.1071/WF14023.

Worland, J. (2015), How the California Drought Is Increasing the Potential for Devastating Wildfires, *Time*. [Available at http://time.com/3849320/california-drought-wildfires/.]

Zhao, T., and A. Dai (2015), The magnitude and causes of global drought changes in the 21st century under a low-moderate emissions scenario, *J. Clim.*, *28*(11), 4490–4512.